

# **National Greenhouse Gas Inventory Report of JAPAN**

**2022**

**Ministry of the Environment, Japan  
Greenhouse Gas Inventory Office of Japan (GIO), CGER, NIES**

**Center for Global Environmental Research**



**National Institute for Environmental Studies, Japan**



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## Foreword

On the basis of Article 4 and 12 of the United Nations Framework Convention on Climate Change (UNFCCC) and Decision 2/CMP.8, all Parties to the Convention and the Kyoto Protocol are required to submit national inventories of greenhouse gas emissions and removals. Therefore, the inventories on emissions and removals of greenhouse gases and precursors are reported in the Common Reporting Format (CRF) and in this National Inventory Report, in accordance with the UNFCCC Inventory Reporting Guidelines (Decision 24/CP.19 Annex I) and Decision 2/CMP.8.

This Report presents Japan's national inventory arrangements, the estimation methods of greenhouse gas emissions and removals from sources and sinks, and the trends in emissions and removals for greenhouse gases (carbon dioxide [CO<sub>2</sub>], methane [CH<sub>4</sub>], nitrous oxide [N<sub>2</sub>O], hydrofluorocarbons [HFCs], perfluorocarbons [PFCs], sulfur hexafluoride [SF<sub>6</sub>], nitrogen trifluoride [NF<sub>3</sub>], and indirect CO<sub>2</sub>), precursors (nitrogen oxides [NO<sub>x</sub>], carbon monoxide [CO], and non-methane volatile organic compounds [NMVOC]), and sulfur oxides [SO<sub>x</sub>]. Supplementary information under Article 7.1 of the Kyoto Protocol is presented as well.

The structure of this report is prepared in line with the structure specified in the Appendix of the UNFCCC Inventory Reporting Guidelines.

The Executive Summary focuses on the latest trends in emissions and removals of greenhouse gases in Japan. Chapter 1 deals with background information on greenhouse gas inventories, national inventory arrangements, the inventory preparation process, methodologies and data sources used, key category analysis, QA/QC plan, and results of uncertainty assessment. Chapter 2 describes the latest information on trends in emissions and removals of greenhouse gases in Japan. Chapters 3 to 7 provide the details of estimation methods for the sources and sinks described in the 2006 IPCC Guidelines. Chapter 8 comprises current status of reporting of the emissions from sources not covered by these guidelines. Chapter 9 provides the current status of reporting of indirect emissions of CO<sub>2</sub> and N<sub>2</sub>O. Chapter 10 provides the explanations on improvements and recalculations (data revision, addition of new categories, etc.) made since the previous submission, and Chapters 11 through 15 provide supplementary information under Article 7.1 of the Kyoto Protocol. Annexes offer additional information to assist further understanding of Japan's inventory.

For the latest updates or changes in data, refer to the website (URL: <https://www.nies.go.jp/gio/en/index.html>) of the Greenhouse Gas Inventory Office of Japan (GIO).

April, 2022

Decarbonized Society Promotion Office  
Global Environment Bureau  
Ministry of the Environment



## Preface

The GHG inventory of Japan including this report represents the combined knowledge of over 60 experts in a range of fields from universities, industrial bodies, regional governments, relevant government departments and agencies, and relevant research institutes, who are members of the Committee for the Greenhouse Gas Emissions Estimation Methods established by the Environment Agency (the current Ministry of the Environment) in November 1999 and held every year since.

In compiling the GHG inventory, the Greenhouse Gas Inventory Office of Japan (GIO) would like to acknowledge the contribution not only of the Committee members in seeking to develop the methodology, but of other experts who provided the latest scientific knowledge, the industrial bodies and government departments and agencies that provided the data necessary for compiling the inventory, and the secretariat members of the above-mentioned Committee. We would like to express our gratitude to the Decarbonized Society Promotion Office of the Global Environment Bureau of the Ministry of the Environment, for their support to GIO.

Upon preparation of this report, we have made efforts to improve it through receiving feedback from many internal and external experts. We hope this report will help fulfill our international obligations such as that under the Paris Agreement and is used widely as an index that shows the extent of Japan's measures implemented against global warming.

My appreciation also extends to Ms. Naoko Ikeda, together with Ms. Akiko Higuchi, Ms. Masae Aoki, Ms. Mutsuko Fujii, and Ms. Kumiko Shiba, our assistants, who supported us with the smooth operation of GIO.

April, 2022

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# Table of Contents

Foreword	i
Preface	iii
Contents	v
<b>EXECUTIVE SUMMARY OF THE NATIONAL GHG INVENTORY REPORT OF JAPAN</b>	<b>1</b>
E.S.1. Background Information on the GHG Inventory	1
E.S.2. Summary of National Emission and Removal Related Trends	2
E.S.2.1. GHG Inventory	2
E.S.2.2. KP-LULUCF Activities	4
E.S.3. Overview of Source and Sink Category Emission Estimates and Trends	5
E.S.3.1. GHG Inventory	5
E.S.3.2. KP-LULUCF Activities	6
<b>CHAPTER 1. INTRODUCTION</b>	<b>1-1</b>
1.1. Background Information on Japan's Greenhouse Gas Inventory and Climate Change	1-1
1.2. Description of Japan's National Inventory Arrangements	1-1
1.2.1. Institutional, Legal and Procedural Arrangements	1-1
1.2.1.1. Institutional and legal Arrangement for the Inventory Preparation	1-1
1.2.1.2. Roles and responsibilities of each entity involved in the inventory preparation process	1-3
1.2.1.3. Response for UNFCCC inventory review	1-5
1.2.2. Overview of Inventory Planning, Preparation and Management	1-6
1.2.3. Quality Assurance, Quality Control and Verification Plan	1-7
1.2.3.1. QA/QC Procedures Applied	1-7
1.2.3.2. QA/QC Plan	1-11
1.2.3.3. Verification Activities	1-11
1.2.3.4. Treatment of Confidential Information	1-11
1.2.4. Changes in the National Inventory Arrangements since the Previous Annual GHG Inventory Submission	1-11
1.3. Inventory Preparation, and Data Collection, Processing and Storage	1-12
1.3.1. Annual cycle of inventory preparation	1-12
1.3.2. Process of the inventory preparation	1-12
1.3.3. Documentation and Archiving of Inventory Information	1-14
1.3.3.1. Documentation of information	1-14
1.3.3.2. Archiving of information	1-14
1.3.3.3. QC activity for documentation and archiving of inventory information	1-15
1.4. Brief General Description of Methodologies and Data Sources Used (including tiers used)	1-15
1.4.1. Collection Process of Activity Data	1-15
1.4.2. Selection Process of Emission Factors and Estimation Methods	1-16
1.4.3. Improvement Process of Estimations for Emissions and Removal	1-16
1.5. Brief Description of Key Categories	1-17
1.5.1. GHG Inventory	1-17
1.5.2. KP-LULUCF Activity	1-19

1.6. General Uncertainty Assessment, including Data on the Overall Uncertainty for the Inventory Totals	1-20
1.6.1. GHG Inventory	1-20
1.6.2. KP-LULUCF Activity	1-20
1.7. General Assessment of the Completeness	1-21
<b>CHAPTER 2. TRENDS IN GHG EMISSIONS AND REMOVALS</b>	<b>2-1</b>
2.1. Description and Interpretation of Emission and Removal Trends for Aggregate GHGs	2-1
2.1.1. Overview of GHGs Emissions and Removals	2-1
2.1.2. CO <sub>2</sub>	2-3
2.1.3. CH <sub>4</sub>	2-7
2.1.4. N <sub>2</sub> O	2-8
2.1.5. HFCs	2-9
2.1.6. PFCs	2-10
2.1.7. SF <sub>6</sub>	2-11
2.1.8. NF <sub>3</sub>	2-12
2.1.9. Indirect CO <sub>2</sub>	2-13
2.2. Description and Interpretation of Emission and Removal Trends by Categories	2-14
2.2.1. Energy	2-16
2.2.2. Industrial Processes and Product Use	2-16
2.2.3. Agriculture	2-18
2.2.4. Land Use, Land Use Change and Forestry (LULUCF)	2-19
2.2.5. Waste	2-20
2.2.6. Indirect CO <sub>2</sub>	2-20
2.3. Description and Interpretation of Emission Trends for Indirect GHGs and SO <sub>x</sub>	2-21
2.4. Emissions and removals from KP-LULUCF activities	2-22
<b>CHAPTER 3. ENERGY (CRF SECTOR 1)</b>	<b>3-1</b>
3.1. Overview of Sector	3-1
3.2. Fuel Combustion (1.A.)	3-1
3.2.1. Comparison of the Sectoral Approach with the Reference Approach	3-4
3.2.1.1. Methodological Issues of the Reference Approach	3-4
3.2.1.2. Difference in Energy Consumption	3-5
3.2.1.3. Difference in CO <sub>2</sub> Emissions	3-5
3.2.1.4. Comparison between Differences in Energy Consumption and that of CO <sub>2</sub> Emissions	3-6
3.2.1.5. Causes of the difference between Reference Approach and Sectoral Approach	3-7
3.2.2. International Bunker Fuels	3-9
3.2.3. Feedstocks and Non-Energy Use of Fuels	3-12
3.2.4. CO <sub>2</sub> Emissions from Energy Industries (1.A.1.: CO <sub>2</sub> )	3-14
3.2.5. CH <sub>4</sub> and N <sub>2</sub> O Emissions from Energy Industries (1.A.1.: CH <sub>4</sub> , N <sub>2</sub> O)	3-29
3.2.6. CO <sub>2</sub> Emissions from Manufacturing Industries and Construction (1.A.2.: CO <sub>2</sub> )	3-41
3.2.7. CH <sub>4</sub> and N <sub>2</sub> O Emissions from Manufacturing Industries and Construction	



(1.A.2.: CH <sub>4</sub> , N <sub>2</sub> O)	3-44
3.2.8. CO <sub>2</sub> Emissions from Transport (1.A.3.: CO <sub>2</sub> )	3-48
3.2.9. CH <sub>4</sub> and N <sub>2</sub> O Emissions from Transport (1.A.3.: CH <sub>4</sub> , N <sub>2</sub> O)	3-51
3.2.9.1. Domestic Aviation (1.A.3.a.)	3-51
3.2.9.2. Road Transportation (1.A.3.b.)	3-54
3.2.9.3. Railways (1.A.3.c.)	3-65
3.2.9.4. Domestic Navigation (1.A.3.d.)	3-67
3.2.9.5. Other Transportation (1.A.3.e.)	3-68
3.2.10. CO <sub>2</sub> Emissions from Other Sectors and Other (1.A.4., 1.A.5: CO <sub>2</sub> )	3-68
3.2.11. CH <sub>4</sub> and N <sub>2</sub> O Emissions from Other Sectors and Other (1.A.4., 1.A.5: CH <sub>4</sub> and N <sub>2</sub> O)	3-71
3.2.12. Emissions from waste incineration with energy recovery	3-74
3.3. Fugitive Emissions from Fuels (1.B.)	3-78
3.3.1. Solid Fuels (1.B.1.)	3-78
3.3.1.1. Coal Mining and Handling (1.B.1.a.)	3-78
3.3.1.2. Solid Fuel Transformation (1.B.1.b.)	3-85
3.3.1.3. Others (Uncontrollable combustion and burning coal dumps) (1.B.1.c.)	3-87
3.3.2. Oil, Natural Gas and Other Emissions from Energy Production (1.B.2.)	3-88
3.3.2.1. Oil (1.B.2.a.)	3-88
3.3.2.2. Natural Gas (1.B.2.b.)	3-95
3.3.2.3. Venting and Flaring (1.B.2.c.)	3-105
3.3.2.4. Other (Fugitive Emissions Associated with the Geothermal Power Generation) (1.B.2.d.)	3-113
3.4. CO <sub>2</sub> transport and storage (1.C.)	3-115
3.4.1. Transport of CO <sub>2</sub> (1.C.1)	3-115
3.4.1.1. Pipelines (1.C.1.a.)	3-115
3.4.1.2. Ships (1.C.1.b.)	3-115
3.4.1.3. Other (1.C.1.c.)	3-116
3.4.2. Injection and Storage (1.C.2)	3-116
3.4.2.1. Injection (1.C.2.a.)	3-116
3.4.2.2. Storage (1.C.2.b.)	3-116
3.4.3. Other (1.C.3)	3-117
3.4.4. Information item	3-117
 CHAPTER 4. INDUSTRIAL PROCESSES AND PRODUCT USE (CRF SECTOR 2)	 4-1
4.1. Overview of Sector	4-1
4.2. Mineral Industry (2.A.)	4-3
4.2.1. Cement Production (2.A.1.)	4-4
4.2.2. Lime Production (2.A.2.)	4-7
4.2.3. Glass Production (2.A.3.)	4-9
4.2.4. Other Process Uses of Carbonates (2.A.4.)	4-12
4.2.4.1. Ceramics (2.A.4.a)	4-12
4.2.4.2. Other uses of soda ash (2.A.4.b)	4-14
4.2.4.3. Non-metallurgical Magnesium Production (2.A.4.c)	4-15
4.2.4.4. Other (2.A.4.d)	4-15

4.3. Chemical Industry (2.B.)	4-17
4.3.1. Ammonia Production (2.B.1.)	4-18
4.3.2. Nitric Acid Production (2.B.2.)	4-21
4.3.3. Adipic Acid Production (2.B.3.)	4-22
4.3.4. Caprolactam, Glyoxal and Glyoxylic Acid Production (2.B.4.)	4-23
4.3.4.1. Caprolactam Production (2.B.4.a)	4-23
4.3.4.2. Glyoxal Production (2.B.4.b)	4-24
4.3.4.3. Glyoxylic acid Production (2.B.4.c)	4-25
4.3.5. Carbide Production (2.B.5.)	4-26
4.3.5.1. Silicon Carbide Production (2.B.5.a)	4-26
4.3.5.2. Calcium Carbide Production and Use (2.B.5.b)	4-28
4.3.6. Titanium Dioxide Production (2.B.6)	4-29
4.3.7. Soda Ash Production (2.B.7.)	4-31
4.3.8. Petrochemical and Carbon Black Production (2.B.8.)	4-32
4.3.8.1. Methanol Production (2.B.8.a)	4-32
4.3.8.2. Ethylene Production (2.B.8.b)	4-33
4.3.8.3. 1,2-Dichloroethane and Chloroethylene (2.B.8.c)	4-35
4.3.8.4. Ethylene Oxide Production (2.B.8.d)	4-37
4.3.8.5. Acrylonitrile Production (2.B.8.e)	4-39
4.3.8.6. Carbon Black Production (2.B.8.f)	4-41
4.3.8.7. Styrene Production (2.B.8.g.-)	4-42
4.3.8.8. Phthalic Anhydride Production (2.B.8.g.-)	4-43
4.3.8.9. Maleic Anhydride Production (2.B.8.g.-)	4-45
4.3.8.10. Hydrogen Production (2.B.8.g.-)	4-46
4.3.9. Fluorochemical Production (2.B.9.)	4-47
4.3.9.1. By-product Emissions: Production of HCFC-22 (2.B.9.-)	4-47
4.3.9.2. Fugitive Emissions (2.B.9.-)	4-49
4.4. Metal Industry (2.C.)	4-50
4.4.1. Iron and Steel Production (2.C.1.)	4-51
4.4.1.1. Steel Production (2.C.1.a)	4-52
4.4.1.2. Use of Electric Arc Furnaces in Steel Production (2.C.1.a)	4-52
4.4.1.3. Pig Iron Production (2.C.1.b)	4-54
4.4.1.4. Limestone and Dolomite Use in Iron and Steel Production (2.C.1.b)	4-54
4.4.1.5. By-product Gas Flaring in Iron and Steel Production (2.C.1.b)	4-56
4.4.1.6. Direct Reduced Iron Production (2.C.1.c)	4-57
4.4.1.7. Sinter Production (2.C.1.d)	4-57
4.4.1.8. Pellet Production (2.C.1.e)	4-57
4.4.2. Ferroalloys Production (2.C.2.)	4-58
4.4.3. Aluminum Production (2.C.3.)	4-59
4.4.3.1. By-product emissions (2.C.3.-)	4-59
4.4.3.2. F-gases used in foundries (2.C.3.-)	4-61
4.4.4. Magnesium Production (2.C.4.)	4-61
4.4.5. Lead Production (2.C.5.)	4-62
4.4.6. Zinc Production (2.C.6.)	4-62
4.4.7. Rare Earths Production (2.C.7.)	4-62

4.5. Non-energy Products from Fuels and Solvent Use (2.D.)	4-63
4.5.1. Lubricant Use (2.D.1.)	4-63
4.5.2. Paraffin Wax Use (2.D.2.)	4-64
4.5.3. Other (2.D.3.)	4-66
4.5.3.1. Urea used as a catalyst (2.D.3.-)	4-66
4.5.3.2. NMVOC Incineration (2.D.3.-)	4-67
4.5.3.3. Road Paving with Asphalt (2.D.3.-)	4-69
4.5.3.4. Asphalt Roofing (2.D.3.-)	4-69
4.6. Electronics Industry (2.E.)	4-70
4.6.1. Semiconductor (2.E.1.)	4-70
4.6.2. Liquid Crystals (2.E.2.)	4-72
4.6.3. Photovoltaics (2.E.3.)	4-74
4.6.4. Heat Transfer Fluid (2.E.4.)	4-74
4.7. Product Uses as Substitutes for ODS (2.F.)	4-74
4.7.1. Refrigeration and Air Conditioning Equipment (2.F.1.)	4-74
4.7.1.1. Domestic Refrigeration Production, Use and Disposal (2.F.1.-)	4-74
4.7.1.2. Commercial Refrigeration Production, Use and Disposal (2.F.1.-)	4-76
4.7.1.3. Transport Refrigeration Production, Use and Disposal (2.F.1.-)	4-81
4.7.1.4. Industrial Refrigeration Production, Use and Disposal (2.F.1.-)	4-83
4.7.1.5. Stationary Air-Conditioning (Household) Production, Use and Disposal (2.F.1.-)	4-83
4.7.1.6. Mobile Air-Conditioning Production, Use and Disposal (2.F.1.-)	4-85
4.7.2. Foam Blowing Agents (2.F.2.)	4-87
4.7.2.1. Closed Cells (2.F.2.-)	4-87
4.7.2.2. Open Cells (2.F.2.-)	4-90
4.7.3. Fire Protection (2.F.3.)	4-91
4.7.4. Aerosols (2.F.4.)	4-93
4.7.4.1. Metered Dose Inhalers (2.F.4.-)	4-93
4.7.4.2. Aerosols (2.F.4.-)	4-94
4.7.5. Solvents (2.F.5.)	4-96
4.7.6. Other Applications (2.F.6.)	4-98
4.8. Other Product Manufacture and Use (2.G.)	4-98
4.8.1. Electrical Equipment (2.G.1.)	4-99
4.8.2. SF <sub>6</sub> and PFCs from Other Product Use (2.G.2.)	4-101
4.8.2.1. Military applications (2.G.2.-)	4-101
4.8.2.2. Accelerators (2.G.2.-)	4-102
4.8.2.3. Soundproof windows (2.G.2.-)	4-103
4.8.2.4. Adiabatic properties: shoes and tyres (2.G.2.-)	4-103
4.8.2.5. Other - Railway Silicon Rectifiers (2.G.2.-)	4-103
4.8.3. N <sub>2</sub> O from Product Uses (2.G.3.)	4-104
4.8.3.1. Medical Applications (2.G.3.a)	4-104
4.8.3.2. Other (2.G.3.b)	4-105
4.9. Other (2.H.)	4-106
4.9.1. Food and Beverages Industry (2.H.2.)	4-107
4.9.2. Emissions from Imported Carbonated Gas (2.H.3.)	4-107

CHAPTER 5. AGRICULTURE (CRF SECTOR 3)	5-1
5.1. Overview of Sector	5-1
5.2. Enteric Fermentation (3.A.)	5-2
5.2.1. Cattle (3.A.1.)	5-2
5.2.2. Buffalo, Sheep, Goats, Horses & Swine (3.A.2., 3.A.3., 3.A.4.-)	5-9
5.2.3. Other Livestock (3.A.4.-)	5-10
5.3. Manure Management (3.B.)	5-11
5.3.1. Cattle, Swine and Poultry (Hen and Broiler) (3.B.1., 3.B.3., 3.B.4.-)	5-11
5.3.2. Buffalo, Sheep, Goats, Horses, Rabbits and Mink (3.B.2., 3.B.4.-)	5-32
5.3.3. Other Livestock (3.B.4.-)	5-34
5.3.4. Indirect N <sub>2</sub> O emissions (3.B.5.)	5-35
5.3.4.1. Atmospheric Deposition (3.B.5.-)	5-35
5.3.4.2. Nitrogen Leaching and Run-off (3.B.5.-)	5-37
5.4. Rice Cultivation (3.C.)	5-37
5.4.1. Irrigated (Intermittently Flooded (Single Aeration) and Continuously Flooded) (3.C.1.)	5-38
5.4.2. Rainfed, Deep Water and Other (3.C.2., 3.C.3., 3.C.4.)	5-45
5.5. Agricultural Soils (3.D.)	5-45
5.5.1. Direct N <sub>2</sub> O Emissions from Managed Soils (3.D.a.)	5-46
5.5.1.1. Inorganic N Fertilizers (3.D.a.1.)	5-46
5.5.1.2. Organic N Fertilizers (3.D.a.2.)	5-50
5.5.1.3. Urine and Dung Deposited by Grazing Animals (3.D.a.3.)	5-54
5.5.1.4. Crop Residues (3.D.a.4.)	5-54
5.5.1.5. Mineralization/Immobilization Associated with Loss/Gain of Soil Organic Matter (3.D.a.5.)	5-58
5.5.1.6. Plowing of Organic Soils (3.D.a.6.)	5-60
5.5.2. Indirect N <sub>2</sub> O Emissions from Managed Soils (3.D.b.)	5-63
5.5.2.1. Atmospheric Deposition (3.D.b.1.)	5-63
5.5.2.2. Nitrogen Leaching and Run-off (3.D.b.2.)	5-65
5.6. Prescribed Burning of Savannas (3.E.)	5-67
5.7. Field Burning of Agricultural Residues (3.F.)	5-67
5.8. Liming (3.G.)	5-70
5.9. Urea application (3.H.)	5-71
5.10. Other Carbon-containing Fertilizers (3.I.)	5-72
5.11. Other (3.J.)	5-72
CHAPTER 6. LAND USE, LAND-USE CHANGE AND FORESTRY (CRF SECTOR 4)	6-1
6.1. Overview of Sector	6-1
6.2. Land-use definitions and the classification systems used and their correspondence to the land use, land-use change and forestry categories	6-2
6.3. Approaches for estimating land areas and land-use database used for the inventory preparation	6-4
6.3.1. Survey methods and due dates of major land area statistics	6-4
6.3.2. Land area estimation methods	6-4
6.3.3. Land-use transition matrix	6-4

6.4. Parameters for estimating carbon stock changes due to land-use conversions	6-5
6.5. Forest land (4.A.)	6-9
6.5.1. Forest land remaining Forest land (4.A.1.)	6-10
6.5.2. Land converted to Forest land (4.A.2.)	6-21
6.6. Cropland (4.B.)	6-26
6.6.1. Cropland remaining Cropland (4.B.1.)	6-26
6.6.2. Land converted to Cropland (4.B.2.)	6-36
6.7. Grassland (4.C.)	6-41
6.7.1. Grassland remaining Grassland (4.C.1.)	6-42
6.7.2. Land converted to Grassland (4.C.2.)	6-45
6.8. Wetlands (4.D.)	6-49
6.8.1. Wetlands remaining Wetlands (4.D.1.)	6-50
6.8.2. Land converted to Wetlands (4.D.2.)	6-51
6.9. Settlements (4.E.)	6-53
6.9.1. Settlements remaining Settlements (4.E.1.)	6-54
6.9.2. Land converted to Settlements (4.E.2.)	6-61
6.10. Other land (4.F.)	6-68
6.10.1. Other land remaining Other land (4.F.1.)	6-68
6.10.2. Land converted to Other land (4.F.2.)	6-69
6.11. Harvested Wood Products (4.G.)	6-72
6.11.1. Buildings	6-73
6.11.2. Wood used for other than buildings	6-78
6.11.3. Paper and paperboard	6-81
6.12. Direct N <sub>2</sub> O emissions from N inputs to managed soils (4. (I))	6-84
6.13. CH <sub>4</sub> and N <sub>2</sub> O Emissions and Removals from Drainage and Rewetting and Other Management of Organic and Mineral soils (4.(II))	6-86
6.14. Direct N <sub>2</sub> O emissions from N mineralization/immobilization associated with loss/gain of soil organic matter resulting from change of land use or management of mineral soils (4.(III))	6-88
6.15. Indirect nitrous oxide (N <sub>2</sub> O) emissions from managed soils (4.(IV))	6-92
6.16. Biomass burning (4.(V))	6-95
 CHAPTER 7. WASTE (CRF SECTOR 5)	 7-1
7.1. Overview of Sector	7-1
7.1.1. Overview of Waste Management and Estimation Category	7-1
7.1.2. Overview of Greenhouse Gas Emissions on Waste Sector	7-2
7.1.3. General Description for Methodological Issues on the Waste Sector	7-3
7.1.4. General Assessment Procedure for the Uncertainty on the Waste Sector	7-4
7.1.5. General Recalculations for Emissions from Waste Sector	7-5
7.2. Solid Waste Disposal (5.A.)	7-6
7.2.1. Managed Disposal Sites (5.A.1.)	7-7
7.2.2. Unmanaged Waste Disposal Sites (5.A.2.)	7-18
7.2.3. Uncategorized Waste Disposal Sites (5.A.3.)	7-18
7.2.3.1. Inappropriate Disposal (5.A.3.-)	7-18
7.3. Biological Treatment of Solid Waste (5.B.)	7-20

7.3.1. Composting (5.B.1)	7-21
7.3.2. Anaerobic Digestion at Biogas Facilities (5.B.2.)	7-23
7.4. Incineration and Open Burning of Waste (5.C.)	7-25
7.4.1. Waste Incineration (without Energy Recovery) (5.C.1.)	7-30
7.4.1.1. Municipal Solid Waste (5.C.1.-)	7-30
7.4.1.2. Industrial Waste (5.C.1.-)	7-41
7.4.1.3. Specially-Controlled Industrial Waste (5.C.1.-)	7-49
7.4.2. Open Burning of Waste (5.C.2.)	7-53
7.4.2.1. Municipal Solid Waste (5.C.2.-)	7-53
7.4.2.2. Industrial Waste (5.C.2.-)	7-53
7.4.3. Waste Incineration and Energy Use (Reported on Energy Sector) (1.A.)	7-56
7.4.3.1. Waste Incineration with Energy Recovery (1.A.)	7-56
7.4.3.2. Direct Use of Waste as Alternative Fuel (1.A.)	7-58
7.4.3.3. Incineration of Waste Processed as Fuel (1.A.)	7-68
7.5. Wastewater Treatment and Discharge (5.D.)	7-74
7.5.1. Domestic Wastewater (5.D.1.)	7-75
7.5.1.1. Sewage Treatment Plant (5.D.1.-)	7-76
7.5.1.2. Domestic Sewage Treatment Plant (Mainly <i>Johkasou</i> ) (5.D.1.-)	7-78
7.5.1.3. Human-Waste Treatment Plant (5.D.1.-)	7-81
7.5.1.4. Natural Decomposition of Domestic Wastewater (5.D.1.-)	7-85
7.5.2. Industrial Wastewater (5.D.2.)	7-90
7.5.2.1. Industrial Wastewater Treatment (5.D.2.-)	7-90
7.5.2.2. Natural Decomposition of Industrial Wastewater (5.D.2.-)	7-94
7.5.2.3. Landfill Leachate Treatment (5.D.2.-)	7-97
7.6. Other (5.E.)	7-100
7.6.1. Decomposition of Petroleum-Derived Surfactants (5.E.-)	7-100
<b>CHAPTER 8. OTHER</b>	<b>8-1</b>
8.1. Overview of Sector	8-1
8.2. CO <sub>2</sub> , CH <sub>4</sub> , N <sub>2</sub> O, HFCs, PFCs, SF <sub>6</sub> , and NF <sub>3</sub>	8-1
8.3. NO <sub>x</sub> , CO, NMVOC, and SO <sub>x</sub>	8-1
<b>CHAPTER 9. INDIRECT CO<sub>2</sub> AND N<sub>2</sub>O EMISSIONS</b>	<b>9-1</b>
9.1. Overview of Sector	9-1
<b>CHAPTER 10. RECALCULATION AND IMPROVEMENTS</b>	<b>10-1</b>
10.1. Explanations and Justifications for Recalculations	10-1
10.1.1. General Issues	10-1
10.1.2. Recalculations in Each Sector	10-1
10.2. Implications for Emission Levels	10-1
10.2.1. GHG Inventory	10-1
10.2.2. KP-LULUCF Inventory	10-9
10.3. Implication for Emission Trends, including Time Series Consistency	10-10
10.3.1. GHG Inventory	10-10
10.4. Recalculations and improvement plan, including response to the review process	10-10

10.4.1. Improvements after submission of the inventory _____	10-10
10.4.1.1. Methodology for estimating emissions and removals of GHGs _____	10-10
10.4.1.2. National Greenhouse Gas Inventory Report _____	10-13
10.4.1.3. Improvements by following UNFCCC-ERT recommendations _____	10-13
10.4.2. Planned Improvements _____	10-14
CHAPTER 11. SUPPLEMENTARY INFORMATION ON LULUCF ACTIVITIES UNDER ARTICLE 3, PARAGRAPHS 3 AND 4 OF THE KYOTO PROTOCOL _____	11-1
11.1. Summary of removal related trends, and emissions and removals from KP LULUCF activities _____	11-1
11.2. Information relating to the decision 3/CMP.11 in paragraph 8 _____	11-2
11.3. General information _____	11-2
11.3.1. Definition of forest and any other criteria _____	11-2
11.3.2. Elected activities under Article 3, paragraph 4 of the Kyoto Protocol _____	11-4
11.3.2.1. Forest Management _____	11-4
11.3.2.2. Cropland Management _____	11-4
11.3.2.3. Grazing Land Management _____	11-5
11.3.2.4. Revegetation _____	11-5
11.3.3. Description of how the definitions of each activity under Article 3.3 and each elected activity under Article 3.4 have been implemented and applied consistently over time _____	11-5
11.3.4. Description of precedence conditions and/or hierarchy among elected Article 3.4 activities, and how they have been consistently applied in determining how land was classified _____	11-5
11.4. Land-related information _____	11-5
11.4.1. Spatial assessment unit used for determining the area of the units of land under Article 3.3 _____	11-5
11.4.2. Methodology used to develop the land transition matrix _____	11-6
11.4.2.1. Description of land transition matrix (CRF-NIR Table 2) _____	11-6
11.4.2.2. Overview of the procedures to estimate emissions and removals _____	11-6
11.4.2.3. Afforestation/Reforestation and Deforestation _____	11-7
11.4.2.4. Forest Management _____	11-10
11.4.2.5. Cropland Management _____	11-12
11.4.2.6. Grazing Land Management _____	11-12
11.4.2.7. Revegetation _____	11-12
11.4.3. Maps and/or database to identify the geographical locations, and the system of identification codes for the geographical locations _____	11-17
11.5. Activity-specific information _____	11-18
11.5.1. Methods for carbon stock change and GHG emission and removal estimates _____	11-18
11.5.1.1. Description of the methodologies and the underlying assumptions used _____	11-18
11.5.1.2. Justification when omitting any carbon pool or GHG emissions/removals from activities under Article 3.3, forest management and elected activities under Article 3.4 _____	11-44
11.5.1.3. Information relating to exclusions of emission from natural disturbances _____	11-44

11.5.1.4. Information relating to Harvest Wood Products (HWP)	11-45
11.5.1.5. Information on whether or not indirect and natural GHG emissions and removals have been factored out	11-46
11.5.1.6. QA/QC and verification	11-46
11.5.1.7. Changes in data and methods since the previous submission (recalculations)	11-46
11.5.1.8. Uncertainty estimates	11-48
11.5.1.9. Information on other methodological issues (methods dealing with the effects of natural disturbances)	11-52
11.5.1.10. The year of the onset of an activity	11-52
11.6. Article 3.3	11-53
11.6.1. Information that demonstrates that activities under Article 3.3 began on or after 1 January 1990 and before 31 December 2020 and are direct human-induced	11-53
11.6.2. Information on how harvesting or forest disturbance that is followed by the re-establishment of forest is distinguished from deforestation	11-53
11.7. Article 3.4	11-54
11.7.1. Information that demonstrates that activities under Article 3.4 have occurred since 1 January 1990 and are human-induced	11-54
11.7.1.1. Forest Management	11-54
11.7.1.2. Cropland Management	11-54
11.7.1.3. Grazing Land Management	11-54
11.7.1.4. Revegetation	11-54
11.7.2. Information relating to cropland management, grazing land management and revegetation for the base year and the commitment period	11-56
11.7.3. Information that demonstrates the emissions and removals resulting from elected Article 3.4 activities are not accounted for under activities under Article 3.3 activities	11-56
11.7.3.1. Information on emissions and removals by FM activities are not accounted for under Article 3.3 activities	11-56
11.7.3.2. Information on emissions and removals from CM activities are not accounted under Article 3.3 activities	11-56
11.7.3.3. Information on emissions and removals from GM activities are not accounted under Article 3.3 activities	11-56
11.7.3.4. Information on emissions and removals from RV activities are not accounted under Article 3.3 activities	11-56
11.7.4. Information relating to the conversion of natural forests to planted forests	11-57
11.7.5. Information on forest reference level (Consistency)	11-57
11.7.6. Information relating forest management reference (technical correction)	11-57
11.7.7. Information on newly established forest will reach at least the equivalent carbon stock	11-57
11.8. Other information	11-58
11.8.1. Key category analysis for Article 3.3 activities and any elected activities under Article 3.4	11-58
11.8.2. Further improvements	11-58



11.9. Information relating to Article 6	11-59
11.10. Information on the reporting status of the Annex II to decision 2/CMP.8	11-59
CHAPTER 12. INFORMATION ON ACCOUNTING OF KYOTO UNITS	12-1
12.1. Summary of information reported in the SEF tables	12-1
12.2. Discrepancies and notifications	12-1
12.3. Publicly accessible information	12-1
12.4. Calculation of the commitment period reserve (CPR)	12-2
CHAPTER 13. INFORMATION ON CHANGES IN NATIONAL SYSTEM	13-1
CHAPTER 14. INFORMATION ON CHANGES IN NATIONAL REGISTRY	14-1
14.1. Summary of changes made on national registry of Japan in 2021	14-1
14.2. Information relevant to the changes made on national registry of Japan	14-1
CHAPTER 15. INFORMATION ON MINIMIZATION OF ADVERSE IMPACTS IN ACCORDANCE WITH ARTICLE 3, PARAGRAPH 14	15-1
15.1. Overview	15-1
15.2. Actions to minimize adverse impacts in accordance with Article 3, paragraph 14	15-1
ANNEX 1. KEY CATEGORIES	ANNEX 1-1
A1.1. Outline of Key Category Analysis	Annex 1-1
A1.2. Results of Key Category Analysis	Annex 1-1
ANNEX 2. ASSESSMENT OF UNCERTAINTY	ANNEX 2-1
A2.1. Methodology of Uncertainty Assessment	Annex 2-1
A2.2. Results of Uncertainty Assessment	Annex 2-1
ANNEX 3. DETAILED METHODOLOGICAL DESCRIPTIONS FOR INDIVIDUAL SOURCE OR SINK CATEGORIES	ANNEX 3-1
A3.1. Methodology for Estimating Emissions of Precursors	Annex 3-1
A3.1.1 Energy Sector	Annex 3-1
A3.1.2 Industrial Processes and Product Use (IPPU)	Annex 3-27
A3.1.3 Agriculture	Annex 3-63
A3.1.4 Land Use, Land-Use Change and Forestry	Annex 3-63
A3.1.5 Waste	Annex 3-65
A3.1.6 Other sectors	Annex 3-70
ANNEX 4. THE NATIONAL ENERGY BALANCE FOR THE MOST RECENT INVENTORY YEAR	ANNEX 4-1
A4.1. Discrepancies between the figures reported in the CRF tables and the IEA statistics	Annex 4-1
A4.2. General Energy Statistics	Annex 4-12

A4.2.1 General Energy Statistics Overview	Annex 4-12
A4.2.2 General Energy Statistics and CRF	Annex 4-17
A4.3. Quality Standard for Diesel Oil	Annex 4-21
A4.4. Conversion factors of calorific values	Annex 4-21
ANNEX 5. ASSESSMENT OF COMPLETENESS, DEFINITION OF NOTATION KEYS, AND SOURCES AND SINKS REPORTED AS “NE”	
A5.1. Assessment of Completeness	Annex 5-1
A5.2. Definition of Notation Keys	Annex 5-1
A5.3. Decision Tree for Application of Notation Keys	Annex 5-2
A5.4. Emission sources reported as “NE” (considered insignificant) in Japan	Annex 5-3
A5.5. Source and sink categories not estimated in Japan’s inventory	Annex 5-4
ANNEX 6. HIERARCHICAL STRUCTURE OF JAPAN’S NATIONAL GHG INVENTORY FILE SYSTEM	
	ANNEX 6-1

Abbreviations

## Executive Summary of the National GHG Inventory Report of Japan

### E.S.1. Background Information on the GHG Inventory

Japan reports its Greenhouse Gas (GHG) Inventory, which contains the information on emissions and removals of GHGs, including indirect GHGs and SO<sub>x</sub> in Japan for FY1990 to FY2020<sup>1</sup>, on the basis of Articles 4 and 12 of the United Nations Framework Convention on Climate Change (UNFCCC) and Decision 2/CMP.8.

Estimation methodologies of GHGs inventories are required to be in line with the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (hereafter *2006 IPCC Guidelines*) which was developed by the Intergovernmental Panel on Climate Change (IPCC), and Japan's estimation methodologies are basically in line with these guidelines. In order to enhance transparency, consistency, comparability, completeness and accuracy of the inventory, Japan also applies the *2013 Supplement to the 2006 IPCC Guidelines: Wetlands* (hereafter *Wetlands Guidelines*) and the *2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol* (hereafter *KP Supplement*), and the *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories* (hereafter *2019 Refinement*).

Japan's national inventory is reported in accordance with the *UNFCCC Reporting Guidelines on Annual Inventories* (Decision 24/CP.19 Annex I, hereinafter referred to as the *UNFCCC Inventory Reporting Guidelines*) decided by the Conference of the Parties.

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<sup>1</sup> "FY" (fiscal year), from April of the reporting year through March of the next year, is used because CO<sub>2</sub> is the primary GHGs emissions and estimated on a fiscal year basis. "CY" stands for "calendar year".

## E.S.2. Summary of National Emission and Removal Related Trends

### E.S.2.1. GHG Inventory

Total GHGs emissions<sup>2</sup> in FY2020 (excluding LULUCF<sup>3</sup>, including indirect CO<sub>2</sub><sup>4</sup>, hereafter, definition omitted) were 1,150 million tonnes (in CO<sub>2</sub> eq.). They decreased by 9.8% compared to the emissions in FY1990.

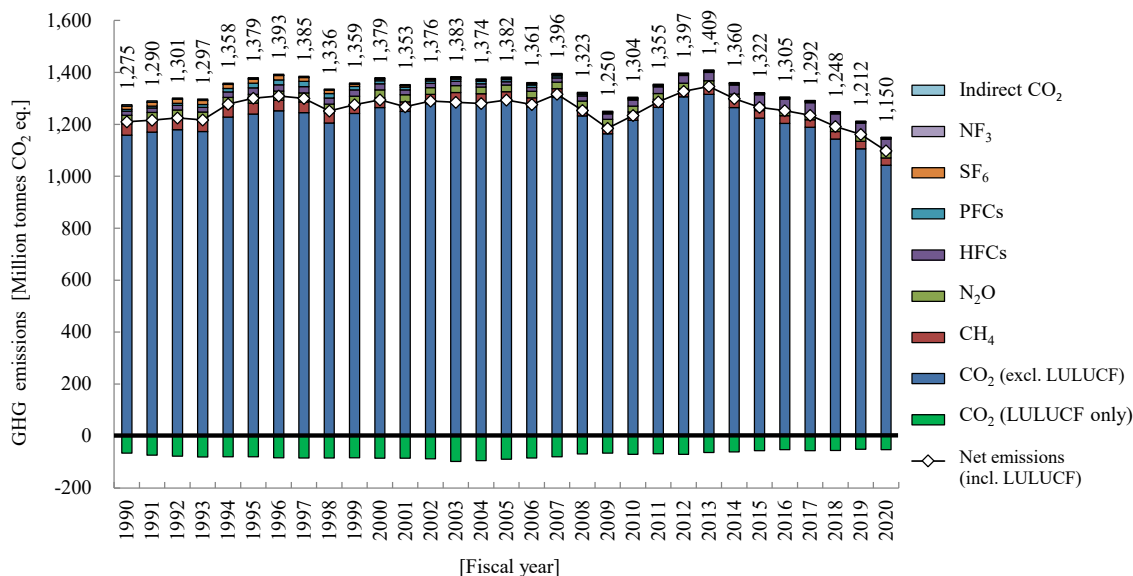


Figure 1 Trends in GHG emissions and removals in Japan

<sup>2</sup> The sum of CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O, HFCs, PFCs, SF<sub>6</sub>, and NF<sub>3</sub> emissions converted to CO<sub>2</sub> equivalents multiplied by their respective global warming potential (GWP). The GWP is a coefficient by means of which greenhouse gas effects of a given gas are made relative to those of an equivalent amount of CO<sub>2</sub>. The coefficients (100 year time horizon) are drawn from the *Fourth Assessment Report (2007)* issued by the IPCC.

<sup>3</sup> Abbreviation of “Land Use, Land-Use Change and Forestry”

<sup>4</sup> Carbon monoxide (CO), methane (CH<sub>4</sub>) and non-methane volatile organic compounds (NMVOC) are oxidized in the atmosphere in the long term and converted to CO<sub>2</sub>. Indirect CO<sub>2</sub> means value in CO<sub>2</sub> equivalent of these emissions. However, emissions of CO, CH<sub>4</sub> and NMVOC derived from combustion origin and biomass origin are excluded to avoid double counting and/or by concept of carbon neutral.

Table 1 Trends in GHGs emissions and removals in Japan

[Million tonnes CO <sub>2</sub> eq.]	GWP	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CO <sub>2</sub> (excl. LULUCF) *1	1	1,158.1	1,169.8	1,179.5	1,172.5	1,227.5	1,239.9	1,252.4	1,245.1	1,205.2	1,241.8	1,264.6	1,250.0	1,279.4	1,287.7	1,283.1	1,290.6	1,267.6	1,303.4	1,232.5	1,163.4
CO <sub>2</sub> (incl. LULUCF) *1	1	1,092.5	1,096.1	1,102.4	1,092.1	1,147.4	1,160.4	1,168.7	1,160.4	1,120.4	1,157.9	1,179.6	1,164.4	1,192.0	1,189.6	1,188.6	1,201.6	1,183.3	1,223.5	1,163.4	1,097.4
CO <sub>2</sub> (LULUCF only)	1	-65.7	-73.7	-77.1	-80.4	-80.4	-79.5	-83.7	-84.7	-84.8	-84.0	-85.0	-85.0	-87.3	-98.0	-94.5	-89.0	-84.3	-79.9	-69.1	-66.0
CH <sub>4</sub> (excl. LULUCF)	25	44.1	43.5	43.5	42.6	42.8	41.7	40.5	40.1	38.5	38.2	37.6	36.5	35.8	34.9	34.7	34.7	34.2	33.7	32.9	32.4
CH <sub>4</sub> (incl. LULUCF)	25	44.2	43.6	43.6	42.8	42.9	41.8	40.6	40.2	38.6	38.3	37.7	36.6	35.9	35.0	34.8	34.8	34.3	33.7	33.0	32.5
N <sub>2</sub> O (excl. LULUCF)	298	32.4	32.0	32.2	32.1	33.3	33.6	34.7	35.5	33.9	33.9	30.3	26.7	26.1	26.0	25.8	25.5	25.4	24.8	23.9	23.3
N <sub>2</sub> O (incl. LULUCF)	298	32.6	32.3	32.4	32.3	33.6	33.8	34.9	35.7	34.2	28.0	30.6	26.9	26.3	26.3	26.0	25.7	25.6	25.0	24.1	23.5
HFCs	HFC-134a 1,430 etc. 7,390 etc.	15.9	17.3	17.8	18.1	21.1	25.2	24.6	24.4	23.7	24.4	22.9	19.5	19.5	16.2	12.4	12.8	14.6	16.7	19.3	20.9
PFCs	PFC-14: 7,390 etc.	6.5	7.5	7.6	10.9	13.4	17.7	18.3	20.0	16.6	13.1	11.9	9.9	9.2	8.9	9.2	8.6	9.0	7.9	5.8	4.1
SF <sub>6</sub>	22,800	12.9	14.2	15.6	15.7	15.0	16.4	17.0	14.5	13.2	9.2	7.0	6.1	5.7	5.4	5.3	5.0	5.2	4.7	4.2	2.4
NF <sub>3</sub>	17,200	0.0	0.0	0.0	0.0	0.1	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.5	1.5	1.4	1.6	1.5	1.4
Indirect CO <sub>2</sub>	1	5.5	5.4	5.1	4.9	4.9	4.8	4.8	4.6	4.2	4.2	4.3	3.9	3.6	3.4	3.4	3.3	3.2	3.0	2.8	2.5
Gross Total (excluding LULUCF, excluding indirect CO <sub>2</sub> )	1	1,269.9	1,284.4	1,296.2	1,292.0	1,353.2	1,374.7	1,387.8	1,379.9	1,331.4	1,354.8	1,374.6	1,349.0	1,372.8	1,379.6	1,371.0	1,378.7	1,357.5	1,392.8	1,320.0	1,247.9
Net Total (including LULUCF, excluding indirect CO <sub>2</sub> )	1	1,204.6	1,211.0	1,219.4	1,211.9	1,273.4	1,295.5	1,304.4	1,295.5	1,246.9	1,271.2	1,289.9	1,263.7	1,285.8	1,281.8	1,276.8	1,290.0	1,273.4	1,313.1	1,251.2	1,182.2
Gross Total (including LULUCF, including indirect CO <sub>2</sub> )	1	1,275.4	1,289.7	1,301.3	1,296.9	1,358.1	1,379.5	1,392.6	1,384.5	1,335.7	1,359.1	1,378.9	1,352.8	1,376.4	1,383.0	1,374.4	1,382.0	1,360.7	1,395.8	1,322.7	1,250.4
Net Total (including LULUCF, including indirect CO <sub>2</sub> )	1	1,210.1	1,216.4	1,224.5	1,216.8	1,278.3	1,300.3	1,309.2	1,300.1	1,251.2	1,275.4	1,294.3	1,267.6	1,289.4	1,285.3	1,280.2	1,293.3	1,276.6	1,316.2	1,253.9	1,184.7
[Million tonnes CO <sub>2</sub> eq.]	GWP	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	1990	Changes in emissions/removals (2020)		Previous year					
CO <sub>2</sub> (excl. LULUCF) *1	1	1,215.1	1,265.0	1,306.2	1,315.6	1,264.4	1,223.6	1,203.9	1,188.4	1,143.4	1,106.0	1,042.2	1,042.2	-10.0%	-5.8%	-10.0%	-5.8%				
CO <sub>2</sub> (incl. LULUCF) *1	1	1,144.9	1,196.7	1,235.8	1,252.3	1,203.2	1,166.9	1,151.3	1,131.7	1,087.4	1,054.8	989.9	989.9	-9.4%	-6.1%	-9.4%	-6.1%				
CO <sub>2</sub> (LULUCF only)	1	-70.2	-68.3	-70.4	-63.2	-61.2	-56.7	-52.5	-56.6	-56.0	-51.2	-52.3	-52.3	-20.4%	2.1%	-20.4%	2.1%				
CH <sub>4</sub> (excl. LULUCF)	25	32.0	30.8	30.1	30.1	29.6	29.3	29.2	29.0	28.7	28.5	28.4	28.4	-35.6%	-0.3%	-35.6%	-0.3%				
CH <sub>4</sub> (incl. LULUCF)	25	32.1	30.9	30.2	30.2	29.7	29.3	29.3	29.1	28.7	28.5	28.5	28.5	-35.6%	-0.3%	-35.6%	-0.3%				
N <sub>2</sub> O (excl. LULUCF)	298	22.8	22.5	22.1	22.0	21.6	21.3	20.8	21.1	20.6	20.3	20.0	20.0	-38.2%	-1.3%	-38.2%	-1.3%				
N <sub>2</sub> O (incl. LULUCF)	298	23.0	22.6	22.3	22.2	21.8	21.5	21.0	21.3	20.8	20.5	20.2	20.2	-38.0%	-1.3%	-38.0%	-1.3%				
HFCs	HFC-134a: 1,430 etc. 7,390 etc.	23.3	26.1	29.4	32.1	35.8	39.3	42.6	45.0	47.0	49.7	51.7	51.7	22.4%	4.0%	22.4%	4.0%				
PFCs	PFC-14: 7,390 etc.	4.3	3.8	3.4	3.3	3.4	3.3	3.4	3.5	3.5	3.4	3.5	3.5	-46.9%	1.5%	-46.9%	1.5%				
SF <sub>6</sub>	22,800	2.4	2.2	2.2	2.1	2.0	2.1	2.2	2.1	2.1	2.0	2.0	2.0	-84.2%	1.4%	-84.2%	1.4%				
NF <sub>3</sub>	17,200	1.5	1.8	1.5	1.6	1.1	0.6	0.6	0.4	0.3	0.3	0.3	0.3	785.7%	10.5%	785.7%	10.5%				
Indirect CO <sub>2</sub>	1	2.5	2.4	2.3	2.3	2.2	2.2	2.2	2.1	2.1	2.1	2.0	2.0	-64.6%	-4.8%	-64.6%	-4.8%				
Gross Total (excluding LULUCF, excluding indirect CO <sub>2</sub> )	1	1,301.4	1,352.2	1,395.0	1,406.8	1,357.9	1,319.4	1,302.7	1,289.4	1,245.5	1,210.2	1,148.1	1,148.1	-9.6%	-5.1%	-9.6%	-5.1%				
Net Total (including LULUCF, excluding indirect CO <sub>2</sub> )	1	1,231.5	1,284.2	1,324.8	1,343.9	1,297.0	1,263.0	1,250.4	1,233.1	1,189.9	1,159.2	1,096.1	1,096.1	-9.0%	-5.4%	-9.0%	-5.4%				
Gross Total (including LULUCF, including indirect CO <sub>2</sub> )	1	1,303.9	1,354.6	1,397.3	1,409.1	1,360.2	1,321.6	1,304.9	1,291.6	1,247.7	1,212.2	1,150.1	1,150.1	-9.8%	-5.1%	-9.8%	-5.1%				
Net Total (including LULUCF, including indirect CO <sub>2</sub> )	1	1,234.0	1,286.5	1,327.1	1,346.2	1,299.2	1,265.2	1,252.6	1,235.2	1,192.0	1,161.3	1,098.1	1,098.1	-9.3%	-5.4%	-9.3%	-5.4%				

\*1 Excluding indirect CO<sub>2</sub>

\*2 LULUCF: Land Use, Land-Use Change and Forestry

### E.S.2.2. KP-LULUCF Activities

In accordance with the decision 2/CMP.8 in paragraph 4 adopted by the Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol (COP/MOP8), Japan reports afforestation/reforestation (AR), deforestation (D), forest management (FM), cropland management (CM), grazing land management (GM), and revegetation (RV) as LULUCF activities under article 3, paragraphs 3 and 4 of the Kyoto Protocol for the second commitment period<sup>5</sup>. The breakdown of emissions and removals for each activity is shown in Table 2. For detailed information, see Chapter 11.

Table 2 Accounting summary for activities under articles 3.3 and 3.4 of the Kyoto Protocol

GREENHOUSE GAS SOURCE AND SINK ACTIVITIES	Base Year (1990)	EMISSIONS/REMOVALS									Accounting parameters	Accounting quantity
		2013	2014	2015	2016	2017	2018	2019	2020	Total		
(kt CO <sub>2</sub> eq)												
<b>A. Article 3.3 activities</b>												
<b>A.1. Afforestation/reforestation</b>		-1,478	-1,483	-1,486	-1,488	-1,465	-1,375	-1,316	-1,245	-11,336		-11,336
Excluded emissions from natural disturbances		NA	NA	NA	NA	NA	NA	NA	NA	NA		NA
Excluded subsequent removals from land subject to natural disturbances		NA	NA	NA	NA	NA	NA	NA	NA	NA		NA
<b>A.2. Deforestation</b>		2,005	2,007	2,317	2,316	1,827	1,819	1,683	1,696	15,669		15,669
<b>B. Article 3.4 activities</b>												
<b>B.1. Forest management</b>										-370,363		-382,808
Net emissions/removals		-51,174	-51,512	-49,255	-46,642	-46,353	-45,229	-41,259	-38,939	-370,363		
Excluded emissions from natural disturbances		NA	NA	NA	NA	NA	NA	NA	NA	NA		NA
Excluded subsequent removals from land subject to natural disturbances		NA	NA	NA	NA	NA	NA	NA	NA	NA		NA
Any debits from newly established forest (CEF-ne)		NA	NA	NA	NA	NA	NA	NA	NA	NA		NA
Forest management reference level (FMRL)		0	0	0	0	0	0	0	0	0		0
Technical corrections to FMRL		1,044	1,220	1,366	1,499	1,635	1,762	1,899	2,019	12,446		1,556
Forest management cap												355,669
<b>B.2. Cropland management</b>		7,561	5,490	6,230	5,749	5,525	4,712	4,130	4,747	4,759	41,341	-19,147
<b>B.3. Grazing land management</b>		443	966	1,582	1,291	1,008	855	622	751	617	7,692	4,151
<b>B.4. Revegetation</b>		-80	-1,230	-1,249	-1,270	-1,287	-1,310	-1,325	-1,350	-1,360	-10,381	-9,743
<b>B.5. Wetland drainage and rewetting (not elected)</b>		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sum of emissions and removals from Article 3.3 and 3.4 activities for each year		-45,421	-44,425	-42,654	-40,570	-41,734	-41,357	-36,745	-34,472			
Sum of the accounting quantity for Article 3.3 and 3.4 activities of the Kyoto Protocol for the second commitment period												-376,075

\* The total values and results of summing up each element are not always the same because of the difference in display digit.

<sup>5</sup> The emissions/removals occurring from Kyoto Protocol Article 3.3. and 3.4 activities correspond to a part of the LULUCF emission/removals reported under the Convention. Detailed information on LULUCF under the Convention and KP-LULUCF activities can be found in chapter 6 and 11 of this report, respectively.

## E.S.3. Overview of Source and Sink Category Emission Estimates and Trends

### E.S.3.1. GHG Inventory

The breakdown of GHGs emissions and removals in FY2020 by sector<sup>6</sup> shows that the energy (excluding indirect CO<sub>2</sub>) accounts for 86.5% of total GHGs emissions. It is followed by the industrial processes and product use sector (excluding indirect CO<sub>2</sub>) (8.8%), the agriculture sector (2.8%), the waste sector (1.8%), and indirect CO<sub>2</sub> emissions (0.2%).

Removals by the LULUCF in FY2020 were equivalent to 4.5% of total GHGs emissions.

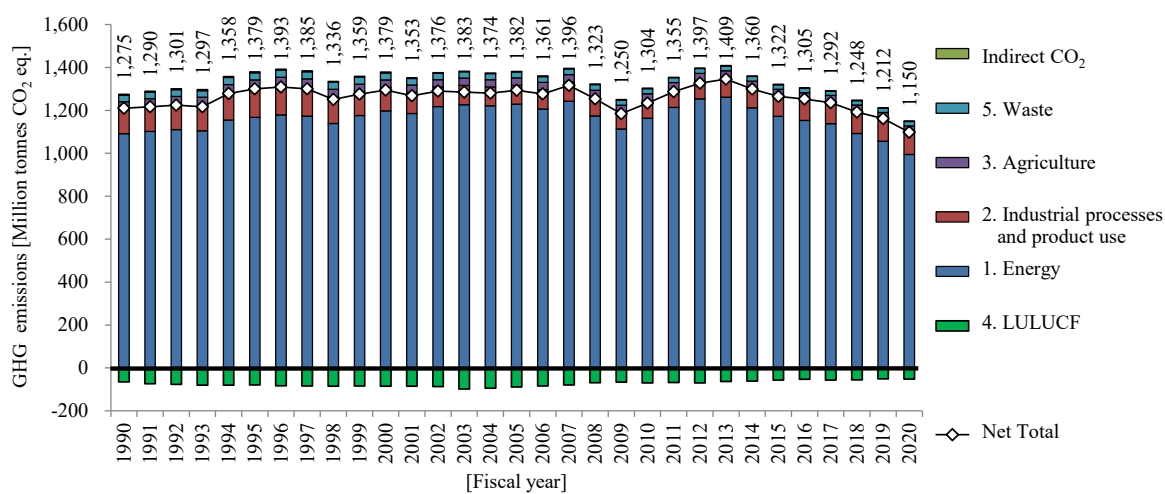


Figure 2 Trends in GHGs emissions and removals in each sector

<sup>6</sup> As indicated in the 2006 IPCC Guidelines and the CRF.

Table 3 Trends in GHGs emissions and removals in each sector

[Million tonnes CO <sub>2</sub> eq.]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
1. Energy <sup>*1</sup>	1,091.9	1,102.3	1,110.4	1,104.4	1,155.4	1,167.4	1,178.9	1,175.5	1,139.3	1,175.9	1,197.8	1,185.6	1,217.2	1,226.1	1,221.9	1,228.8	1,206.1	1,242.3	1,174.4	1,113.0
2. Industrial processes and product use <sup>*1</sup>	111.0	115.5	117.3	119.5	127.0	137.2	139.4	136.5	123.7	111.1	109.1	98.1	91.2	89.8	86.4	87.6	90.5	89.6	85.1	77.7
3. Agriculture	37.5	37.1	37.9	37.8	38.0	37.1	36.3	36.4	35.2	35.3	35.3	34.6	34.8	34.3	34.2	34.6	34.4	34.8	33.7	33.5
4. LULUCF <sup>*2</sup>	-65.3	-73.4	-76.8	-80.1	-79.8	-79.2	-83.4	-84.4	-84.5	-83.7	-84.7	-85.2	-87.0	-97.8	-94.2	-88.7	-84.0	-79.6	-68.8	-65.7
5. Waste	29.6	29.5	30.7	30.3	32.8	33.0	33.2	33.6	33.2	32.6	32.4	30.7	29.6	29.3	28.5	27.7	26.5	26.1	26.7	23.7
Indirect CO <sub>2</sub>	5.5	5.4	5.1	4.9	4.9	4.8	4.8	4.6	4.2	4.2	4.3	3.9	3.6	3.4	3.4	3.3	3.2	3.0	2.8	2.5
Gross Total (excluding LULUCF, excluding indirect CO <sub>2</sub> )	1,269.9	1,284.4	1,296.2	1,292.0	1,353.2	1,374.7	1,387.8	1,379.9	1,331.4	1,354.8	1,374.6	1,349.0	1,372.8	1,379.6	1,371.0	1,378.7	1,357.5	1,392.8	1,320.0	1,247.9
Net Total (including LULUCF, excluding indirect CO <sub>2</sub> )	1,204.6	1,211.0	1,219.4	1,211.9	1,273.4	1,295.5	1,304.4	1,295.5	1,246.9	1,271.2	1,289.9	1,263.7	1,285.8	1,281.8	1,276.8	1,290.0	1,273.4	1,313.1	1,251.2	1,182.2
Gross Total (excluding LULUCF, including indirect CO <sub>2</sub> )	1,275.4	1,289.7	1,301.3	1,296.9	1,358.1	1,379.5	1,392.6	1,384.5	1,335.7	1,359.1	1,378.9	1,352.8	1,376.4	1,383.0	1,374.4	1,382.0	1,360.7	1,395.8	1,322.7	1,250.4
Net Total (including LULUCF, including indirect CO <sub>2</sub> )	1,210.1	1,216.4	1,224.5	1,216.8	1,278.3	1,300.3	1,309.2	1,300.1	1,251.2	1,275.4	1,294.3	1,267.6	1,289.4	1,285.3	1,280.2	1,293.3	1,276.6	1,316.2	1,253.9	1,184.7

[Million tonnes CO <sub>2</sub> eq.]	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
1. Energy <sup>*1</sup>	1,163.1	1,213.8	1,254.1	1,261.7	1,211.5	1,172.3	1,153.5	1,137.9	1,092.5	1,056.3	994.4
2. Industrial processes and product use <sup>*1</sup>	81.0	82.9	85.4	89.8	92.3	93.5	96.5	99.2	100.2	101.5	101.4
3. Agriculture	33.7	33.0	32.6	32.8	32.4	32.2	32.2	32.3	32.1	32.1	32.2
4. LULUCF <sup>*2</sup>	-69.9	-68.0	-70.1	-63.0	-60.9	-56.4	-52.3	-56.3	-55.7	-51.0	-52.0
5. Waste	23.5	22.5	22.8	22.5	21.7	21.5	20.5	20.0	20.7	20.3	20.2
Indirect CO <sub>2</sub>	2.5	2.4	2.3	2.3	2.2	2.2	2.2	2.1	2.1	2.1	2.0
Gross Total (excluding LULUCF, excluding indirect CO <sub>2</sub> )	1,301.4	1,352.2	1,395.0	1,406.8	1,357.9	1,319.4	1,302.7	1,289.4	1,245.5	1,210.2	1,148.1
Net Total (including LULUCF, excluding indirect CO <sub>2</sub> )	1,231.5	1,284.2	1,324.8	1,343.9	1,297.0	1,263.0	1,250.4	1,233.1	1,189.9	1,159.2	1,096.1
Gross Total (excluding LULUCF, including indirect CO <sub>2</sub> )	1,303.9	1,354.6	1,397.3	1,409.1	1,360.2	1,321.6	1,304.9	1,291.6	1,247.7	1,212.2	1,150.1
Net Total (including LULUCF, including indirect CO <sub>2</sub> )	1,234.0	1,286.5	1,327.1	1,346.2	1,299.2	1,265.2	1,252.6	1,235.2	1,192.0	1,161.3	1,098.1

\*1 Excluding indirect CO<sub>2</sub>

\*2 LULUCF: Land Use, Land-Use Change and Forestry

## E.S.3.2. KP-LULUCF Activities

See section 2.2 of this executive summary.



## Chapter 1. Introduction

### 1.1. Background Information on Japan's Greenhouse Gas Inventory and Climate Change

Japan hereby reports its greenhouse gas (GHG) inventory, which contains information on emissions and removals of GHGs, including precursors (nitrogen oxides [NO<sub>x</sub>], carbon monoxide [CO], non-methane volatile organic compounds [NMVOC]), and sulfur oxides (SO<sub>x</sub>) in Japan from FY1990 to FY2020<sup>1</sup>, on the basis of Article 4 and 12 of the United Nations Framework Convention on Climate Change (UNFCCC) and Decision 2/CMP.8.

Estimation methodologies for the GHG inventories are required to be in line with the *2006 IPCC Guidelines for National Greenhouse Gas Inventories (2006 IPCC Guidelines)*, prepared by the Intergovernmental Panel on Climate Change (IPCC), and Japan's estimation methodologies are basically in line with these guidelines. In order to enhance transparency, consistency, comparability, completeness, and accuracy of the inventory, Japan also applies the *2013 Supplement to the 2006 IPCC Guidelines: Wetlands (Wetlands Guidelines)*, the *2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol (KP Supplement (2013))*, and the *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (2019 Refinement)*.

Japan's national inventory is reported in accordance with the *UNFCCC Reporting Guidelines on Annual Greenhouse Gas Inventories* (Decision 24/CP.19 Annex I, hereinafter referred to as the *UNFCCC Inventory Reporting Guidelines*) decided by the Conference of the Parties.

### 1.2. Description of Japan's National Inventory Arrangements

#### 1.2.1. Institutional, Legal and Procedural Arrangements

##### 1.2.1.1. Institutional and legal Arrangement for the Inventory Preparation

The Government of Japan is to calculate the emissions and removals of GHGs for Japan and disclose the results every year, in accordance with Article 7 of Chapter 1 "General Provisions", the Act on Promotion of Global Warming Countermeasures,<sup>2</sup> which determines the domestic measures for the UNFCCC and Kyoto Protocol. The Ministry of the Environment (MOE), with the cooperation of relevant ministries, agencies and organizations, prepares Japan's national inventory and compiles supplementary information required under Decision 2/CMP.8, etc., which is annually submitted in accordance with the UNFCCC and the Kyoto Protocol.

The MOE assumes overall responsibilities for the national inventory and organizes the Committee for the Greenhouse Gas Emission Estimation Methods (Committee) in order to integrate the latest scientific knowledge into the inventory and to modify it to meet international requirements. The estimation of GHG emissions and removals are then carried out by taking the decisions of the Committee into consideration. Substantial activities, such as the estimation of emissions and removals and the preparation of the Common Reporting Format (CRF) tables and National Inventory Report (NIR), are done by the Greenhouse Gas Inventory Office of Japan (GIO), which belongs to the Center for Global

<sup>1</sup> "FY (fiscal year)" is used because CO<sub>2</sub>, which constitutes the largest part of the emission estimate, is on the fiscal year basis (April to March).

<sup>2</sup> Enacted in October 1998. The enforcement of the latest amendment was made on April 1, 2022.

Environmental Research in the Earth System Division of the National Institute for Environmental Studies. The relevant ministries, agencies and organizations provide the GIO with the appropriate data (e.g., activity data, emission factors, and GHG emissions and removals) through compiling various statistics and providing relevant information on supplementary information required under Decision 2/CMP.8, etc. The relevant ministries and agencies check the inventories (i.e., CRF, NIR), including the spreadsheets that are actually utilized for the estimation (Japan National Greenhouse gas Inventory files, hereinafter referred to as “JNGI files”), as a part of the Quality Control (QC) activities.

The checked inventories are determined as Japan’s official GHG emission/removal values. The inventories are then published and submitted to the UNFCCC Secretariat.

Figure 1-1 shows the overall institutional arrangement for Japan’s inventory preparation. More detailed information on the roles and responsibilities of relevant ministries, agencies and organizations in the inventory preparation process is described below.

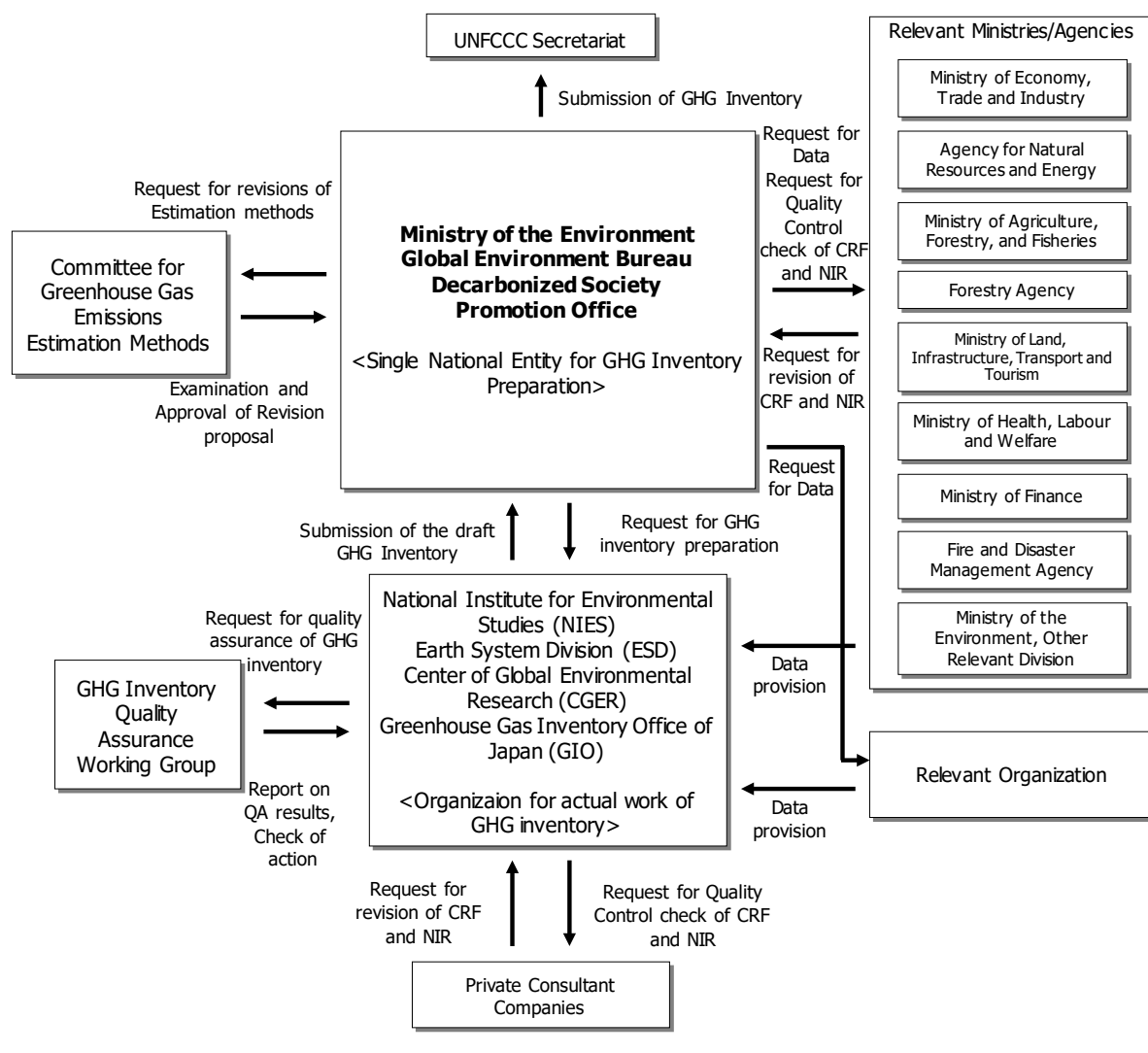


Figure 1-1 Japan’s institutional arrangement for the national inventory preparation

### 1.2.1.2. Roles and responsibilities of each entity involved in the inventory preparation process

The following are the agencies involved in the inventory compilation process, and the roles of those agencies.

#### 1) *Ministry of the Environment (Decarbonized Society Promotion Office, Global Environment Bureau)*

- The single national agency responsible for preparing Japan's inventory, which was designated pursuant to the UNFCCC Inventory Reporting Guidelines and the Kyoto Protocol Article 5.1.
- It is responsible for editing and submitting the inventory.
- It coordinates the Quality Assurance and Quality Control (QA/QC) activities for the inventory.
- It checks and approves the QA/QC plan.
- It checks and approves the inventory improvement plan.

#### 2) *Greenhouse Gas Inventory Office of Japan (GIO), Center for Global Environmental Research, Earth System Division, National Institute for Environmental Studies*

- Performs the actual work of inventory compilation. Responsible for inventory calculations, editing, and the archiving and management of all data.
- Prepares the revised draft of the QA/QC plan.
- Prepares the draft of the inventory improvement plan.

#### 3) *Relevant Ministries/Agencies*

The relevant ministries and agencies have the following roles and responsibilities regarding inventory compilation.

- Preparation and provision of data such as activity data and emission factors required for the preparation of the inventory.
- Confirmation of data provided for the preparation of the inventory.
- Confirmation of the inventory (CRF, NIR, JNGI files, and other information) prepared by the GIO (Category-specific QC).
- (When necessary), responding to questions from expert review teams (ERTs) about the statistics controlled by relevant ministries and agencies, or about certain data they have prepared, and preparing comments on draft reviews.
- (When necessary), responding to in-country review by ERTs.

#### 4) *Relevant Organizations*

Relevant organizations have the following roles and responsibilities regarding inventory compilation.

- Preparation and provision of data such as activity data and emission factors required for the preparation of the inventory.
- Confirmation of data provided for the preparation of the inventory.

- (When necessary), responding to questions from ERTs about the statistics controlled by relevant organizations, or about certain data they have prepared, and preparing comments on draft review reports.

### 5) Committee for the Greenhouse Gas Emissions Estimation Methods

The Committee for the Greenhouse Gas Emissions Estimation Methods (the Committee) is a committee created and run by the MOE. Its role is to consider the methods for calculating inventory emissions and removals, and the selection of parameters such as activity data (AD) and emission factors (EFs). Under the Committee, the inventory working group (WG) that examines cross-cutting issues, and breakout groups that consider sector-specific issues (Breakout group on Energy and Industrial Processes, Breakout group on Transport, Breakout group on F-gases [HFCs, PFCs, SF<sub>6</sub>, and NF<sub>3</sub>], Breakout group on Agriculture, Breakout group on Waste, Breakout group on LULUCF, and Breakout group on NMVOC), as well as the Sub-breakout group on Carbon Capture and Utilization (CCU) are set up. The inventory WG and the breakout groups/sub-breakout group comprise experts in various fields and consider suggestions for inventory improvements.

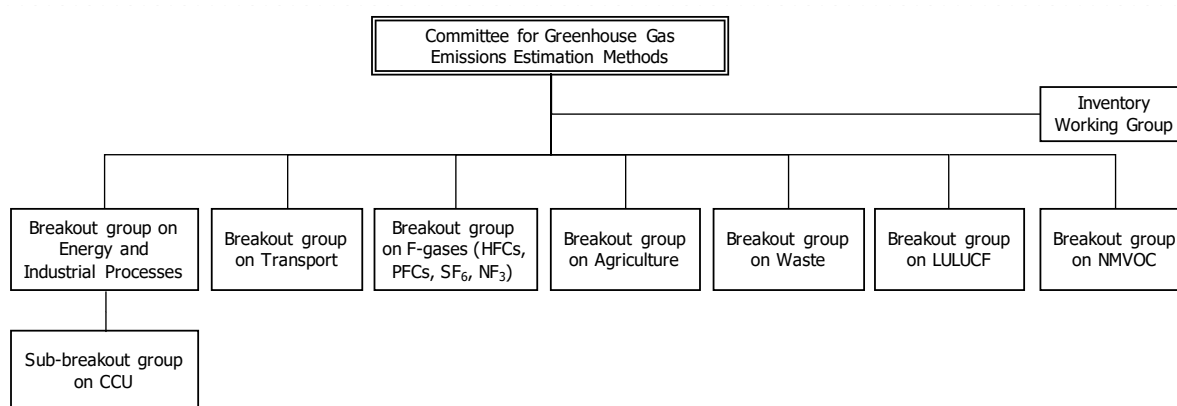


Figure 1-2 Structure of the Committee for the Greenhouse Gas Emissions Estimation Methods

### 6) Private Consulting Companies

Private consultant companies that are contracted by the MOE to perform tasks related to inventory compilation play the following roles in inventory compilation based on their contracts.

- Quality Control (QC) of the inventory (CRF, NIR, JNGI files) compiled by the MOE and the GIO.
- (When necessary), providing support for responding to questions from ERTs and for preparing comments on draft reviews.
- (When necessary), providing support for responding to in-country review by ERTs.

### 7) GHG Inventory Quality Assurance Working Group (QAWG)

The GHG Inventory Quality Assurance Working Group (the QAWG) is an organization for QA activities and comprises experts who are not directly involved in inventory compilation. Its role is to assure inventory quality and to identify places that need improvement by conducting detailed reviews of each emission source and sink in the inventory.

### 1.2.1.3. Response for UNFCCC inventory review

The convention inventory and Kyoto Protocol supplementary information on sinks that Japan submits each year are to be reviewed by an ERTs pursuant to UNFCCC inventory review guidelines (Decision 13/CP.20 Annex), Kyoto Protocol Article 8, Decision 22/CMP.1, and other requirements. Specifically, rigorous checks are performed from perspectives including: whether emissions and removals are accurately and completely estimated and reported, or whether transparent explanations are provided for estimation methods, or whether QA/QC activities and uncertainty assessments are performed appropriately in accordance with the designated guidelines<sup>3</sup>.

In view of the fact that ensuring the transparency of the inventory is a matter of importance, since Japan does not have a reduction commitment under the second commitment period of the Kyoto Protocol, the system shown in Figure 1-3 is used for responding to reviews.

[Basic structure]

The MOE (Decarbonized Society Promotion Office, Global Environment Bureau), which in Japan is responsible for editing and submitting the inventory, is assigned to be the agency with overall control (responsibility) for review response, while the GIO performs the actual work, such as preparing source materials and communicating with the UNFCCC Secretariat. The relevant ministries and agencies, relevant organizations, and private consultant companies<sup>4</sup> that are involved in inventory compilation cooperate with review response through activities including providing relevant information, support for source material preparation, and QC implementation.

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<sup>3</sup> UNFCCC Inventory Reporting Guidelines, 2006 IPCC Guidelines, and the KP Supplement (2013)

<sup>4</sup> Private consultant companies cooperate in responding to reviews based on the operating agreement with MOE.

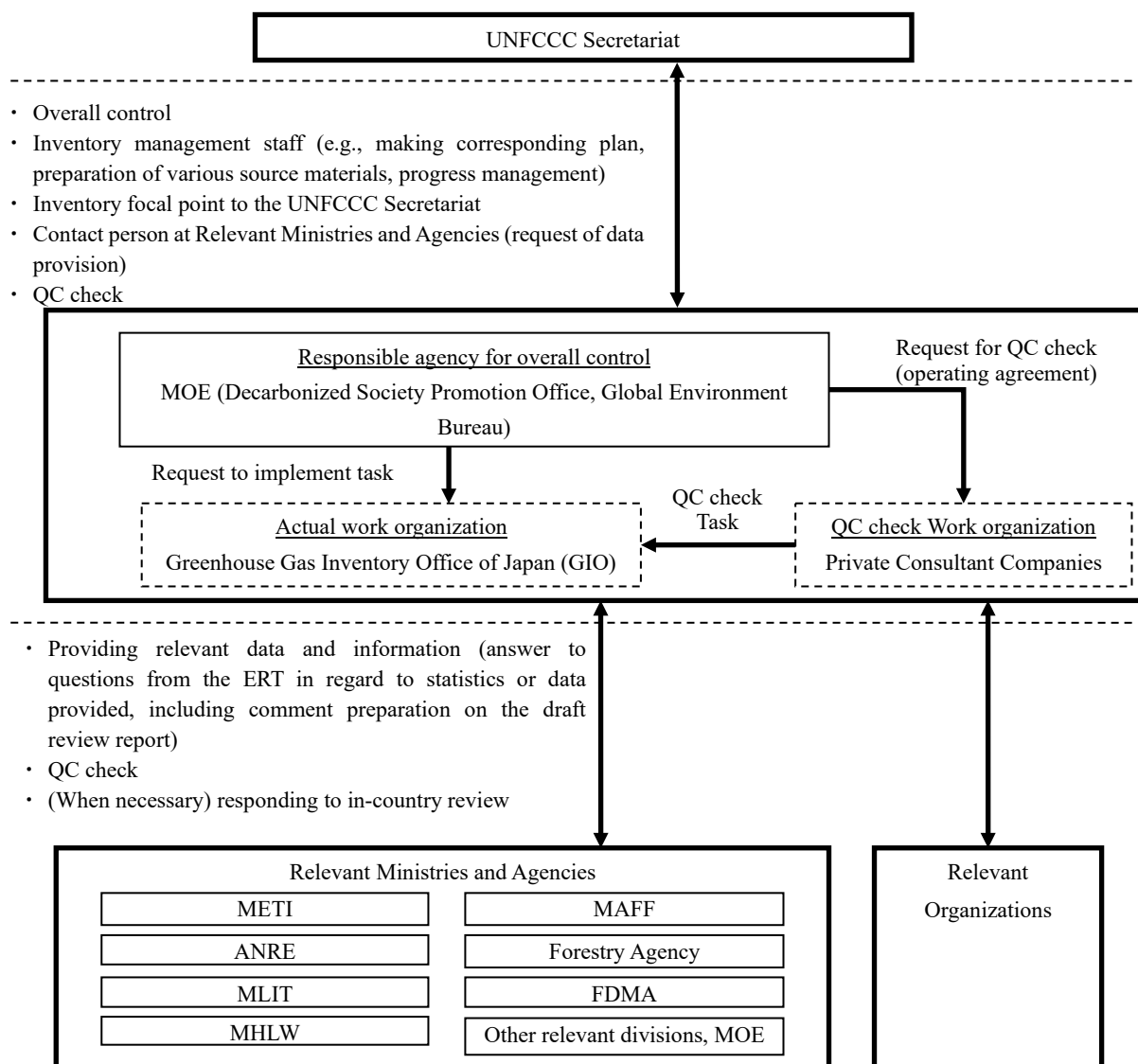


Figure 1-3 Basic structure of Japan's national system to respond to inventory review

### 1.2.2. Overview of Inventory Planning, Preparation and Management

MOE (Decarbonized Society Promotion Office, Global Environment Bureau) is the single national agency responsible for preparing Japan's inventory, and the GIO performs the actual work of inventory compilation. Relevant ministries and organizations are also involved in the preparation of the inventory, mainly by preparing AD, EFs, and other data needed for inventory compilation. Private consulting companies are contracted by MOE to perform tasks related to QC of the inventory, mainly prepared by MOE and GIO.

The Committee, run by MOE, considers the methods, AD and EFs used. Under the Committee, the inventory WG that examines crosscutting issues, and breakout groups that consider sector-specific problems (Breakout group on Energy and Industrial Processes, Breakout group on Transport, Breakout group on F-gases, Breakout group on Agriculture, Breakout group on Waste, Breakout group on LULUCF, and Breakout group on NMVOC), as well as the Sub-breakout group on CCU are set up.

The emissions and removals are prepared in accordance with the Inventory Reporting Guidelines (See sectoral chapters for details). The key category analysis is performed in accordance with the *2006 IPCC Guidelines*, and both Approach 1 and 2 are applied (See section 1.5 for results). No additional key categories were identified using the qualitative approach. Key categories have been identified for activities under Article 3, paragraphs 3 and 4, of the Kyoto Protocol following the guidance on establishing the relationship between the activities under the Kyoto Protocol and the associated key categories in the UNFCCC inventory. The key category analysis is used to prioritize inventory improvements. The uncertainty analysis is carried out in accordance with the *2006 IPCC Guidelines*, and Approach 1 is applied (See section 1.6 for results).

QC procedures are used in the inventory and are documented as part of the QA/QC plan (See section 1.2.3 for details). As part of inventory QA, detailed reviews (expert peer reviews) are regularly performed by experts not directly involved in inventory compilation for each emission source and sink.

Japan has a centralized archiving system, which includes the archiving of disaggregated EFs and AD, and documentation on how these factors and data have been generated and aggregated for the preparation of the inventory. The archived information also includes internal documentation on QA/QC procedures, UNFCCC review and QA peer review, and documentation on annual key categories identification and planned inventory improvements. The archiving system is run by GIO and is comprised of electronic and paper versions of documents.

### **1.2.3. Quality Assurance, Quality Control and Verification Plan**

#### **1.2.3.1. QA/QC Procedures Applied**

When compiling the inventory in Japan, inventory quality is controlled by performing QC activities (such as checking the correctness of calculations and archiving of documents) at each step, in accordance with *2006 IPCC Guidelines*. In Japan, the QC activities relating to inventory compilation performed by personnel belonging to agencies involved in inventory compilation—that is, the MOE (including the GIO and private consultant companies), relevant ministries and agencies—are considered to be QC. External reviews by experts who are outside the inventory compilation system are considered to be QA. They assess data quality from the perspectives of scientific knowledge and data availability with respect to current calculation methods. Table 1-1 sketches Japan's QA/QC activities.

Table 1-1 Summary of Japan's QA/QC activity

	Implementing entity	Main contents of activity
QC (Quality Control)	Ministry of the Environment (Decarbonized Society Promotion Office, Global Environment Bureau)	<ul style="list-style-type: none"> <li>• Coordinating QA/QC activities for inventory preparation</li> <li>• Checking and approving the QA/QC plan</li> <li>• Checking and approving the inventory improvement plan</li> </ul>
	Greenhouse Gas Inventory Office of Japan, Center for Global Environmental Research, Earth System Division, National Institute for Environmental Studies (GIO)	<ul style="list-style-type: none"> <li>• Conducting general QC check</li> <li>• Archiving QA/QC activity records and relevant data and documents</li> <li>• Developing inventory improvement plan</li> <li>• Revising QA/QC plan</li> </ul>
	Relevant Ministry and Agencies	<ul style="list-style-type: none"> <li>• Checking data necessary for inventory preparation</li> <li>• Checking JNGI files and inventory prepared by GIO (Category-specific QC)</li> </ul>
	Committee for the Greenhouse Gas Emissions Estimation Methods	<ul style="list-style-type: none"> <li>• Discussing and assessing estimation methods, EFs, and AD (Category-specific QC)</li> </ul>
	Private Consultant Companies	<ul style="list-style-type: none"> <li>• Checking JNGI files and inventory prepared by GIO (Category-specific QC)</li> </ul>
QA (Quality Assurance)	Inventory Quality Assurance Working Group (QAWG)	<ul style="list-style-type: none"> <li>• Conducting expert peer review of inventory</li> </ul>

### 1.2.3.1.a. QC activity

#### a) General QC procedures

In accordance with Table 6.1, Chapter 6, Vol.1 of the *2006 IPCC Guidelines*, general QC procedures include the general items to be confirmed which are related to the calculation, data processing, completeness, and documentation applicable to all emission source and sink categories. General QC procedures are implemented by each inventory compiler.

Following are the QC activities conducted by GIO's sectoral experts (SEs), who perform the work of compiling the emissions/removals estimation files for each category, the CRF transition files and NIR; the National Inventory compiler (NIC), who integrates the information from the individual SEs and compiles the inventory; and the data providers, who provide the AD and other data used to calculate emissions and removals.

#### 1) Sectoral expert (SE)

SEs perform mainly the following QC activities.

- Checking for transcription errors in data entry and referencing
- Checking to ensure that emissions are accurately estimated
- Checking to see that parameters and emission units are accurately recorded, and that proper conversion factors are used
- Checking the conformity of databases and/or files
- Checking the consistency of data from one category to another
- Checking the accuracy of inventory data behavior from one processing step to the next
- Checking completeness
- Checking time series consistency
- Checking trends
- Conducting comparisons with past estimated values



- Checking that uncertainties in emissions and removals are accurately estimated and calculated
- Carrying out reviews of internal documentation
- Checking that the assumptions and criteria for selecting AD and EFs are documented

## **2) National inventory compiler (NIC)**

The NIC performs mainly the following QC activities.

- Confirming that CRF Reporter data provided by SEs are imported without omission
- Confirming that the information needed for the documentation box is properly entered
- Confirming that the reasons for “NE” and “IE” are correctly entered
- Confirming that the key category analysis results are correctly outputted
- Confirming that the reasons for recalculations are provided for all categories
- Confirming that emissions and removals are correctly aggregated
- Confirming that data are corrected after the coordination with the relevant ministries and agencies

### **b) QC procedure for source and sink each category**

The following category-specific QC activities are performed in Japan:

#### **1) QC by private consultant companies (External QC)**

QC on the estimation files and CRF and NIR drafts prepared by the GIO, are performed by mutual checks of estimation results with private consultant companies, through the use of estimation files like those of the GIO, and confirming the data entered into estimation files for each source and sink category and the equations for calculating emissions and removal.

#### **2) QC through coordination with the relevant ministries and agencies (External QC)**

The relevant ministries and agencies are sent the sets of files for estimation, CRF, NIR, and the drafts of documents for domestic release showing estimated values for emissions and removals. Through this, category-specific QC is implemented for the content of categories relevant to each ministry or agency.

#### **3) Committee for the Greenhouse Gas Emissions Estimation Methods**

Since the Committee considers and selects the methodologies, AD and parameters including EFs, which are actually applied to the estimation of emissions/removals from each category, it also implements category-specific QC activities.

### **c) QC activities of the documentation and archiving of inventory information**

GIO promptly implements QC activities of the documentation and archiving of inventory information, after the inventory submission to the UNFCCC.

#### **1.2.3.1.b. QA activity**

QA refers to assessment of inventory quality by third units that are not directly involved in inventory compilation. In Japan, the expert peer review is held by the GHG Inventory Quality Assurance Working Group (QAWG) as a QA activity, to assure inventory quality.

## a) GHG Inventory Quality Assurance Working Group (QAWG)

### 1) Summary

The QAWG performs detailed reviews by experts (expert peer reviews) not directly involved in inventory compilation for each emission source and sink in order to assure inventory quality and to identify places that need improvement.

The secretariat for the QAWG is established within the GIO. The secretariat and the MOE determine the sectors/categories to be reviewed by the QAWG. The experts for the QAWG are selected by taking the following requirements into account.

<Requirements for QAWG review experts>

- a. No direct involvement in the inventory preparation process for estimating emissions/ removals from the sectors/categories to be reviewed (i.e., no involvement in the Committee, the data creation and the data provision for those sectors/categories)
- b. No specific interests related to the inventory and the capability to judge objectively without being affected by any specific organizations and/or stakeholders
- c. Sufficient skills, knowledge and experiences to assure the quality of the inventory

### 2) Scope of review

The QAWG performs reviews mainly in the following areas. The results are utilized for the preparation of the inventory for the next submission.

- Confirming the soundness of estimation methods, AD, EFs, and other items.
- Confirming the soundness of content reported in the CRF and NIR.

### 3) Recent activities

The LULUCF sector was reviewed by two experts in FY2021, and the schedule was as follows.

Table 1-2 Schedule for the review by the QAWG in FY2021

Schedule	Matter
Beginning of April 2021	Selection of experts
Late April	Briefing of the experts by secretariat
Mid-May to Beginning of July	Review by the experts (The detailed review of the GHG inventory, the listing of questionable points and issues, and proposals for improvement)
August 30	Holding of the QAWG meeting
September to January 2022	Bringing up of suggestions from the QAWG to the Committee and relevant breakout groups in the Committee for discussion
February to April	Summarizing QAWG activities and results in the inventory Reporting to QAWG experts on how their comments were considered/addressed Checking of results of consideration and modifications by QAWG experts

It was confirmed by the QAWG that the inventory for the LULUCF sector was generally valid. Identified issues by this QAWG were brought up to the Committee and the relevant breakout group in the Committee for discussion, and some issues were improved in this submitted inventory. In addition, the QAWG also identified insufficient explanations in the NIR. These findings lead to improve transparency and accuracy of the NIR.

The MOE and the secretariat determine the sectors/categories reviewed by the QAWG, and the entire GHG inventory is covered over the course of several years.

### 1.2.3.2. QA/QC Plan

The QA/QC Plan is an internal document that documents, among other things, the specifics of all QA/QC activities in all processes from the start of inventory compilation to the final report, the compilation schedule, and the apportionment of all involved entities' roles. It organizes and systematizes the QA/QC activities of inventory compilation and clarifies what each entity involved in compilation is supposed to do. Additionally, it is prepared for the purpose of guaranteeing the implementation of QA/QC activities.

The QA/QC Plan's scope includes the processes of preparing, reporting, and reviewing the inventory under the UNFCCC, and the supplementary information on sinks under Kyoto Protocol Articles 3.3 and 3.4, as stipulated in Decision 2/CMP.8.

### 1.2.3.3. Verification Activities

Confirmation such as the following have been undertaken in the Breakout groups of the Committee for the Greenhouse Gas Emission Estimation Methods: checking the appropriateness of EFs which were established based on actual measurements in the past, against new measurements, or checking the appropriateness of applying specific EFs based on models, to the national inventory. Additionally, the inventory emissions are checked against entity-based emission data reported under the Mandatory GHG Accounting and Reporting System<sup>5</sup> - a system that aims to reduce emissions from entities by requiring them to estimate and understand the amount of GHG emissions originating from their own activities. This mutual verification activity is to avoid any possible large omission of emissions.

### 1.2.3.4. Treatment of Confidential Information

Part of the AD and EFs, other parameters, and emissions obtained from ministries or the private sector correspond to confidential information. These are listed and archived. At the stage of obtaining and archiving data, and in the QC process, data is protected by using a password, and confidential files are distinguished from others, together with restricted access. When sending data to relevant ministries for checks, confidential data are sent only to the ministry which provided the data. At the stage of UN reporting, a minimum level of aggregation with other sub-categories is performed, and the notation key "C" (confidential) is used.

## 1.2.4. Changes in the National Inventory Arrangements since the Previous Annual GHG Inventory Submission

In line with paragraph 50 (J) of the UNFCCC Inventory Reporting Guidelines and paragraph 21 of the annex to decision 15/CMP.1, Japan reports the changes in its national inventory arrangements from the previous inventory submission.

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<sup>5</sup> This system was established in 2006 under the Act on Promotion of Global Warming Countermeasures and requires entities that emit GHGs over a certain amount to estimate and report their emissions to the government. It generally covers all sectors excluding the LULUCF sector and part of the Energy sector (residential and transport (private vehicles)). The methods used to calculate emissions are generally consistent with those used in compiling the inventory.

### 1.3. Inventory Preparation, and Data Collection, Processing and Storage

#### 1.3.1. Annual cycle of inventory preparation

Table 1-3 shows the annual cycle of inventory preparation. The inventory preparation cycle is set in conjunction with Japan's fiscal year calendar (starting April 1 and ending March 31 of the next year) In Japan, in advance of the estimation of national inventory submitted to the UNFCCC (submission deadline: April 15), preliminary figures are estimated and published as a document for an official announcement (In preliminary figures, only GHG emissions excluding removals are published.).

Table 1-3 Annual cycle of the inventory preparation

\*Inventory preparation in fiscal yaer "n"

	Process	Relevant Entities	Calendar Year n+1								CY n+2				
			Fiscal Year n+1								Jan	Feb	Mar	FY n+2 Apr	
			May	Jun	Jul	Aug	Sep	Oct	Nov	Dec					
1	Holding the meeting of the QAWG	MOE, GIO	→	→	→	→									
2	Discussion on the inventory improvement	MOE, GIO		→	→	→	→								
3	Holding the meeting of the Committee	MOE, (GIO, Private consultant)		→	→	→	→	→	→	→	→				
4	Collection of data for the national inventory	MOE, GIO, Relevant Ministries/Agencies, Relevant organization, Private consultant									→	→	→	→	
5	Preparation of a draft of CRF	GIO, Private consultant									→	→	→		
6	Preparation of a draft of NIR	GIO, Private consultant									→	→	→		
7	Implementation of the exterior QC and the coordination with the relevant ministries and agencies	MOE, GIO, Relevant Ministries/Agencies, Private consultant										→	→	→	
8	Correction of the drafts of CRF and NIR	MOE, GIO, Private consultant											→	→	
9	Submission and official announcement of the national inventory	MOE, GIO													★

#### 1.3.2. Process of the inventory preparation

##### 1) Holding the meeting of the Greenhouse Gas Inventory Quality Assurance Working Group (QAWG) (Step 1)

The QAWG, which is composed of experts who are not directly involved in nor related to the inventory preparation process, is organized in order to conduct peer review and assure the inventory's quality and to find possible improvements.

This QAWG reviews the appropriateness of the estimation methodologies, AD, EFs, and the contents of the CRF and NIR. The GIO utilizes the items identified for improvement by the QAWG in discussions on the inventory estimation methods and in subsequent inventory preparation.

##### 2) Discussion on inventory improvement (Step 2)

The MOE and the GIO identify the items that need to be addressed by the Committee, based on the results of the previous inventory review of the UNFCCC, the recommendations of the QAWG, the items needing improvement as identified at former Committee meetings, and any other items requiring revision, as determined during previous inventory preparations. The schedule for the expert evaluation (step 3) is developed by taking the above-mentioned information into account.

##### 3) Holding meetings of the Committee for the Greenhouse Gas Emission Estimation Methods [evaluation and examination of estimation methods by experts] (Step 3)

The MOE holds meetings of the Committee, in which estimation methodologies for an annual inventory and the issues that require technical reviews are discussed by experts with different scientific backgrounds.

**4) Collection of data for the national inventory (Step 4)**

The data required for preparing the national inventory and the supplementary information required under Decision 2/CMP.8 are collected.

**5) Preparation of a draft of the CRF [including the implementation of the key category analysis and the uncertainty assessment] (Step 5)**

The data input and estimation of emissions and removals are carried out simultaneously by utilizing JNGI files, which have interconnecting links based on the calculation formulas for emissions and removals. Subsequently, the key category analysis and the uncertainty assessment are also carried out.

**6) Preparation of a draft of NIR (Step 6)**

The GIO identifies the points that need to be revised in the NIR or that require an additional description by taking the discussion at step 2 into account. The organization of the NIR is generally the same every year, but if large modifications such as changes in chapters are envisaged, this is proposed to the MOE and approval is sought. The GIO prepares the new NIR draft by updating the data and by adding and revising descriptions.

**7) Implementation of the external QC and the coordination with the relevant ministries and agencies (Step 7)**

As a QC activity, the selected private consulting companies check the JNGI files and the initial draft of the CRF (the 0<sup>th</sup> draft) prepared by the GIO (external QC). The companies not only check the input data and the calculation formulas in the files but also check the estimations by calculating the amount of GHG emissions and removals by utilizing the same files. Because of this crosscheck, any possible data input and emission estimation mistakes are avoided. They also check the content and descriptions of the initial draft of the NIR (the 0<sup>th</sup> draft) prepared by the GIO. JNGI files, draft CRF and draft NIR, which have been checked by the private consulting companies, are regarded as the primary drafts of inventories.

Subsequently, the GIO sends out the primary drafts of the inventories and press releases as electronic computer files to the MOE and the relevant ministries and agencies and asks them to check the contents of the primary drafts. The data, which are estimated based on confidential data, are only sent out for confirmation to the ministries and/or agencies that provided the confidential data.

For some sources/sinks, emissions/removals are estimated by entities other than GIO, and the QC implemented in these entities are checked.

**8) Correction of the drafts of CRF and NIR (Step 8)**

When revisions are requested as a result of the check of the primary drafts of the inventories and official announcements by the relevant ministries and agencies (step 7), the MOE, GIO, and relevant ministries and/or agencies that submit requests for revision then coordinate the details of any revision, revise the primary drafts, and prepare the secondary drafts. The secondary drafts are sent out again to the relevant ministries and/or agencies for conclusive confirmation. If there is no additional request for revision, the secondary drafts are considered the final versions.

**9) Submission and official announcement of the national inventory (Step 9)**

The completed inventory is submitted to the UNFCCC Secretariat. At the same time of the submission, information on the estimated GHG emissions and removals are officially announced and published on

the MOE's website (<https://www.env.go.jp/earth/ondanka/ghg-mrv/index.html>) with additional relevant information. The inventory is also published on the GIO's website (<https://www.nies.go.jp/gio/en/index.html>).

### 1.3.3. Documentation and Archiving of Inventory Information

In Japan, the information needed for inventory compilation is documented and as a rule archived by the agency which compiles the inventory (GIO).

The main files (all JNGI files, NIR word files, and CRFs) needed for inventory compilation is electronically archived at MOE as well.

#### 1.3.3.1. Documentation of information

The GIO documents all the inventory-related information in electronic or printed form and archives it. Examples of information that must be archived follow.

- The inventory related files submitted every year to the UNFCCC Secretariat
- Published materials for preliminary and finalized data
- Statistical data and provided data (including data providers, time period when provided, and other related information) used in compiling the inventory
- Information on the discussion process and discussion results related to the selection of AD, estimation methods, EFs, and other items (relevant source materials for the discussion process by the Committee for the Greenhouse Gas Emissions Estimation Methods)
- Records of communications with related entities in the inventory compilation process
- Information on inventory recalculations (such as reasons for recalculations, and when performed)
- QA/QC Plan and records of QA/QC activities conducted, including holding the QAWG
- Comments by experts on the inventory
- In relation to UNFCCC inventory reviews, review reports and records of questions and answers with ERTs

#### 1.3.3.2. Archiving of information

##### *1) Archiving electronic information*

##### *i) Inventory-related electronic information*

- Each year's JNGI files and CRF- and NIR-related files have file names with the year when the estimation was performed, and files are saved in folders prescribed for each year.
- Electronic files of statistical data, provided data, etc. used to prepare the inventory's emissions/removals estimates and other related data are given file names, etc. with the date on which the data were obtained and the data provider, and saved in prescribed folders.
- Source materials in electronic form (files in Word, PDF, or other format) used when considering emissions/removals estimation methods are labeled with the source material title and the date the file was obtained (and if necessary, the file provider), and saved in prescribed folders.
- If the exchange of information on the inventory has been conducted by email, the email files are saved in prescribed folders.

**ii) Backup and risk management of electronic information**

- The server, hosted by the National Institute for Environmental Studies (in which GIO is included), and where inventory-related information is stored, is automatically backed up every day. Access to the server is restricted to specific ID holders only.
- Once a year, after submission of the annual inventory to the UNFCCC Secretariat, all inventory-related electronic information is saved to CD-ROMs and other electronic media and archived.

**2) Archiving in printed form**

- Books of statistics, data and source materials in printed form that have been provided, and other source materials in printed form that have been used in inventory emissions/removals estimates are filed in a prescribed storage location.

**1.3.3.3. QC activity for documentation and archiving of inventory information**

Immediately after the inventory is submitted to the UNFCCC Secretariat, the GIO carries out QC activities related to the documentation and archive of inventory information.

**1.4. Brief General Description of Methodologies and Data Sources Used (including tiers used)**

The methodology used in estimation of GHG emissions or removals is basically in accordance with the *2006 IPCC Guidelines*. The country-specific methodologies are also used for some source/sink categories in order to more accurately reflect the actual emission status in Japan.

The results of the actual measurements or estimates based on research conducted in Japan are used to determine the EFs (country-specific emissions factors). The default values given in the *2006 IPCC Guidelines* are used for some categories, emissions of which are assumed to be quite low (e.g., “1.B.2.a.ii fugitive emissions from fuel (oil and natural gas (CO<sub>2</sub> and CH<sub>4</sub>))”) etc.

**1.4.1. Collection Process of Activity Data**

When the AD needed for calculations are available from sources such as publications and the internet, the necessary data are gathered from these media. Data that are not released in publications, the internet, or in other media, and unpublished data that are used when compiling the inventory are obtained by the MOE or the GIO by requesting them from the relevant ministries and agencies and the relevant organizations which control those data. The main relevant ministries, agencies, and relevant organizations, and their statistics and data are as shown in Table 1-4.

Table 1-4 Main relevant ministries, agencies, and the relevant organizations, and their statistics and data

Ministries/Agencies/Organizations		Major data or statistics
Relevant Ministries/ Agencies	MOE	Research of Air Pollutant Emissions from Stationary Sources/ Waste Treatment in Japan/ Report of the research on the state of wide-range movement and cyclical use of wastes (the volume on cyclical use)/ Survey of Industrial Waste Treatment Facilities
	METI	General Energy Statistics / Yearbook of Chemical Industry Statistics / Yearbook of Ceramics and Building Materials Statistics/ Amount of nitric acid production/ Documents of Fluorocarbons etc Measures Working Group, Group for Chemical Substance Policy, Manufacturing Industries Sub-Group, Industrial Structure Council
	MLIT	Statistical Yearbook of Motor Vehicle Fuel Consumption / Land Use Status Survey
	MAFF	Livestock Statistics / Statistics of Arable and Planted Land Area / Yearbook of Fertilizer Statistics (Pocket Edition)/ A Move and Conversion of Cropland / National Forest Resources Database/ Report on Forest GHG Inventory Information Development Project
Relevant Organizations	Federation of Electric Power Companies	Amount of Fuel Used by Pressurized Fluidized Bed Boilers
	Japan Coal Energy Center	Coal Production/ History of Coal Policy
	Japan Cement Association	Amount of clinker production / Cement Handbook
	Japan Iron and Steel Federation	Emissions from Coke Oven Covers, Desulfurization Towers, and Desulfurization Recycling Towers
	Japan Paper Association	Amount of final disposal of industrial waste / Amount of RPF incineration

#### 1.4.2. Selection Process of Emission Factors and Estimation Methods

Calculation methods for Japan's emission and removal amounts are determined by having the Committee explore calculation methods suited to Japan's situation for all the activity categories necessary for calculating Japan's greenhouse gas emission and removal amounts, based on the 2006 IPCC Guidelines.

#### 1.4.3. Improvement Process of Estimations for Emissions and Removal

In Japan, improvements in the calculation methods are considered in accordance with necessity whenever an inventory item requiring improvement is identified because of, for example, a UNFCCC review or an observation by the QAWG, progress in international negotiations such as the creation of new guidelines, progress or changes in scientific research or in the compilation of statistics, or the acquisition of new information by the Mandatory GHG Accounting and Reporting System. Proposals for improving the estimation of emissions and removals are considered by scientific research or the Committee, and the results are incorporated into the inventory. Figure 1-4 is a diagram of the inventory improvement process.



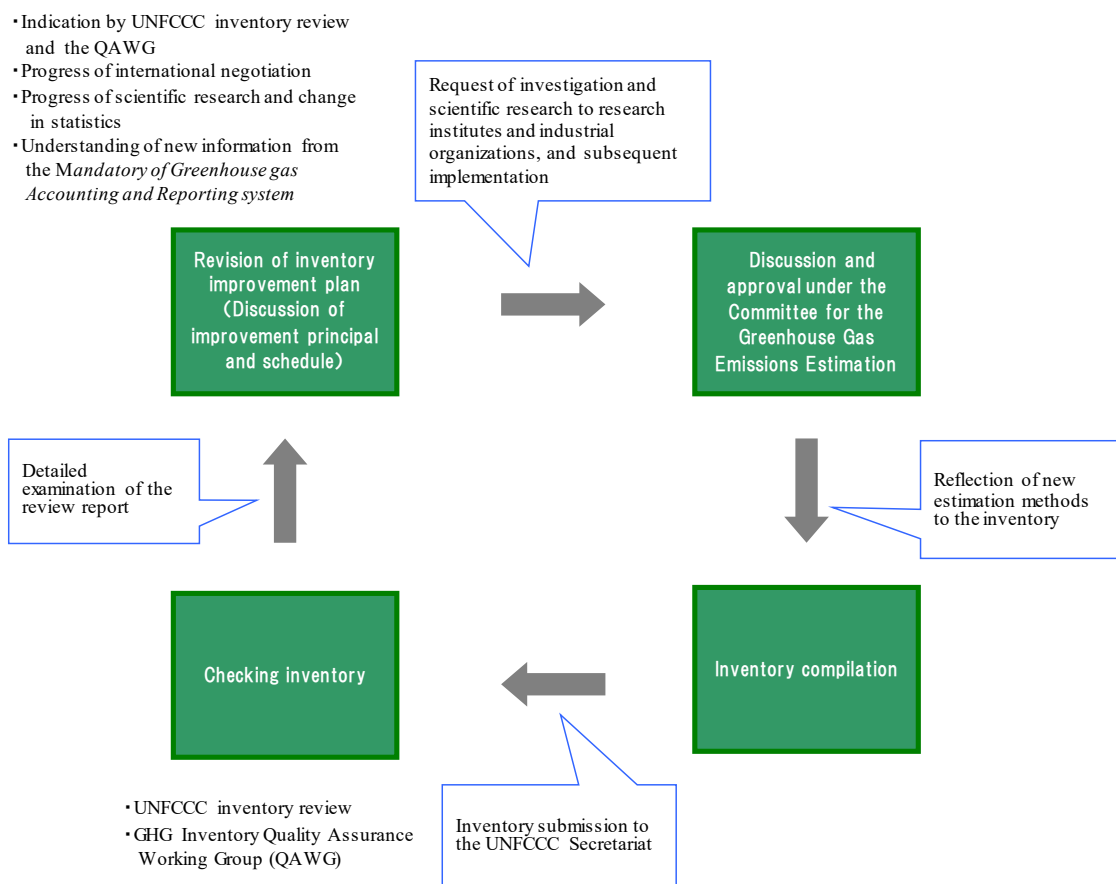


Figure 1-4 Diagram of the inventory improvement process

## 1.5. Brief Description of Key Categories

Key category analysis was carried out in accordance with the *2006 IPCC Guidelines* and the *KP Supplement (2013)* (Approach 1 and Approach 2 level/trend assessment).

### 1.5.1. GHG Inventory

In FY2020, 42 sources and sinks were identified as Japan's key categories (Table 1-5). For the base year of the UNFCCC (FY1990), 40 sources and sinks were identified as key categories (Table 1-6). More detailed information is described in Annex 1.

Table 1-5 Japan's key categories in FY2020

	A IPCC Code	B IPCC Category	C GHGs	Ap1-L	Ap1-T	Ap2-L	Ap2-T
#1	1.A.1.	Energy Industries	Solid Fuels	CO2	#1	#1	#1
#2	1.A.3.	Transport	b. Road Transportation	CO2	#2		#3
#3	1.A.1.	Energy Industries	Gaseous Fuels	CO2	#3	#3	#7
#4	1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO2	#4	#6	#2
#5	1.A.4.	Other Sectors	Liquid Fuels	CO2	#5	#7	#5
#6	4.A	Forest Land	1. Forest Land remaining Forest Land	CO2	#6	#8	#4
#7	1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO2	#7	#4	#10
#8	2.F	Product uses as substitutes for ODS	1. Refrigeration and Air conditioning	HFCs	#8	#5	#9
#9	1.A.1.	Energy Industries	Liquid Fuels	CO2	#9	#2	#11
#10	1.A.4.	Other Sectors	Gaseous Fuels	CO2	#10	#9	#24
#11	1.A.2.	Manufacturing Industries and Construction	Gaseous Fuels	CO2	#11	#10	#26
#12	2.A	Mineral Product	1. Cement Production	CO2	#12	#12	#23
#13	3.C	Rice Cultivation		CH4	#13		#29
#14	5.C	Incineration and Open Burning of Waste		CO2	#14		#14
#15	1.A.2.	Manufacturing Industries and Construction	Other Fossil Fuels	CO2	#15	#13	#13
#16	1.A.3.	Transport	d. Domestic Navigation	CO2	#16		
#17	1.A.4.	Other Sectors	Other Fossil Fuels	CO2	#17		#15
#18	3.A	Enteric Fermentation		CH4	#18		#12
#19	1.A.4.	Other Sectors	Solid Fuels	CO2	#19	#17	
#20	2.A	Mineral Product	2. Lime Production	CO2	#20		
#21	4.B	Cropland	1. Cropland remaining Cropland	CO2			#22
#22	3.B	Manure Management		N2O			#8
#23	3.D	Agricultural Soils	1. Direct Emissions	N2O			#27
#24	2.F	Product uses as substitutes for ODS	2. Foam Blowing Agents	HFCs		#21	#17
#25	5.A	Solid Waste Disposal		CH4		#18	#14
#26	2.D	Non-energy Products from Fuels and Solvent Use		CO2			#18
#27	3.D	Agricultural Soils	2. Indirect Emissions	N2O			#6
#28	2.B	Chemical Industry	Other products except Ammonia	CO2			#19
#29	5.D	Wastewater Treatment and Discharge		N2O			#28
#30	2.E	Electronics Industry		PFCs			#16
#31		Indirect CO2	from IPPU sector	Ind CO2			#30
#32	4.E	Settlements	2. Land converted to Settlements	CO2			#22
#33	5.C	Incineration and Open Burning of Waste		N2O			#21
#34	2.G	Other Product Manufacture and Use		SF6		#14	#20
#35	1.A.3.	Transport	b. Road Transportation	N2O			#26
#36	4.A	Forest Land	2. Land converted to Forest Land	CO2		#15	#17
#37	1.B	Fugitive Emission from Fuel	1. Fugitive emissions from Solid Fuels	CH4		#19	#7
#38	2.B	Chemical Industry	3. Adipic Acid Production	N2O		#16	#20
#39	2.E	Electronics Industry		SF6			#25
#40	2.B	Chemical Industry	9. Fluorochemical Production (Fugitive Emissions)	HFCs		#11	
#41	2.B	Chemical Industry	4. Caprolactam, Glyoxal and Glyoxylic Acid Production	N2O			#12
#42	2.B	Chemical Industry	9. Fluorochemical Production (Fugitive Emissions)	SF6		#20	

Note1: Ap1-L: Approach 1-Level Assessment, Ap1-T: Approach 1-Trend Assessment,  
Ap2-L: Approach 2-Level Assessment, Ap2-T: Approach 2-Trend Assessment

Note2: Figures recorded in the Level and Trend columns indicate the ranking of individual level and trend assessments.

Table 1-6 Japan's key categories in FY1990

	A IPCC Code	B IPCC Category		C GHGs	Ap1-L	Ap2-L
#1	1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO2	#1	#1
#2	1.A.3.	Transport	b. Road Transportation	CO2	#2	#3
#3	1.A.1.	Energy Industries	Liquid Fuels	CO2	#3	#4
#4	1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO2	#4	#6
#5	1.A.4.	Other Sectors	Liquid Fuels	CO2	#5	#8
#6	1.A.1.	Energy Industries	Solid Fuels	CO2	#6	#7
#7	1.A.1.	Energy Industries	Gaseous Fuels	CO2	#7	#18
#8	4.A	Forest Land	1. Forest Land remaining Forest Land	CO2	#8	#2
#9	2.A	Mineral Product	1. Cement Production	CO2	#9	#21
#10	1.A.4.	Other Sectors	Gaseous Fuels	CO2	#10	
#11	2.B	Chemical Industry	9. Fluorochemical Production (Fugitive Emissions)	HFCs	#11	
#12	1.A.3.	Transport	d. Domestic Navigation	CO2	#12	
#13	5.C	Incineration and Open Burning of Waste		CO2	#13	#17
#14	3.C	Rice Cultivation		CH4	#14	
#15	1.A.2.	Manufacturing Industries and Construction	Gaseous Fuels	CO2	#15	
#16	5.A	Solid Waste Disposal		CH4	#16	#14
#17	3.A	Enteric Fermentation		CH4	#17	#12
#18	2.G	Other Product Manufacture and Use		SF6	#18	#5
#19	4.B	Cropland	1. Cropland remaining Cropland	CO2	#19	#19
#20	2.C	Metal Production	1. Iron and Steel Production	CO2	#20	
#21	2.B	Chemical Industry	3. Adipic Acid Production	N2O	#21	
#22	1.A.3.	Transport	a. Domestic Aviation	CO2	#22	
#23	2.A	Mineral Product	2. Lime Production	CO2	#23	
#24	4.A	Forest Land	2. Land converted to Forest Land	CO2	#24	#30
#25	1.A.4.	Other Sectors	Other Fossil Fuels	CO2	#25	#23
#26	1.B	Fugitive Emission from Fuel	1. Fugitive emissions from Solid Fuels	CH4	#26	#11
#27	3.D	Agricultural Soils	1. Direct Emissions	N2O	#27	#24
#28		Indirect CO2	from IPPU sector	Ind CO2		#15
#29	4.E	Settlements	2. Land converted to Settlements	CO2		#29
#30	3.B	Manure Management		N2O		#10
#31	1.A.2.	Manufacturing Industries and Construction	Other Fossil Fuels	CO2		#31
#32	2.B	Chemical Industry	Other products except Ammonia	CO2		#16
#33	1.A.3.	Transport	b. Road Transportation	N2O		#13
#34	3.D	Agricultural Soils	2. Indirect Emissions	N2O		#9
#35	5.D	Wastewater Treatment and Discharge		N2O		#28
#36	2.D	Non-energy Products from Fuels and Solvent Use		CO2		#27
#37	2.B	Chemical Industry	4. Caprolactam, Glyoxal and Glyoxylic Acid Production	N2O		#20
#38	2.E	Electronics Industry		PFCs		#25
#39	5.C	Incineration and Open Burning of Waste		N2O		#26
#40	2.E	Electronics Industry		SF6		#22

Note1: Ap1-L: Approach 1-Level Assessment, Ap2-L: Approach 2-Level Assessment

Note2: Figures recorded in the Level and Trend columns indicate the ranking of individual level and trend assessments.

### 1.5.2. KP-LULUCF Activity

As a result of analysis implemented in accordance with the 2006 IPCC Guidelines and the KP Supplement (2013), “Afforestation/Reforestation”, “Deforestation”, “Forest management”, “Cropland management”, and “Revegetation” activities (CO<sub>2</sub>) were identified as key categories for Japan’s KP-LULUCF activities in FY2020. More detailed information is described in section 11.8.1 of chapter 11.

## 1.6. General Uncertainty Assessment, including Data on the Overall Uncertainty for the Inventory Totals

### 1.6.1. GHG Inventory

Total net GHG emissions in Japan for FY2020 were approximately 1,098 million tonnes (CO<sub>2</sub> equivalents). The total net emissions uncertainties calculated by approach 1 (propagation of error) were -4% to +2% and the uncertainties introduced into the trend in the total emissions were -4% to +2%. More detailed information on the uncertainty assessment is described in Annex 2.

Table 1-7 Uncertainty of Japan's total net emissions

Category	A	B GHGs	C 1990 emissions / removals kt-CO <sub>2</sub> eq.	D 2020 emissions / removals kt-CO <sub>2</sub> eq.	G-1990		G-2020		I Inventory trend in national emissions for 2020 increase with respect to 1990 %	J Uncertainty introduced into the trend in total national emissions (-) % (+) %	
					(-) %	(+) %	(-) %	(+) %		(-) %	(+) %
1A. Fuel Combustion (CO <sub>2</sub> )		CO <sub>2</sub>	1,078,663	986,615	-5%	+2%	-4%	+2%	-8.5%	-4.4%	+2.3%
1A. Fuel Combustion (Stationary:CH <sub>4</sub> ,N <sub>2</sub> O)		CH <sub>4</sub> , N <sub>2</sub> O	3,896	5,152	-23%	+29%	-24%	+28%	32.2%	0.0%	+0.0%
1A. Fuel Combustion (Transport:CH <sub>4</sub> ,N <sub>2</sub> O)		CH <sub>4</sub> , N <sub>2</sub> O	4,031	1,557	-32%	+92%	-30%	+88%	-61.4%	0.0%	+0.0%
1B. Fugitive Emissions from Fuels		CO <sub>2</sub> , CH <sub>4</sub> , N <sub>2</sub> O	5,301	1,037	-40%	+80%	-24%	+42%	-80.4%	0.0%	+0.0%
2. IPPU (CO <sub>2</sub> ,CH <sub>4</sub> ,N <sub>2</sub> O)		CO <sub>2</sub> , CH <sub>4</sub> , N <sub>2</sub> O	75,616	43,873	-4%	+4%	-5%	+5%	-42.0%	-0.1%	+0.1%
2. IPPU (HFCs,PFCs,SF <sub>6</sub> ,NF <sub>3</sub> )		HFCs, PFCs, SF <sub>6</sub> , NF <sub>3</sub>	35,354	57,517	-7%	+36%	-7%	+8%	62.7%	-0.6%	+0.6%
3. Agriculture		CO <sub>2</sub> , CH <sub>4</sub> , N <sub>2</sub> O	37,479	32,186	-11%	+29%	-10%	+25%	-14.1%	0.0%	+0.0%
4. LULUCF		CO <sub>2</sub> , CH <sub>4</sub> , N <sub>2</sub> O	-65,317	-52,010	-14%	+14%	-14%	+14%	-20.4%	-0.4%	+0.4%
5. Waste		CO <sub>2</sub> , CH <sub>4</sub> , N <sub>2</sub> O	29,559	20,186	-10%	+10%	-12%	+12%	-31.7%	-0.2%	+0.2%
Indirect CO <sub>2</sub>		Ind CO <sub>2</sub>	5,548	1,963	-27%	+48%	-27%	+47%	-64.6%	0.0%	+0.0%
Total Net Emissions			1,210,133	1,098,075	-4.5%	+2.3%	-3.6%	+2.2%	-9.3%	-4.5%	+2.4%

### 1.6.2. KP-LULUCF Activity

Japan's net removals in FY2020 were 34.5 million tonnes (CO<sub>2</sub> equivalents) and the uncertainty was 17%. More detailed information on the uncertainty assessment is described in section 11.5.1.8 of chapter 11.

Table 1-8 Uncertainty of Japan's KP-LULUCF activities

Greenhouse gas source and sink activities	GHGs	Emissions/ Removals [kt CO <sub>2</sub> eq.]	Emissions/Removals Uncertainty [%]		Emissions/Removals Uncertainty as % of net removals [%]	
			(-) [%]	(+) [%]	(-) [%]	(+) [%]
Article 3.3 activities Afforestation and Reforestation	CO <sub>2</sub> , N <sub>2</sub> O, CH <sub>4</sub>	-1,245	-36%	36%	-1%	1%
Article 3.3 activities Deforestation	CO <sub>2</sub> , N <sub>2</sub> O, CH <sub>4</sub>	1,696	-23%	23%	-1%	1%
Article 3.4 activities Forest management	CO <sub>2</sub> , N <sub>2</sub> O, CH <sub>4</sub>	-38,939	-14%	14%	-16%	16%
Article 3.4 activities Cropland management	CO <sub>2</sub> , N <sub>2</sub> O, CH <sub>4</sub>	4,759	-24%	24%	-3%	3%
Article 3.4 activities Grazing land management	CO <sub>2</sub> , N <sub>2</sub> O, CH <sub>4</sub>	617	-9%	9%	0%	0%
Article 3.4 activities Revegetation	CO <sub>2</sub> , N <sub>2</sub> O, CH <sub>4</sub>	-1,360	-33%	33%	-1%	1%
Total		-34,472	-17%	17%		

### **1.7. General Assessment of the Completeness**

In this inventory report, emissions from some categories are not estimated and reported as “NE (Not Estimated)”. Source categories reported as NE in this year’s report include those whose emissions are thought to be very small, those whose emissions are unknown, and those for which emission estimation methods have not been developed. For these categories, further investigation on their emission possibility and the development of estimation methodologies will be carried out in accordance with Japan’s QA/QC plan. See Annex 5 for a list of not-estimated emission source categories.

## References

1. IPCC, *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, 2006.
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6. UNFCCC, *Guidelines for the Preparation of the Information Required under Article 7 of the Kyoto Protocol*, Decision 15/CMP.1, FCCC/KP/CMP/2005/8/Add.2, 2005.
7. UNFCCC, *Guidelines for Review under Article 8 of the Kyoto Protocol*, Decision 22/CMP.1, FCCC/KP/CMP/2005/8/Add.3, 2005.
8. UNFCCC, *Implications of the Implementation of Decisions 2/CMP.7 to 5/CMP.7 on the Previous Decisions on Methodological Issues Related to the Kyoto Protocol, including those relating to Articles 5, 7 and 8 of the Kyoto Protocol*, Decision 2/CMP.8, FCCC/KP/CMP/2012/13/Add.1, 2013.

## Chapter 2. Trends in GHG Emissions and Removals

### 2.1. Description and Interpretation of Emission and Removal Trends for Aggregate GHGs

#### 2.1.1. Overview of GHGs Emissions and Removals

Total GHG emissions in FY2020<sup>1,2</sup> (excluding LULUCF<sup>3</sup>, including indirect CO<sub>2</sub><sup>4</sup>, hereafter, definition omitted) were 1,150 million tonnes (in CO<sub>2</sub> eq.). They decreased by 9.8% compared to the emissions in FY1990.

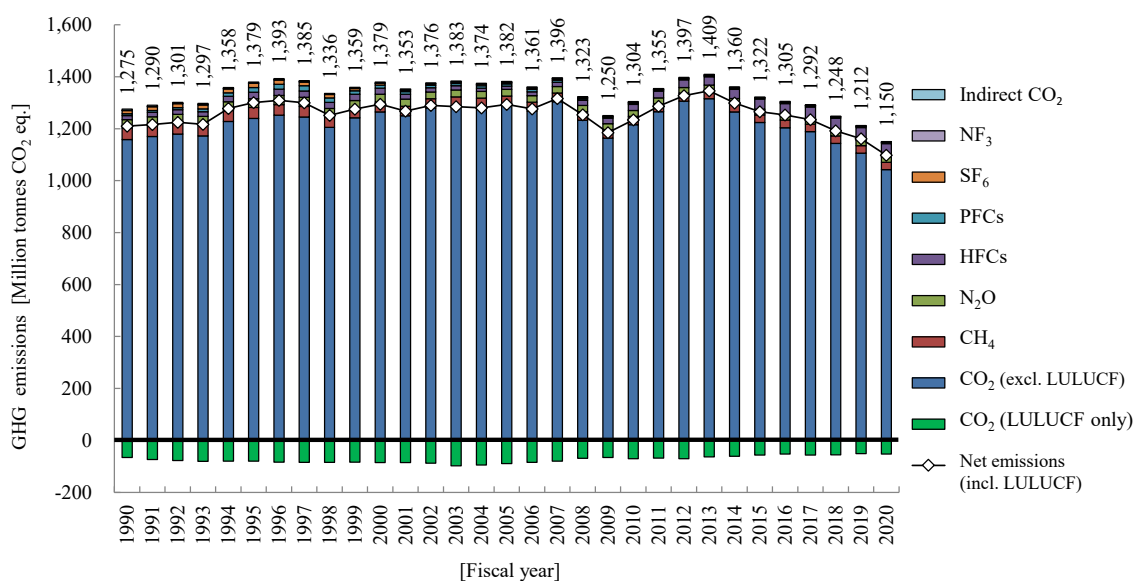


Figure 2-1 Trends in GHG emissions and removals in Japan

CO<sub>2</sub> emissions in FY2020 were 1,042 million tonnes (excluding LULUCF, excluding indirect CO<sub>2</sub>, hereafter, definition omitted), accounting for 90.6% of total GHG emissions. They decreased by 10.0% since FY1990 and decreased by 5.8% compared to the previous year. CO<sub>2</sub> removals<sup>5</sup> in FY2020 were 52.3 million tonnes, which were equivalent to 4.5% of total GHG emissions. They decreased by 20.4% since FY1990 and increased by 2.1% compared to the previous year.

<sup>1</sup> Fiscal year (FY), from April of the reporting year through March of the next year, is used because CO<sub>2</sub> is the primary GHGs emissions and estimated on a fiscal year basis. "CY" stands for calendar year.

<sup>2</sup> The sum of CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O, HFCs, PFCs, SF<sub>6</sub>, and NF<sub>3</sub> emissions converted to CO<sub>2</sub> equivalents, multiplied by their respective global warming potential (GWP). The GWP is a coefficient by means of which greenhouse gas effects of a given gas are made relative to those of an equivalent amount of CO<sub>2</sub>. The coefficients (100 year time horizon) are drawn from the *Fourth Assessment Report (2007)* issued by the Intergovernmental Panel on Climate Change (IPCC).

<sup>3</sup> Abbreviation of "Land Use, Land-Use Change and Forestry"

<sup>4</sup> Carbon monoxide (CO), methane (CH<sub>4</sub>) and non-methane volatile organic compounds (NMVOC) are oxidized in the atmosphere in the long term and converted to CO<sub>2</sub>. Indirect CO<sub>2</sub> means the CO<sub>2</sub> equivalent value of these emissions. However, emissions derived from combustion-origin and biomass-origin CO, CH<sub>4</sub>, and NMVOC are excluded to avoid double counting and/or by the concept of carbon neutrality.

<sup>5</sup> Since the inventory to be submitted under the UNFCCC reports all GHG emissions and removals from the LULUCF sector, these values do not correspond to emissions and removals under the Kyoto Protocol.

Table 2-1 Trends in GHG emissions and removals in Japan

[Million tonnes CO <sub>2</sub> eq.]	GWP	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	
		CO <sub>2</sub> (excl. LULUCF) *1	CO <sub>2</sub> (incl. LULUCF) *1	CO <sub>2</sub> (LULUCF only)	CH <sub>4</sub> (excl. LULUCF)	CH <sub>4</sub> (incl. LULUCF)	N <sub>2</sub> O (excl. LULUCF)	N <sub>2</sub> O (incl. LULUCF)	HFCs	PFCs	SF <sub>6</sub>	Indirect CO <sub>2</sub>	Gross Total (excluding LULUCF, excluding indirect CO <sub>2</sub> )	Net Total (including LULUCF, excluding indirect CO <sub>2</sub> )	Gross Total (excluding LULUCF, including indirect CO <sub>2</sub> )	Net Total (including LULUCF, including indirect CO <sub>2</sub> )	Change in emissions (2000-2019)	Change in emissions (2000-2019) (excluding LULUCF)	Change in emissions (2000-2019) (excluding LULUCF)	Change in emissions (2000-2019) (excluding LULUCF)	Change in emissions (2000-2019) (excluding LULUCF)	Change in emissions (2000-2019) (excluding LULUCF)
CO <sub>2</sub> (excl. LULUCF) *1	1	1,158.1	1,169.8	1,179.5	1,172.5	1,227.5	1,239.9	1,252.4	1,245.1	1,205.2	1,241.8	1,264.6	1,250.0	1,279.4	1,287.7	1,283.1	1,290.6	1,267.6	1,303.4	1,232.5	1,163.4	
CO <sub>2</sub> (incl. LULUCF) *1	1	1,092.5	1,096.1	1,102.4	1,092.1	1,147.4	1,160.4	1,168.7	1,160.4	1,120.4	1,157.9	1,179.6	1,164.4	1,192.0	1,189.6	1,188.6	1,201.6	1,183.3	1,223.5	1,163.4	1,097.4	
CO <sub>2</sub> (LULUCF only)	1	-65.7	-73.7	-77.1	-80.4	-80.1	-79.5	-83.7	-84.7	-84.8	-84.0	-85.0	-85.6	-87.3	-98.0	-94.5	-89.0	-84.3	-79.9	-69.1	-66.0	
CH <sub>4</sub> (excl. LULUCF)	25	44.1	43.5	43.5	42.6	42.8	41.7	40.5	40.1	38.5	38.2	37.6	36.5	35.8	34.9	34.7	34.7	34.2	33.7	32.9	32.4	
CH <sub>4</sub> (incl. LULUCF)	25	44.2	43.6	43.6	42.8	42.9	41.8	40.6	40.2	38.6	38.3	37.7	36.6	35.9	35.0	34.8	34.8	34.3	33.7	33.0	32.5	
N <sub>2</sub> O (excl. LULUCF)	298	32.4	32.0	32.2	32.1	33.3	33.6	34.7	35.5	33.9	27.8	30.3	26.7	26.1	26.0	25.8	25.5	25.4	24.8	23.9	23.3	
N <sub>2</sub> O (incl. LULUCF)	298	32.6	32.3	32.4	32.3	33.6	33.8	34.9	35.7	34.2	28.0	30.6	26.9	26.3	26.2	26.0	25.7	25.6	25.0	24.1	23.5	
HFCs	HFC-134a 1,430.ttc	15.9	17.3	17.8	18.1	21.1	25.2	24.6	24.4	23.7	24.4	22.9	19.5	16.2	16.2	12.4	12.8	14.6	16.7	19.3	20.9	
PFCs	PFC-14 7,390.ttc	6.5	7.5	7.6	10.9	13.4	17.7	18.3	20.0	16.6	13.1	11.9	9.9	9.2	8.9	9.2	8.6	9.0	7.9	5.8	4.1	
SF <sub>6</sub>	22,800	12.9	14.2	15.6	15.7	15.0	16.4	17.0	14.5	13.2	9.2	7.0	6.1	5.7	5.4	5.3	5.0	5.2	4.7	4.2	2.4	
Indirect CO <sub>2</sub>	17,200	0.0	0.0	0.0	0.0	0.1	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.5	1.5	1.4	1.6	1.5	1.4	
Indirect CO <sub>2</sub>	1	5.5	5.4	5.1	4.9	4.9	4.8	4.8	4.6	4.2	4.2	4.3	3.9	3.6	3.4	3.4	3.3	3.2	3.0	2.8	2.5	
Gross Total (excluding LULUCF, excluding indirect CO <sub>2</sub> )		1,269.9	1,284.4	1,296.2	1,292.0	1,353.2	1,374.7	1,387.8	1,379.9	1,331.4	1,354.8	1,374.6	1,349.0	1,372.8	1,379.6	1,371.0	1,378.7	1,357.5	1,392.8	1,320.0	1,247.9	
Net Total (including LULUCF, excluding indirect CO <sub>2</sub> )		1,204.6	1,211.0	1,219.4	1,211.9	1,273.4	1,295.5	1,304.4	1,295.5	1,246.9	1,271.2	1,289.9	1,263.7	1,285.8	1,281.8	1,276.8	1,290.0	1,273.4	1,313.1	1,251.2	1,182.2	
Gross Total (excluding LULUCF, including indirect CO <sub>2</sub> )		1,275.4	1,289.7	1,301.3	1,296.9	1,358.1	1,379.5	1,392.6	1,384.5	1,335.7	1,359.1	1,378.9	1,352.8	1,376.4	1,383.0	1,374.4	1,382.0	1,360.7	1,395.8	1,322.7	1,250.4	
Net Total (including LULUCF, including indirect CO <sub>2</sub> )		1,210.1	1,216.4	1,224.5	1,216.8	1,278.3	1,300.3	1,309.2	1,300.1	1,251.2	1,275.4	1,294.3	1,267.6	1,289.4	1,285.3	1,280.2	1,293.3	1,276.6	1,316.2	1,253.9	1,184.7	
[Million tonnes CO <sub>2</sub> eq.]	GWP	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	1990	Percentage								
CO <sub>2</sub> (excl. LULUCF) *1	1	1,215.1	1,265.0	1,306.2	1,315.6	1,264.4	1,223.6	1,203.9	1,188.4	1,143.4	1,106.0	1,042.2	-10.0%	-10.0%	-5.8%							
CO <sub>2</sub> (incl. LULUCF) *1	1	1,144.9	1,196.7	1,235.8	1,252.3	1,203.2	1,166.9	1,151.3	1,131.7	1,087.4	1,054.8	989.9	-9.4%	-9.4%	-6.1%							
CO <sub>2</sub> (LULUCF only)	1	-70.2	-68.3	-70.4	-63.2	-61.2	-56.7	-52.5	-56.6	-56.0	-51.2	-52.3	-20.4%	-20.4%	2.1%							
CH <sub>4</sub> (excl. LULUCF)	25	32.0	30.8	30.1	30.1	29.6	29.3	29.2	29.0	28.7	28.5	28.4	-35.6%	-35.6%	-0.3%							
CH <sub>4</sub> (incl. LULUCF)	25	32.1	30.9	30.2	30.2	29.7	29.3	29.3	29.1	28.7	28.5	28.5	-35.6%	-35.6%	-0.3%							
N <sub>2</sub> O (excl. LULUCF)	298	22.8	22.5	22.1	22.0	21.6	21.3	20.8	21.1	20.6	20.3	20.0	-38.2%	-38.2%	-1.3%							
N <sub>2</sub> O (incl. LULUCF)	298	23.0	22.6	22.3	22.2	21.8	21.5	21.0	21.3	20.8	20.5	20.2	-38.0%	-38.0%	-1.3%							
HFCs	HFC-134a 1,430.ttc	23.3	26.1	29.4	32.1	35.8	39.3	42.6	45.0	47.0	49.7	51.7	224.7%	224.7%	4.0%							
PFCs	PFC-14 7,390.ttc	4.3	3.8	3.4	3.3	3.4	3.3	3.4	3.5	3.5	3.4	3.5	-46.9%	-46.9%	1.5%							
SF <sub>6</sub>	22,800	2.4	2.2	2.2	2.1	2.0	2.1	2.2	2.1	2.1	2.0	2.0	-84.2%	-84.2%	1.4%							
Indirect CO <sub>2</sub>	17,200	1.5	1.8	1.5	1.6	1.1	0.6	0.6	0.4	0.3	0.3	0.3	-85.7%	-85.7%	10.5%							
Indirect CO <sub>2</sub>	1	2.5	2.4	2.3	2.3	2.2	2.2	2.2	2.1	2.1	2.1	2.0	-64.6%	-64.6%	-4.8%							
Gross Total (excluding LULUCF, excluding indirect CO <sub>2</sub> )		1,301.4	1,352.2	1,395.0	1,406.8	1,357.9	1,319.4	1,302.7	1,289.4	1,245.5	1,210.2	1,148.1	-9.6%	-9.6%	-5.1%							
Net Total (including LULUCF, excluding indirect CO <sub>2</sub> )		1,231.5	1,284.2	1,324.8	1,343.9	1,297.0	1,263.0	1,250.4	1,233.1	1,189.9	1,159.2	1,096.1	-9.0%	-9.0%	-5.4%							
Gross Total (excluding LULUCF, including indirect CO <sub>2</sub> )		1,303.9	1,354.6	1,397.3	1,409.1	1,360.2	1,321.6	1,304.9	1,291.6	1,247.7	1,212.2	1,150.1	-9.8%	-9.8%	-5.1%							
Net Total (including LULUCF, including indirect CO <sub>2</sub> )		1,234.0	1,286.5	1,327.1	1,346.2	1,299.2	1,265.2	1,252.6	1,235.2	1,192.0	1,161.3	1,098.1	-9.3%	-9.3%	-5.4%							

\*1 Excluding indirect CO<sub>2</sub>

\*2 LULUCF: Land Use, Land-Use Change and Forestry



CH<sub>4</sub> emissions in FY2020 (excluding LULUCF) were 28.4 million tonnes (in CO<sub>2</sub> eq.), accounting for 2.5% of total GHG emissions. They decreased by 35.6% since FY1990 and decreased by 0.3% compared to the previous year. N<sub>2</sub>O emissions in FY2020 (excluding LULUCF) were 20.0 million tonnes (in CO<sub>2</sub> eq.), accounting for 1.7% of total GHG emissions. They decreased by 38.2% since FY1990 and decreased by 1.3% compared to the previous year. HFC emissions in CY2020 were 51.7 million tonnes (in CO<sub>2</sub> eq.), accounting for 4.5% of total GHG emissions. They increased by 224.7% since CY1990 and increased by 4.0% compared to the previous year. PFC emissions in CY2020 were 3.5 million tonnes (in CO<sub>2</sub> eq.), accounting for 0.3% of total GHG emissions. They decreased by 46.9% since CY1990 and increased by 1.5% compared to the previous year. SF<sub>6</sub> emissions in CY2020 were 2.0 million tonnes (in CO<sub>2</sub> eq.), accounting for 0.2% of total GHG emissions. They decreased by 84.2% since CY1990 and increased by 1.4% compared to the previous year. NF<sub>3</sub> emissions in CY2020 were 0.3 million tonnes (in CO<sub>2</sub> eq.), accounting for 0.03% of total GHG emissions. They increased 785.7% since CY1990 and increased by 10.5% compared to the previous year.

Indirect CO<sub>2</sub> emissions in FY2020 were 2.0 million tonnes (in CO<sub>2</sub> eq.), accounting for 0.2% of total GHG emissions. They decreased by 64.6% since FY1990 and decreased by 4.8% compared to the previous year.

### 2.1.2. CO<sub>2</sub>

CO<sub>2</sub> emissions in FY2020 were 1,042 million tonnes, accounting for 90.6% of total GHG emissions. They decreased by 10.0% since FY1990 and decreased by 5.8% compared to the previous year.

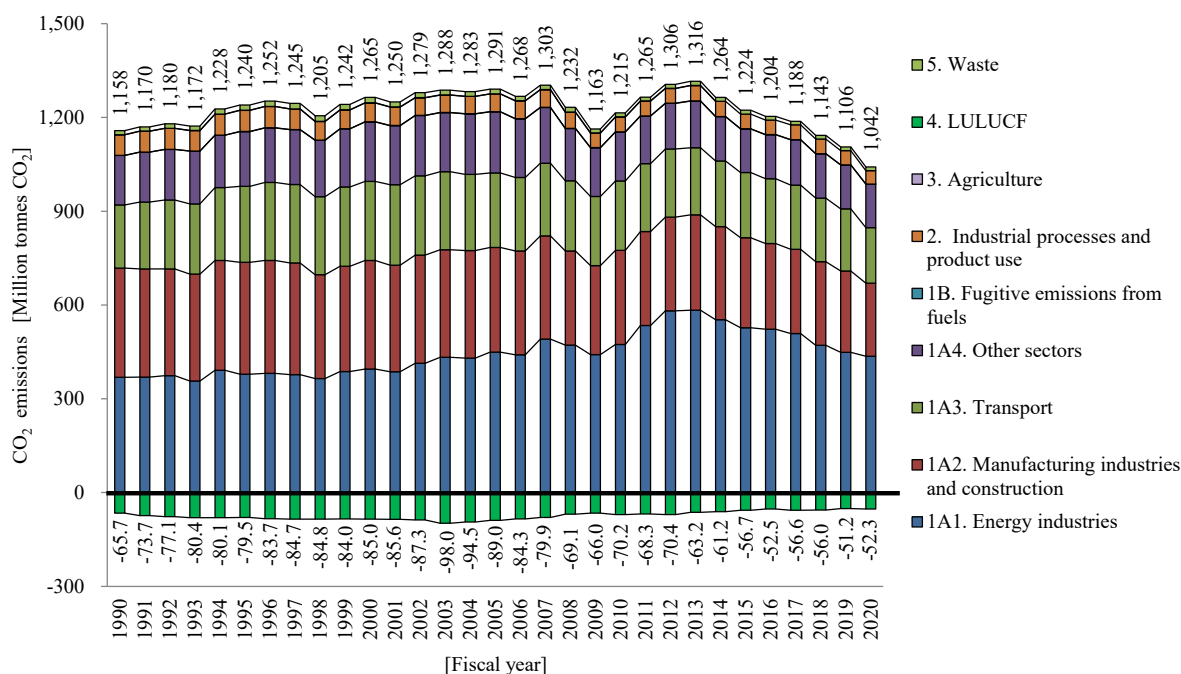


Figure 2-2 Trends in CO<sub>2</sub> emissions

The breakdown of CO<sub>2</sub> emissions in FY2020 shows that fuel combustion accounts for 94.7% and is followed by industrial processes and product use (4.1%) and waste sectors (1.2%). As for the breakdown of CO<sub>2</sub> emissions within the fuel combustion category, energy industries accounts for 41.9% and is

followed by manufacturing industries and construction at 22.4%, transport at 17.0%, and other sectors<sup>6</sup> at 13.3%. The main driving factor for the decrease in CO<sub>2</sub> emissions compared to the previous year is the decrease in CO<sub>2</sub> emissions from the manufacturing industries and construction sector and the transport sector.

By looking at the changes in emissions by sector, emissions from fuel combustion in the energy industries increased by 18.4% since FY1990 and decreased by 2.8% compared to the previous year. The main driving factor for the increase compared to the emissions in FY1990 is the increased emissions from solid and gaseous fuel consumption for electricity power generation, despite the decreased emissions from liquid fuel consumption. Emissions from manufacturing industries and construction decreased by 33.2% since FY1990 and decreased by 10.1% compared to the previous year. The main driving factor for the decrease compared to the emissions in FY1990 is the decreased emissions from solid fuel consumption for the iron and steel industry. Emissions from transport decreased by 12.1% compared to FY1990 and decreased by 10.5% compared to the previous year. The main driving factor for the decrease compared to the emissions in FY1990 is the decrease in emissions from diesel fuel in road transportation. Emissions from other sectors decreased by 12.2% since FY1990 and decreased by 1.3% compared to the previous year. The main driving factor for the decrease compared to the emissions in FY1990 is the decreased emissions from the liquid fuel consumption for the commercial/institutional sub-sectors.

CO<sub>2</sub> removals in FY2020 were 52.3 million tonnes, which were equivalent to 4.5% of total GHG emissions. They decreased by 20.4% since FY1990 and increased by 2.1% compared to the previous year.

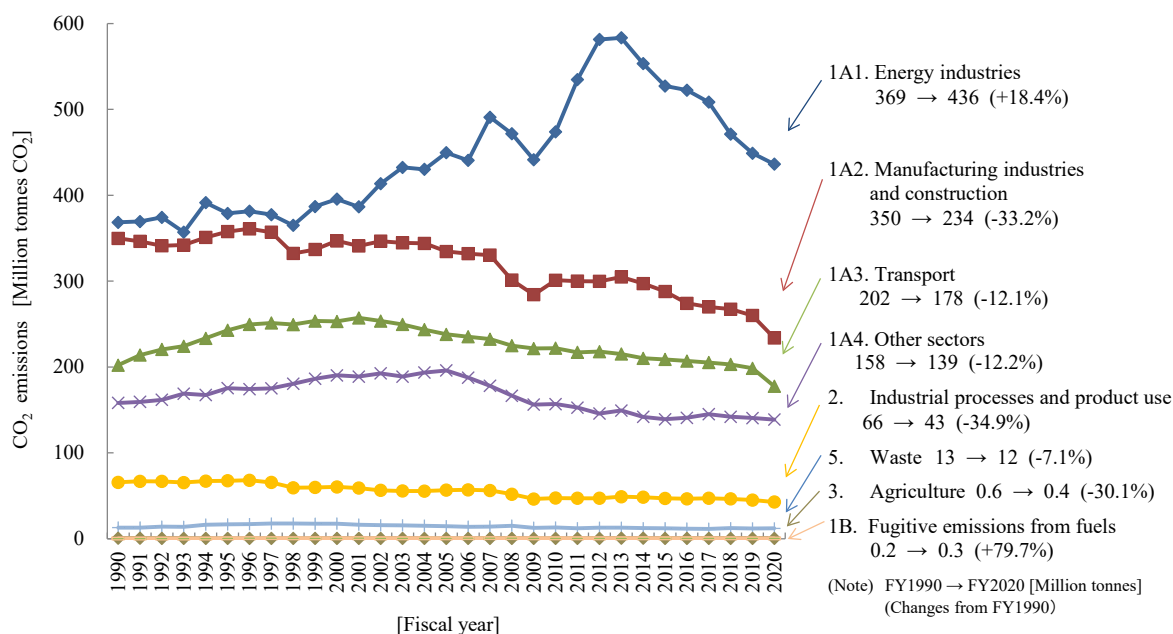


Figure 2-3 Trends in CO<sub>2</sub> emissions in each sector

Note: Figures in brackets indicate relative increase or decrease to the FY1990 values

<sup>6</sup> It covers emissions from commercial/institutional, residential and agriculture/forestry/fishing.

Table 2-2 Trends in CO<sub>2</sub> emissions and removals in each sector

[Thousand tonnes CO <sub>2</sub> ]															
Category	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
IA. Fuel combustion	1,078,663	1,154,838	1,185,785	1,218,316	1,153,798	1,204,732	1,245,119	1,252,760	1,202,701	1,163,458	1,144,721	1,128,800	1,083,793	1,048,150	986,615
IA1. Energy industries	368,530	378,905	395,494	449,664	473,846	534,790	581,481	583,474	553,352	527,291	522,505	508,552	471,310	449,002	436,334
Public electricity and heat production	303,055	317,587	330,118	378,044	404,239	468,951	516,376	521,862	493,837	468,472	467,080	454,977	415,850	396,732	391,961
Petroleum refining	36,397	41,085	46,978	50,888	47,715	44,478	43,298	42,943	41,103	41,664	37,609	36,812	37,600	35,909	29,498
Manufacture of solid fuels and other energy industries	29,078	20,232	18,398	20,732	21,892	21,360	21,807	18,670	18,412	17,155	17,816	16,764	17,860	16,361	14,875
IA2. Manufacturing industries and construction	349,816	357,726	346,942	334,557	301,070	300,078	299,833	304,851	297,268	288,073	274,255	269,955	267,449	259,988	233,834
Iron and steel	150,691	143,097	152,106	154,168	153,154	148,879	151,286	157,550	155,101	148,878	142,756	139,752	136,179	134,140	111,996
Non-ferrous metals	8,429	7,381	6,311	5,686	3,964	3,834	3,994	3,743	3,635	3,242	3,499	3,122	3,284	2,871	2,771
Chemicals	58,039	64,339	59,518	54,952	50,118	49,491	47,332	48,266	46,579	45,564	42,363	42,881	42,208	42,121	39,552
Pulp, paper and print	27,106	31,428	31,672	29,732	22,646	23,318	23,812	23,832	22,899	23,308	20,847	20,491	20,430	18,984	17,855
Food processing, beverages and tobacco	7,649	10,133	11,468	12,169	9,830	10,785	10,535	9,811	9,521	8,471	8,414	7,764	8,738	7,690	8,034
Non-metallic minerals	43,634	46,461	40,100	35,443	28,716	28,625	28,839	29,804	28,989	28,059	27,097	26,885	26,997	25,846	25,119
Other	54,267	54,888	45,766	42,407	32,642	35,147	34,036	31,846	30,545	30,550	29,279	29,060	29,614	28,337	28,506
IA3. Transport	202,140	242,797	253,091	238,065	221,969	217,138	218,004	215,115	210,149	208,875	207,066	205,253	203,016	198,579	177,643
Domestic aviation	7,162	10,278	10,677	10,799	9,193	9,001	9,524	10,149	10,173	10,067	10,187	10,399	10,537	10,488	5,238
Road transportation	180,367	217,028	226,690	213,605	201,457	197,148	197,158	193,437	188,540	187,641	185,722	183,803	181,451	177,185	161,847
Railways	935	822	711	647	574	554	554	540	524	523	499	520	492	490	488
Domestic navigation	13,675	14,669	15,012	13,014	10,745	10,434	10,769	10,989	10,912	10,645	10,659	10,530	10,537	10,417	10,070
IA4. Other sectors	158,178	175,411	190,258	196,029	156,914	152,726	145,801	149,320	141,932	139,220	140,895	145,400	142,017	140,581	138,804
Commercial/institutional	79,069	88,210	98,179	105,958	74,897	73,680	66,989	74,224	69,188	67,108	67,279	67,723	74,580	70,551	66,109
Residential	58,167	67,477	72,226	70,395	64,217	62,541	62,626	60,319	58,014	55,392	55,712	59,260	52,156	53,361	55,807
Agriculture/forestry/fishing	20,942	19,723	19,853	19,676	17,800	16,505	16,186	14,777	14,730	16,720	17,905	18,058	15,280	16,669	16,888
IA5. Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
IB. Fugitive emissions from fuels	192	522	512	508	475	478	490	439	449	425	457	436	423	369	345
IC. CO <sub>2</sub> transport and storage	NE/NO	NE/NO	NE/NO	NE/NO	NE/NO	NE/NO	NE/NO	NE/NO	NE/NO	NE/NO	NE/NO	NE/NO	NE/NO	NE/NO	NE/NO
2. Industrial processes and product use	65,645	67,514	60,316	56,650	47,348	47,157	47,208	48,989	48,375	46,974	46,552	47,175	46,461	45,121	42,748
3. Agriculture	609	359	443	411	403	415	520	578	551	459	446	486	435	435	425
4. LULUCF	-65,667	-79,529	-84,987	-88,992	-70,162	-68,288	-70,380	-63,231	-61,228	-56,719	-52,547	-56,633	-55,966	-51,237	-52,291
5. Waste	13,020	16,676	17,540	14,715	13,034	12,253	12,845	12,803	12,336	12,289	11,712	11,462	12,299	11,940	12,091
Total (including LULUCF)	1,092,462	1,160,380	1,179,608	1,201,608	1,144,896	1,196,746	1,235,802	1,252,338	1,203,185	1,166,886	1,151,342	1,131,726	1,087,446	1,054,779	989,933
Total (excluding LULUCF)	1,158,129	1,239,909	1,264,595	1,290,600	1,215,058	1,265,035	1,306,183	1,315,569	1,264,413	1,223,605	1,203,888	1,188,359	1,143,412	1,106,015	1,042,224

\*1 Excluding indirect CO<sub>2</sub>

\*2 LULUCF: Land Use, Land-Use Change and Forestry

CO<sub>2</sub> emissions per capita in FY2020 were 8.26 tonnes. They decreased by 11.8% since FY1990 and decreased by 5.5% compared to the previous year.

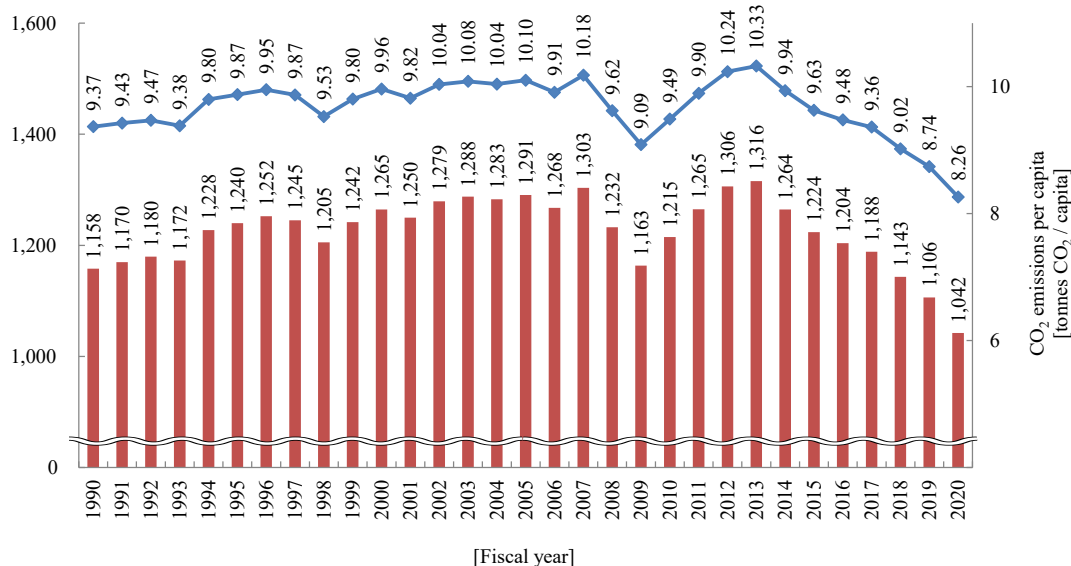


Figure 2-4 Trends in total CO<sub>2</sub> emissions and CO<sub>2</sub> emissions per capita  
Reference of population data: *Population Census and Annual Report of Population Estimates*  
(Ministry of Internal Affairs and Communications, Statistics Bureau)

CO<sub>2</sub> emissions per unit of GDP (million yen) in FY2020 were 1.98 tonnes. They decreased by 27.6% since FY1990 and decreased by 1.3% compared to the previous year.

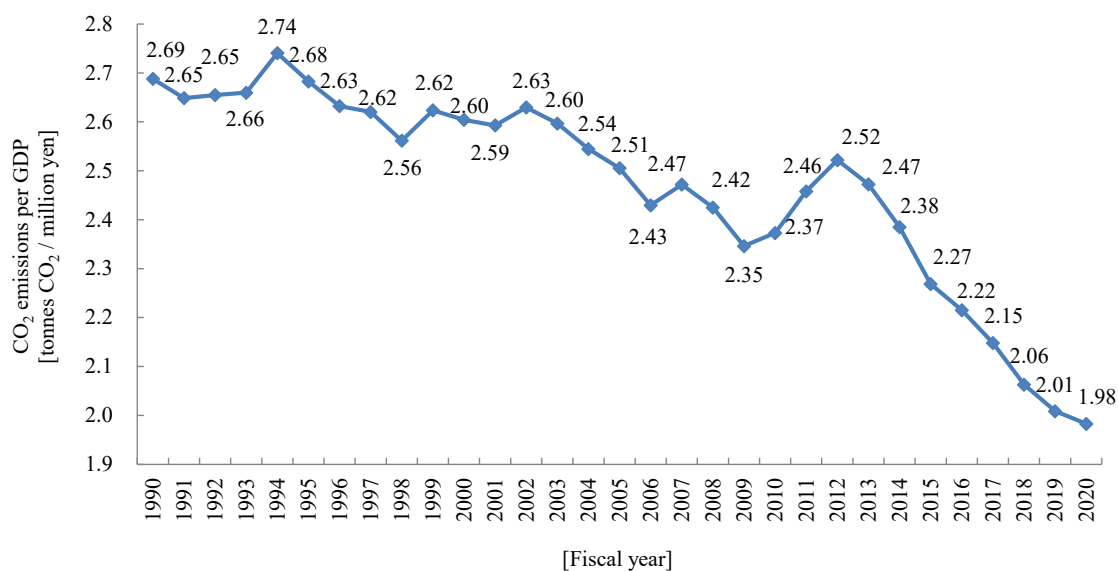


Figure 2-5 Trends in CO<sub>2</sub> emissions per unit of GDP

Reference of GDP data: *Annual Report on National Accounts* (Cabinet Office, Government of Japan)

### 2.1.3. CH<sub>4</sub>

CH<sub>4</sub> emissions in FY2020 were 28.5 million tonnes (in CO<sub>2</sub> eq., including LULUCF), accounting for 2.5% of total GHG emissions. They decreased by 35.6% since FY1990 and decreased by 0.3% compared to the previous year. Their decrease since FY1990 is mainly a result of a 65.5% decrease in emissions from the waste sector (e.g. solid waste disposal).

The breakdown of the FY2020 emissions showed that the largest source was rice cultivation accounting for 42%. It is followed by enteric fermentation (27%) and solid waste disposal (9%).

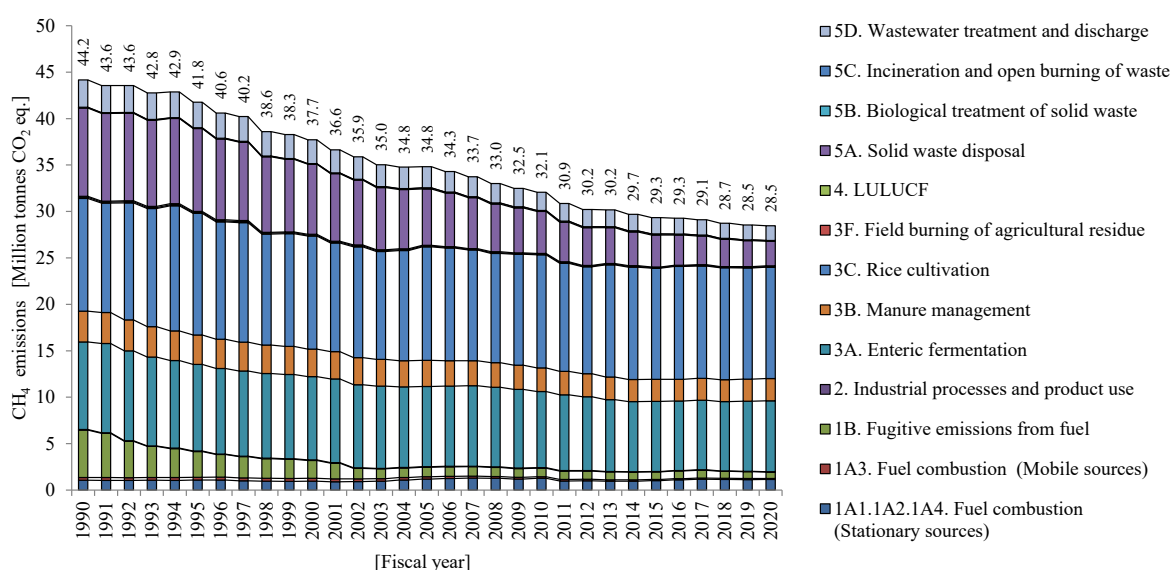


Figure 2-6 Trends in CH<sub>4</sub> emissions

Table 2-3 Trends in CH<sub>4</sub> emissions

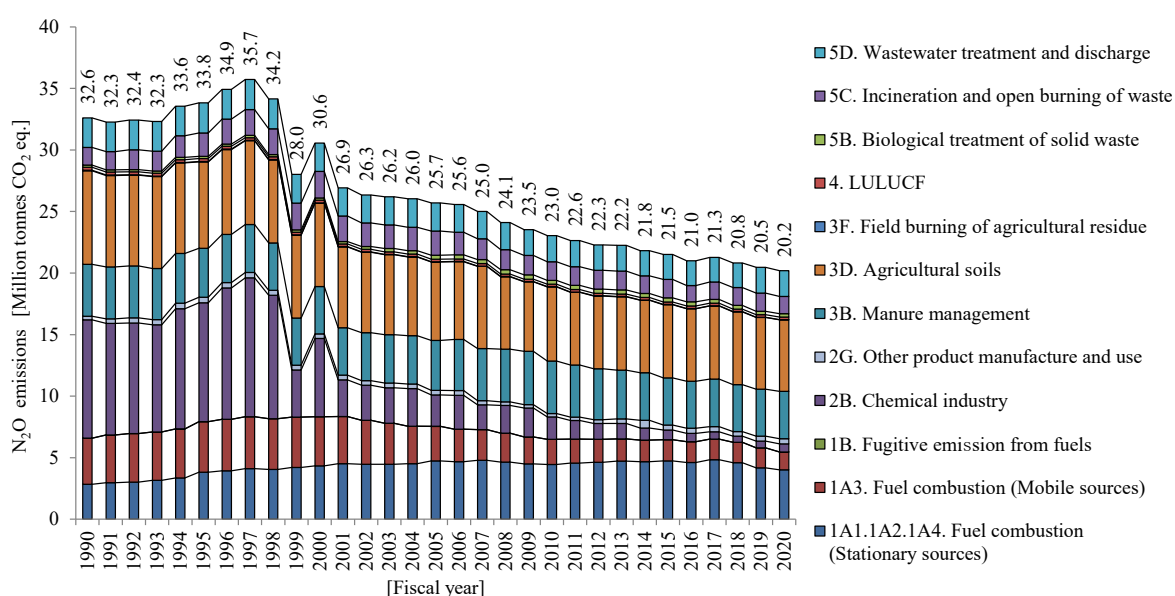
Category	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
<b>1A. Fuel combustion</b>	1,349	1,381	1,273	1,433	1,437	1,147	1,165	1,111	1,097	1,145	1,234	1,300	1,263	1,243	1,252
1A1. Energy industries	459	400	263	249	270	290	300	239	225	277	354	390	374	355	402
1A2. Manufacturing industries and construction	360	378	370	442	538	439	465	495	518	526	540	563	568	568	537
1A3. Transport	291	309	312	247	174	166	159	151	143	137	132	127	124	119	105
1A4. Other sectors	239	293	327	496	455	252	241	225	211	205	208	219	198	202	207
<b>1B. Fugitive emissions from fuels</b>	5,107	2,773	1,922	1,026	920	900	882	848	838	816	824	834	764	726	692
1B1. Solid fuels	4,895	2,520	1,649	704	600	585	577	565	570	549	540	554	499	478	469
1B2. Oil and natural gas and other emissions	213	253	273	322	321	315	305	283	268	267	284	280	265	248	223
<b>2. Industrial processes and product use</b>	61	58	54	54	54	54	46	46	43	48	43	43	40	41	38
<b>3. Agriculture</b>	25,009	25,686	24,199	23,754	22,999	22,395	22,025	22,315	22,100	21,944	22,040	22,007	21,925	21,973	22,088
3A. Enteric fermentation	9,423	9,318	8,966	8,651	8,202	8,154	7,953	7,737	7,543	7,534	7,481	7,494	7,465	7,563	7,633
3B. Manure management	3,329	3,164	2,961	2,801	2,537	2,532	2,490	2,428	2,385	2,382	2,343	2,355	2,356	2,375	2,387
3C. Rice cultivation	12,129	13,092	12,175	12,216	12,186	11,635	11,511	12,078	12,101	11,961	12,149	12,093	12,039	11,970	12,004
3F. Field burning of agricultural residue	127	111	96	86	74	73	71	72	70	67	67	64	65	64	64
<b>4. LULUCF</b>	105	96	90	88	79	79	73	74	93	76	69	91	70	72	69
<b>5. Waste</b>	12,533	11,771	10,179	8,472	6,573	6,288	6,022	5,774	5,520	5,302	5,070	4,839	4,662	4,492	4,324
5A. Solid waste disposal	9,510	8,938	7,548	6,080	4,515	4,267	4,054	3,851	3,631	3,441	3,244	3,090	2,934	2,792	2,654
5B. Biological treatment of solid waste	54	53	54	95	93	102	101	100	100	102	103	90	89	82	82
5C. Incineration and open burning of waste	28	29	21	18	12	11	11	12	10	10	9	10	11	10	10
5D. Wastewater treatment and discharge	2,942	2,750	2,556	2,280	1,954	1,908	1,855	1,811	1,779	1,749	1,714	1,648	1,629	1,607	1,578
<b>Total (including LULUCF)</b>	44,164	41,765	37,718	34,826	32,061	30,862	30,214	30,168	29,691	29,331	29,281	29,113	28,724	28,546	28,463
<b>Total (excluding LULUCF)</b>	44,059	41,669	37,628	34,738	31,983	30,783	30,141	30,094	29,598	29,256	29,212	29,022	28,655	28,474	28,394

\* LULUCF: Land Use, Land-Use Change and Forestry

2.1.4. N<sub>2</sub>O

N<sub>2</sub>O emissions in FY2020 were 20.2 million tonnes (in CO<sub>2</sub> eq., including LULUCF), accounting for 1.8% of total GHG emissions. They decreased by 38.0% since FY1990 and decreased by 1.3% compared to the previous year. Their decrease since FY1990 is mainly a result of a 89.0% decrease in emissions from industrial processes and product use (e.g. adipic acid production in the chemical industry). There is a sharp decline in emissions from the industrial processes and product use from FY1998 to 1999, as N<sub>2</sub>O abatement equipment came on stream in the adipic acid production plant in March 1999. However, the N<sub>2</sub>O emissions increased in FY2000 because of a decrease in the equipment's operation rate due to mechanical failure; the emissions decreased again in FY2001 with the resumption of normal operation.

Breakdown of the FY2020 emissions showed that the largest source was agricultural soils accounting for 29%. It is followed by fuel combustion (stationary sources) (20%) and manure management (19%).

Figure 2-7 Trends in N<sub>2</sub>O emissionsTable 2-4 Trends in N<sub>2</sub>O emissions

Category	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
<b>1A. Fuel combustion</b>	6,578	7,925	8,329	7,545	6,496	6,513	6,490	6,525	6,423	6,455	6,293	6,506	6,249	5,801	5,457
1A1. Energy industries	889	1,353	1,613	2,117	2,072	2,267	2,290	2,358	2,347	2,388	2,255	2,443	2,264	1,880	1,862
1A2. Manufacturing industries and construction	1,260	1,706	1,879	1,868	1,724	1,720	1,737	1,762	1,722	1,735	1,672	1,672	1,645	1,605	1,482
1A3. Transport	3,739	4,104	3,997	2,817	2,053	1,951	1,876	1,803	1,749	1,719	1,694	1,681	1,662	1,630	1,451
1A4. Other sectors	689	761	839	742	646	575	587	602	605	613	672	711	679	686	662
<b>1B. Fugitive emissions from fuels</b>	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1
<b>2. Industrial processes and product use</b>	9,911	10,114	6,720	2,926	2,088	1,777	1,600	1,618	1,606	1,199	1,105	1,020	876	941	1,087
2B. Chemical industry	9,620	9,665	6,348	2,558	1,813	1,507	1,293	1,259	979	798	676	599	506	551	663
2G. Other product manufacture and use	291	449	371	368	275	270	308	359	627	402	429	420	370	390	424
<b>3. Agriculture</b>	11,862	11,031	10,658	10,454	10,317	10,171	10,066	9,954	9,782	9,795	9,723	9,823	9,743	9,667	9,672
3B. Manure management	4,214	3,965	3,849	4,056	4,273	4,235	4,133	3,970	3,869	3,833	3,806	3,853	3,807	3,820	3,843
3D. Agricultural soils	7,608	7,032	6,779	6,371	6,021	5,913	5,911	5,961	5,891	5,941	5,896	5,950	5,916	5,827	5,809
3F. Field burning of agricultural residue	39	34	30	26	23	22	22	22	22	21	21	20	20	20	20
<b>4. LULUCF</b>	245	229	215	205	196	198	199	199	202	201	202	206	207	210	212
<b>5. Waste</b>	4,006	4,525	4,638	4,563	3,939	3,989	3,931	3,952	3,801	3,865	3,683	3,714	3,738	3,843	3,771
5B. Biological treatment of solid waste	181	179	181	319	309	342	338	335	333	340	343	298	296	274	272
5C. Incineration and open burning of waste	1,438	1,908	2,156	1,963	1,515	1,518	1,523	1,535	1,423	1,498	1,312	1,423	1,453	1,473	1,408
5D. Wastewater treatment and discharge	2,387	2,439	2,301	2,280	2,115	2,129	2,069	2,082	2,045	2,027	2,028	1,992	1,990	2,096	2,091
<b>Total (including LULUCF)</b>	32,604	33,827	30,561	25,693	23,038	22,649	22,288	22,248	21,814	21,516	21,006	21,269	20,814	20,462	20,199
<b>Total (excluding LULUCF)</b>	32,359	33,598	30,346	25,489	22,841	22,451	22,089	22,049	21,613	21,315	20,804	21,063	20,607	20,252	19,987

\* LULUCF: Land Use, Land-Use Change and Forestry

### 2.1.5. HFCs

HFC emissions in CY2020<sup>7</sup> were 51.7 million tonnes (in CO<sub>2</sub> eq.), accounting for 4.5% of total GHG emissions. They increased by 224.7% since CY1990, and increased by 4.0% compared to the previous year. Their increase since CY1990 is mainly a result of an increase in emissions from refrigeration and air conditioning (+47.7 million tonnes CO<sub>2</sub> eq.) substituting for HCFC (an ozone depleting substance), despite a decrease in emissions of HFC-23 (-99.1%) produced as a by-product of HCFC-22 production due to regulation under the Act on the Protection of the Ozone Layer Through the Control of Specified Substances and Other Measures. (Act No.53, 1988)

The breakdown of the CY2020 emissions showed that the largest source was refrigerants of refrigeration and air conditioning equipment accounting for 92%. It is followed by foam blowing agents (6%).

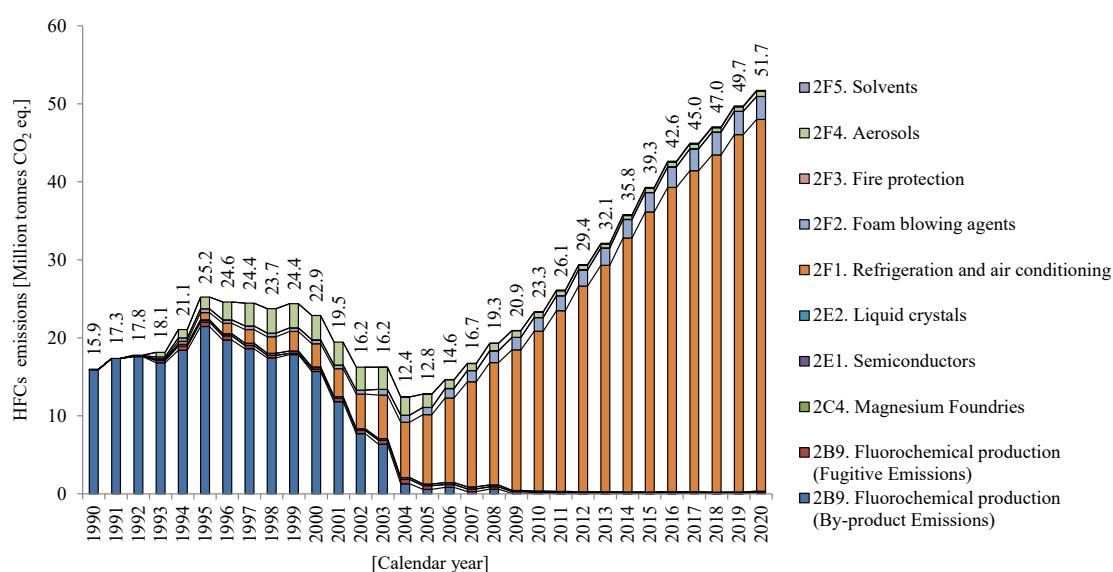


Figure 2-8 Trends in HFC emissions

Table 2-5 Trends in HFC emissions

Category	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
2B9. Fluorochemical production	15,930	22,019	15,984	1,035	181	168	138	147	124	113	172	133	100	132	216
By-product Emissions	15,929	21,460	15,688	586	53	16	18	24	16	30	24	38	12	13	141
Fugitive Emissions	2	559	296	449	128	151	120	131	101	83	149	95	88	119	76
2C4. Magnesium production	NO	NO	NO	NO	NO	1	1	1	1	1	1	1	2	1	1
2E. Electronics industry	1	271	285	227	168	145	124	112	115	115	119	125	115	101	109
2E1. Semiconductors	1	271	283	224	165	142	122	109	113	113	117	123	113	99	108
2E2. Liquid crystals	0.001	0.3	2	3	3	3	2	2	2	2	2	2	2	2	1
2F. Product uses as substitutes for ODS	1	2,923	6,582	11,521	22,977	25,805	29,113	31,860	35,560	39,052	42,349	44,694	46,827	49,498	51,398
2F1. Refrigeration and air conditioning	NO	925	2,976	8,875	20,493	23,153	26,369	29,024	32,553	35,893	38,972	41,167	43,234	45,815	47,678
2F2. Foam blowing agents	1	497	484	937	1,749	1,923	2,081	2,229	2,373	2,484	2,651	2,801	2,922	2,979	2,925
2F3. Fire protection	NO	NO	5	7	8	8	9	9	9	9	10	10	10	10	10
2F4. Aerosols	NO	1,502	3,117	1,695	666	634	561	489	503	540	587	600	544	572	659
2F5. Solvents	NO	NO	NO	6	60	86	94	109	122	126	130	116	117	122	127
Total	15,932	25,213	22,851	12,784	23,327	26,119	29,377	32,121	35,801	39,281	42,642	44,954	47,043	49,733	51,725

<sup>7</sup> Emissions of HFCs, PFCs, SF<sub>6</sub>, and NF<sub>3</sub> are estimated on a calendar year (CY) basis.

### 2.1.6. PFCs

PFC emissions in CY2020 were 3.5 million tonnes (in CO<sub>2</sub> eq.), accounting for 0.3% of total GHG emissions. They decreased by 46.9% since CY1990 and increased by 1.5% compared to the previous year. Their decrease since CY1990 is mainly the result of a decrease in emissions from the solvents. (-68.0%)

The breakdown of the CY2020 emissions showed that the largest source was semiconductor manufacturing accounting for 52%. It is followed by solvents such as those for washing metals (42%).

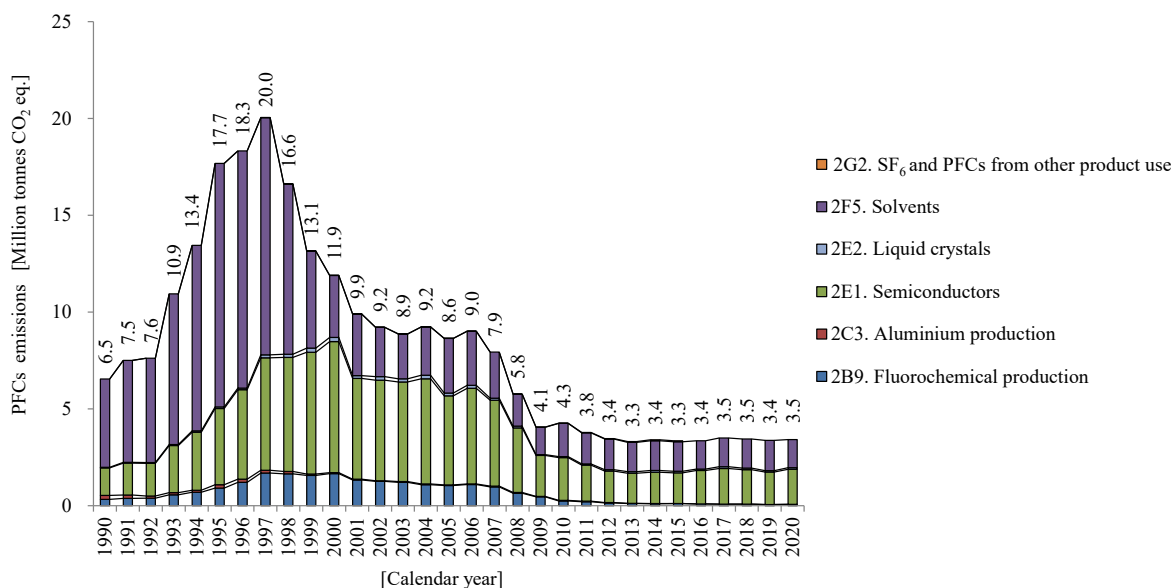


Figure 2-9 Trends in PFC emissions

Table 2-6 Trends in PFC emissions

Category	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
2B9, Fluorochemical production	331	914	1,661	1,041	248	206	148	111	107	115	97	81	87	64	74
2C3, Aluminium production	204	171	44	36	25	25	22	16	3	NO	NO	NO	NO	NO	NO
2E, Electronics industry	1,455	4,020	6,986	4,746	2,261	1,922	1,692	1,631	1,707	1,669	1,792	1,931	1,856	1,752	1,888
2E1, Semiconductors	1,423	3,933	6,771	4,594	2,214	1,863	1,624	1,556	1,617	1,582	1,721	1,847	1,776	1,676	1,811
2E2, Liquid crystals	31	87	214	152	46	59	68	76	90	86	71	84	79	75	77
2F5, Solvents	4,550	12,572	3,200	2,815	1,721	1,605	1,583	1,518	1,537	1,517	1,465	1,484	1,505	1,558	1,457
2G2, SF <sub>6</sub> and PFCs from other product use	NO	NO	NO	0.3	4	6	NO	10	9	8	21	20	39	49	56
<b>Total</b>	<b>6,539</b>	<b>17,677</b>	<b>11,890</b>	<b>8,637</b>	<b>4,259</b>	<b>3,765</b>	<b>3,445</b>	<b>3,286</b>	<b>3,363</b>	<b>3,308</b>	<b>3,375</b>	<b>3,516</b>	<b>3,487</b>	<b>3,423</b>	<b>3,475</b>



### 2.1.7. SF<sub>6</sub>

SF<sub>6</sub> emissions in CY2020 were 2.0 million tonnes (in CO<sub>2</sub> eq.), accounting for 0.2% of total GHG emissions. They decreased by 84.2% since CY1990 and increased by 1.4% compared to the previous year. Their decrease since CY1990 is mainly a result of a decrease from electrical equipment, due to an enhancement of gas management system such as gas recovery largely in electric power companies. (-93.0%)

The breakdown of the CY2020 emissions showed that the largest source was other product use (e.g. accelerator, etc.) accounting for 39%. It is followed by electrical equipment (28%) and magnesium production (15%).

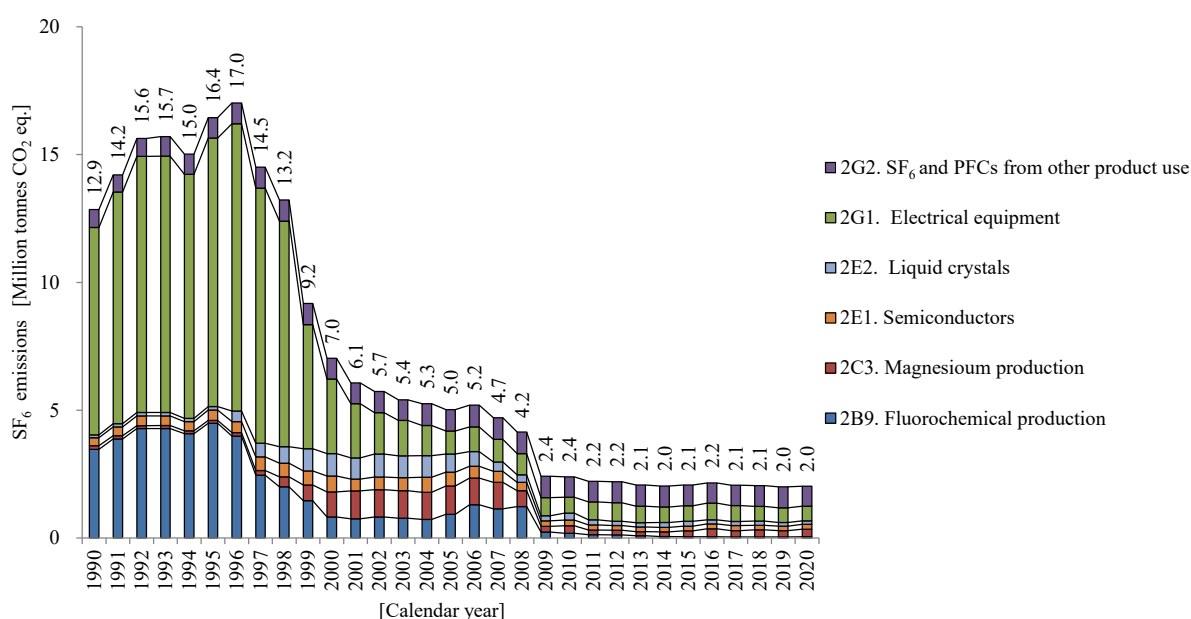


Figure 2-10 Trends in SF<sub>6</sub> emissions

Table 2-7 Trends in SF<sub>6</sub> emissions

Category	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
2B9. Fluorochemical production	3,471	4,492	821	930	189	132	123	93	62	52	50	41	46	40	52
2C3. Magnesium production	147	114	980	1,104	294	182	182	160	182	228	315	246	274	251	296
2E. Electronics industry	419	542	1,506	1,252	494	394	356	351	366	375	349	363	349	321	324
2E1. Semiconductors	309	400	629	540	225	196	184	181	175	184	192	200	182	174	185
2E2. Liquid crystals	110	142	877	712	269	198	172	170	191	191	157	163	167	147	139
2G. Other product manufacture and use	8,814	11,300	3,724	1,741	1,422	1,513	1,546	1,472	1,429	1,419	1,445	1,421	1,387	1,389	1,356
2G1. Electrical equipment	8,112	10,498	2,910	899	622	707	719	643	602	610	655	620	572	573	571
2G2. SF <sub>6</sub> and PFCs from other product use	702	802	815	842	799	806	827	829	827	809	789	801	815	816	784
Total	12,850	16,448	7,031	5,027	2,398	2,222	2,207	2,075	2,039	2,075	2,158	2,071	2,055	2,001	2,028

### 2.1.8. NF<sub>3</sub>

NF<sub>3</sub> emissions in CY2020 were 0.3 million tonnes (in CO<sub>2</sub> eq.), accounting for 0.03% of total GHG emissions. They increased by 785.7% since CY1990 and increased by 10.5% compared to the previous year. The increase since CY1990 is mainly a result of an increase in emissions from semiconductor manufacture, owing to shifts to use NF<sub>3</sub>. (by 833.5%)

The breakdown of the CY2020 emissions showed that the largest source was semiconductor manufacture accounting for 88%. It is followed by liquid crystal manufacture (7%) and fluorochemical production (5%).

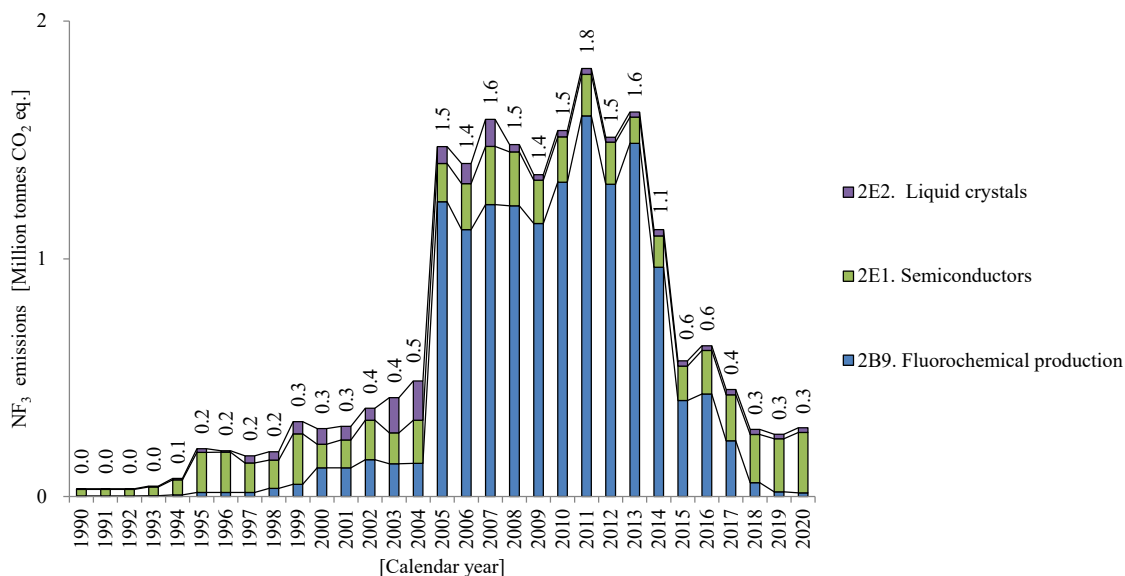


Figure 2-11 Trends in NF<sub>3</sub> emissions

Table 2-8 Trends in NF<sub>3</sub> emissions

Category	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
2B9. Fluorochemical production	3	17	120	1,240	1,323	1,601	1,314	1,486	965	404	432	234	58	19	15
2E. Electronics industry	30	184	165	232	217	199	198	131	158	167	203	216	225	242	274
2E1. Semiconductors	27	168	100	161	191	175	177	110	132	145	183	194	203	224	255
2E2. Liquid crystals	3	16	66	71	26	24	21	21	26	22	20	22	21	19	19
Total	33	201	286	1,472	1,540	1,800	1,512	1,617	1,123	571	634	450	282	261	289

### 2.1.9. Indirect CO<sub>2</sub>

Indirect CO<sub>2</sub> emissions<sup>8</sup> in FY2020 were 2.0 million tonnes (in CO<sub>2</sub> eq.), accounting for 0.2% of total GHG emissions. They decreased by 64.6% since FY1990 and decreased by 4.8% compared to the previous year. Their decrease since FY1990 was due to the decrease in emissions from the use of paint through the wider use of low VOC paint and VOC removal by adsorption devices.

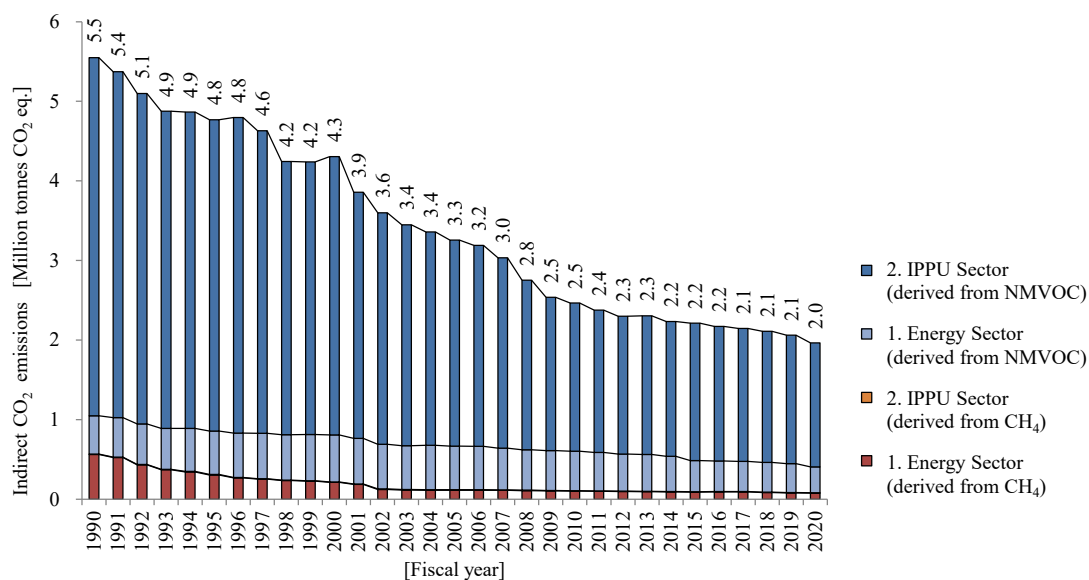


Figure 2-12 Trends in Indirect CO<sub>2</sub> emissions

Table 2-9 Trends in Indirect CO<sub>2</sub> emissions

[Thousand tonnes CO <sub>2</sub> eq.]		1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Derived from CH <sub>4</sub>		568	311	217	119	107	105	102	98	97	95	95	96	88	84	80
1. Energy Sector		562	305	211	113	101	99	97	93	92	90	91	92	84	80	76
2. IPPU Sector		7	6	6	6	6	6	5	5	5	5	5	5	4	5	4
Derived from NMVOC		4,980	4,456	4,088	3,137	2,358	2,271	2,196	2,207	2,135	2,118	2,077	2,049	2,021	1,978	1,883
1. Energy Sector		480	545	590	548	497	482	465	464	441	390	386	380	375	362	327
2. IPPU Sector		4,499	3,911	3,499	2,589	1,860	1,789	1,731	1,743	1,694	1,728	1,692	1,670	1,647	1,615	1,556
Total		5,548	4,768	4,306	3,256	2,465	2,376	2,298	2,305	2,232	2,213	2,173	2,146	2,110	2,062	1,963

<sup>8</sup> Emissions derived from fuel combustion-origin, waste incineration-origin, and biomass-origin CO, CH<sub>4</sub>, and NMVOC are excluded to avoid double counting and/or by concept of carbon neutrality.

## 2.2. Description and Interpretation of Emission and Removal Trends by Categories

The breakdown of GHG emissions and removals in FY2020 by sector<sup>9</sup> showed that energy (excluding indirect CO<sub>2</sub>, hereafter, definition omitted) accounted for 86.5% of total GHG emissions. It is followed by industrial processes and product use (excluding indirect CO<sub>2</sub>, hereafter, definition omitted) (8.8%), agriculture (2.8%), waste (1.8%), and indirect CO<sub>2</sub> emissions (0.2%).

Removals by LULUCF in FY2020 were equivalent to 4.5% of total GHG emissions.

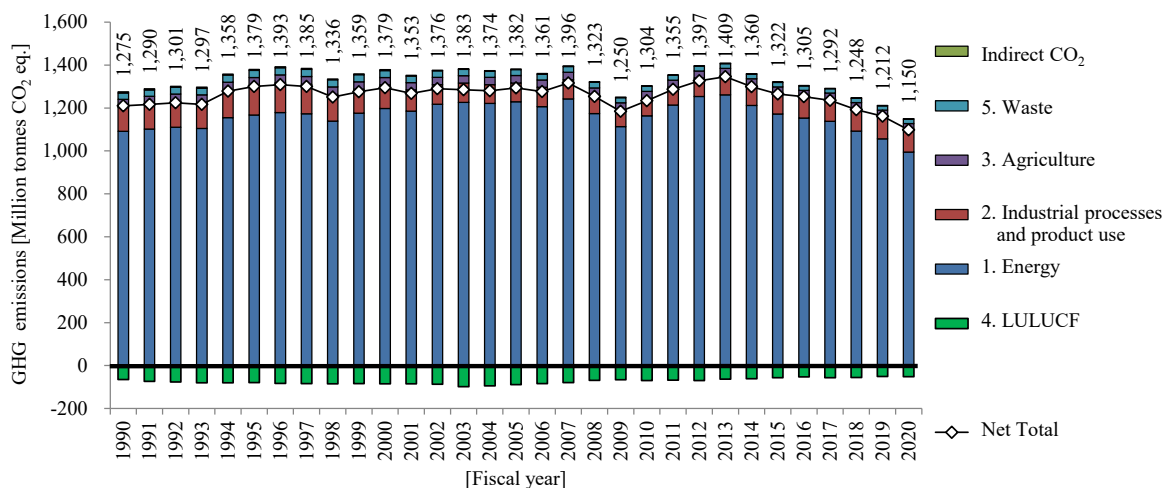


Figure 2-13 Trends in GHG emissions and removals in each sector

<sup>9</sup> As indicated in the 2006 IPCC Guidelines and the CRF.

Table 2-10 Trends in GHG emissions and removals in each sector

[Million tonnes CO <sub>2</sub> eq.]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
1. Energy <sup>*1</sup>	1,091.9	1,102.3	1,110.4	1,104.4	1,155.4	1,167.4	1,178.9	1,173.5	1,139.3	1,175.9	1,197.8	1,185.6	1,217.2	1,226.1	1,221.9	1,228.8	1,206.1	1,242.3	1,174.4	1,113.0
2. Industrial processes and product use <sup>*1</sup>	111.0	115.5	117.3	119.5	127.0	137.2	139.4	136.5	123.7	111.1	109.1	98.1	91.2	89.8	86.4	87.6	90.5	89.6	85.1	77.7
3. Agriculture	37.5	37.1	37.9	37.8	38.0	37.1	36.3	36.4	35.2	35.3	35.3	34.6	34.8	34.3	34.2	34.6	34.4	34.8	33.7	33.5
4. LULUCF <sup>*2</sup>	-65.3	-73.4	-76.8	-80.1	-79.8	-79.2	-83.4	-84.4	-84.5	-83.7	-84.7	-85.2	-87.0	-97.8	-94.2	-88.7	-84.0	-79.6	-68.8	-65.7
5. Waste	29.6	29.5	30.7	30.3	32.8	33.0	33.2	33.6	33.2	32.6	32.4	30.7	29.6	29.3	28.5	27.7	26.5	26.1	26.7	23.7
Indirect CO <sub>2</sub>	5.5	5.4	5.1	4.9	4.9	4.8	4.8	4.6	4.2	4.2	4.3	3.9	3.6	3.4	3.4	3.3	3.2	3.0	2.8	2.5
Gross Total (excluding LULUCF, excluding indirect CO <sub>2</sub> )	1,269.9	1,284.4	1,296.2	1,292.0	1,333.2	1,374.7	1,387.8	1,379.9	1,331.4	1,354.8	1,374.6	1,349.0	1,372.8	1,379.6	1,371.0	1,378.7	1,357.5	1,392.8	1,320.0	1,247.9
Net Total (including LULUCF, excluding indirect CO <sub>2</sub> )	1,204.6	1,211.0	1,219.4	1,211.9	1,273.4	1,295.5	1,304.4	1,295.5	1,246.9	1,271.2	1,289.9	1,263.7	1,285.8	1,281.8	1,276.8	1,290.0	1,273.4	1,313.1	1,251.2	1,182.2
Gross Total (excluding LULUCF, including indirect CO <sub>2</sub> )	1,275.4	1,289.7	1,301.3	1,296.9	1,358.1	1,379.5	1,392.6	1,384.5	1,335.7	1,359.1	1,378.9	1,352.8	1,376.4	1,383.0	1,374.4	1,382.0	1,360.7	1,395.8	1,322.7	1,250.4
Net Total (including LULUCF, including indirect CO <sub>2</sub> )	1,210.1	1,216.4	1,224.5	1,216.8	1,278.3	1,300.3	1,309.2	1,300.1	1,251.2	1,275.4	1,294.3	1,267.6	1,289.4	1,285.3	1,280.2	1,293.3	1,276.6	1,316.2	1,253.9	1,184.7

[Million tonnes CO <sub>2</sub> eq.]	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
1. Energy <sup>*1</sup>	1,163.1	1,213.8	1,254.1	1,261.7	1,211.5	1,172.3	1,153.5	1,137.9	1,092.5	1,056.3	994.4
2. Industrial processes and product use <sup>*1</sup>	81.0	82.9	85.4	89.8	92.3	93.5	96.5	99.2	100.2	101.5	101.4
3. Agriculture	33.7	33.0	32.6	32.8	32.4	32.2	32.2	32.3	32.1	32.1	32.2
4. LULUCF <sup>*2</sup>	-69.9	-68.0	-70.1	-63.0	-60.9	-56.4	-52.3	-56.3	-55.7	-51.0	-52.0
5. Waste	23.5	22.5	22.8	22.5	21.7	21.5	20.5	20.0	20.7	20.3	20.2
Indirect CO <sub>2</sub>	2.5	2.4	2.3	2.3	2.2	2.2	2.2	2.1	2.1	2.1	2.0
Gross Total (excluding LULUCF, excluding indirect CO <sub>2</sub> )	1,301.4	1,352.2	1,395.0	1,406.8	1,337.9	1,319.4	1,302.7	1,289.4	1,245.5	1,210.2	1,148.1
Net Total (including LULUCF, excluding indirect CO <sub>2</sub> )	1,231.5	1,284.2	1,324.8	1,343.9	1,297.0	1,263.0	1,250.4	1,233.1	1,189.9	1,159.2	1,096.1
Gross Total (excluding LULUCF, including indirect CO <sub>2</sub> )	1,303.9	1,354.6	1,397.3	1,409.1	1,360.2	1,321.6	1,304.9	1,291.6	1,247.7	1,212.2	1,150.1
Net Total (including LULUCF, including indirect CO <sub>2</sub> )	1,234.0	1,286.5	1,327.1	1,346.2	1,299.2	1,265.2	1,252.6	1,235.2	1,192.0	1,161.3	1,098.1

\*1 Excluding indirect CO<sub>2</sub>

\*2 LULUCF: Land Use, Land-Use Change and Forestry

### 2.2.1. Energy

Emissions from the energy sector in FY2020 were 994 million tonnes (in CO<sub>2</sub> equivalents). They decreased by 8.9% since FY1990 and decreased by 5.9% compared to the previous year.

The breakdown of the FY2020 emissions showed that CO<sub>2</sub> from fuel combustion accounted for 99.2%. The largest source within fuel combustion<sup>10</sup> was solid fuel CO<sub>2</sub>, which accounted for 40%, and is then followed by liquid fuel CO<sub>2</sub> (36%) and gaseous fuel CO<sub>2</sub> (22%).

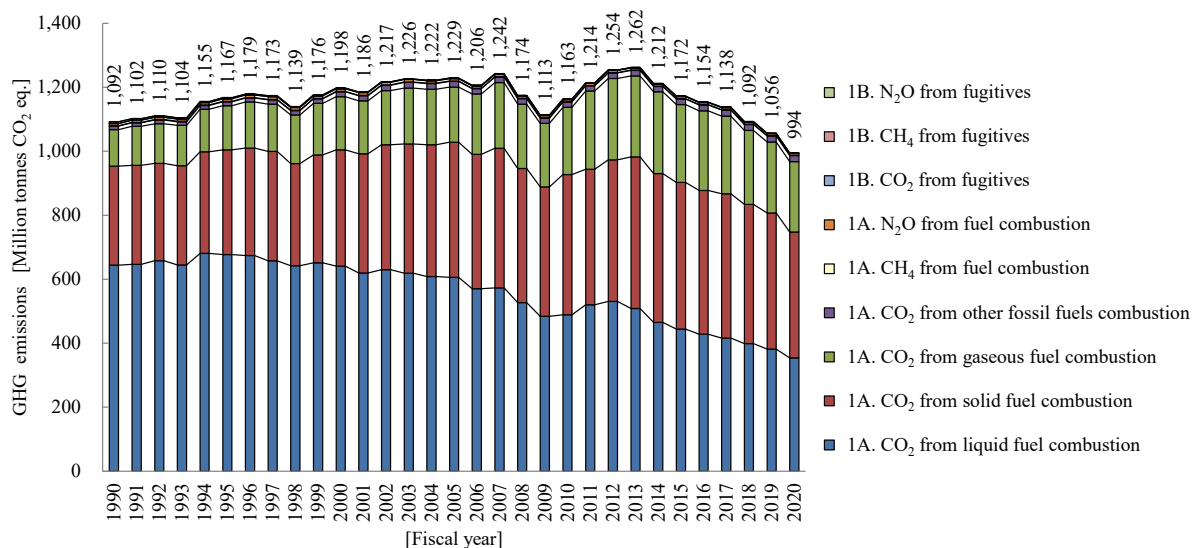


Figure 2-14 Trends in GHG emissions from the energy sector

Table 2-11 Trends in GHG emissions from the energy sector

[Thousand tonnes CO <sub>2</sub> eq.]	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
<b>1A. Fuel combustion</b>	1,086,590	1,164,144	1,195,386	1,227,294	1,161,731	1,212,392	1,252,775	1,260,395	1,210,221	1,171,059	1,152,248	1,136,605	1,091,305	1,055,194	993,324
Liquid fuel CO <sub>2</sub>	644,302	677,416	640,667	606,113	488,924	520,349	530,754	508,466	464,737	444,007	428,227	415,731	398,778	381,650	354,246
Solid fuel CO <sub>2</sub>	309,482	327,201	364,079	422,447	438,513	423,245	442,778	473,817	465,630	458,776	449,606	451,606	435,175	425,704	393,154
Gaseous fuel CO <sub>2</sub>	114,167	137,927	166,073	172,415	209,932	244,686	254,051	253,378	255,508	243,368	248,829	242,817	231,347	221,418	220,220
Other fossil fuels (Waste) CO <sub>2</sub>	10,712	12,294	14,966	17,341	16,430	16,452	17,537	17,100	16,826	17,308	18,060	18,645	18,494	19,377	18,995
CH <sub>4</sub>	1,349	1,381	1,273	1,433	1,437	1,147	1,165	1,111	1,097	1,145	1,234	1,300	1,263	1,243	1,252
N <sub>2</sub> O	6,578	7,925	8,329	7,545	6,496	6,513	6,490	6,525	6,423	6,455	6,293	6,506	6,249	5,801	5,457
<b>1B. Fugitive emissions from fuel</b>	5,301	3,296	2,436	1,535	1,396	1,378	1,373	1,287	1,288	1,241	1,282	1,271	1,188	1,095	1,037
CO <sub>2</sub>	192	522	512	508	475	478	490	439	449	425	457	436	423	369	345
CH <sub>4</sub>	5,107	2,773	1,922	1,026	920	900	882	848	838	816	824	834	764	726	692
N <sub>2</sub> O	2.1	2.1	1.7	1.2	0.9	0.8	0.8	0.8	0.7	0.7	0.6	0.6	0.6	0.6	0.6
<b>1C. CO<sub>2</sub> transport and storage</b>	NE/NO	NE/NO	NE/NO	NE/NO	NE/NO	NE/NO	NE/NO	NE/NO	NE/NO	NE/NO	NE/NO	NE/NO	NE/NO	NE/NO	NE/NO
<b>Total</b>	1,091,892	1,167,441	1,197,822	1,228,829	1,163,127	1,213,770	1,254,148	1,261,683	1,211,509	1,172,300	1,153,530	1,137,876	1,092,493	1,056,289	994,360

### 2.2.2. Industrial Processes and Product Use

Emissions from the industrial processes and product use sector in FY2020 were 101.4 million tonnes (in CO<sub>2</sub> eq.). They decreased by 8.6% since FY1990 and decreased by 0.1% compared to the previous year.

The breakdown of GHG emissions from this sector in FY2020 showed that the largest source was HFC emissions from product uses as ODS substitutes, accounting for 51%. It was followed by the mineral industry emissions such as CO<sub>2</sub> emissions from cement production (31%) and CO<sub>2</sub> emissions from the metal industry (5%).

<sup>10</sup> Fuel types are categorized in accordance with classification indicated in the 2006 IPCC Guidelines and the CRF.

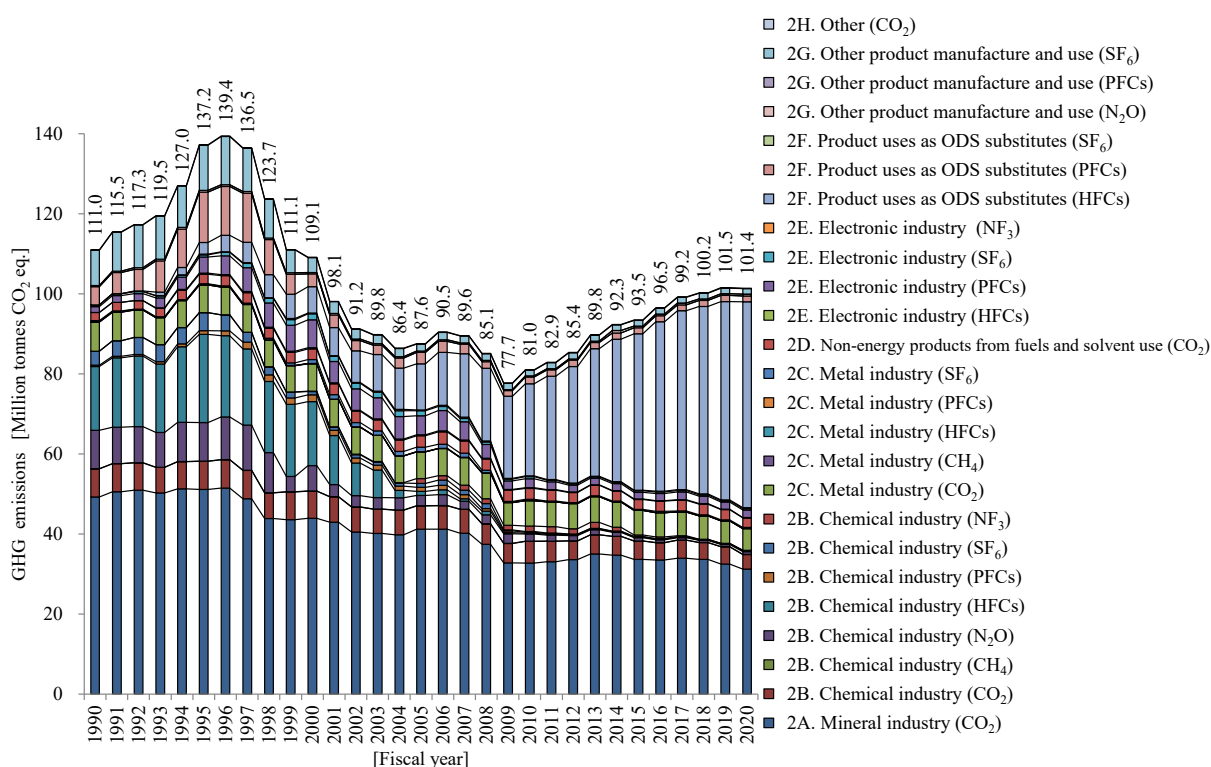


Figure 2-15 Trends in GHG emissions from the industrial processes and product use sector

Table 2-12 Trends in GHG emissions from the industrial processes and product use sector

Category	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
2A. Mineral industry (CO <sub>2</sub> )	49,230	51,146	43,919	41,230	32,752	33,089	33,629	35,004	34,731	33,659	33,534	33,971	33,645	32,481	31,217
2B. Chemical industry	36,433	44,158	31,780	28,633	22,188	22,753	22,796	22,911	22,945	22,754	22,574	22,599	22,504	21,179	20,715
CO <sub>2</sub>	7,041	7,014	6,810	5,795	5,427	5,103	4,652	4,787	4,683	4,591	4,300	4,485	4,220	4,348	3,671
CH <sub>4</sub>	37	37	34	34	36	36	28	28	25	32	27	25	23	25	24
N <sub>2</sub> O	9,620	9,665	6,348	2,558	1,813	1,507	1,293	1,259	979	798	676	599	506	551	663
HFCs	15,930	22,019	15,984	1,035	181	168	138	147	124	113	172	133	100	132	216
PFCs	331	914	1,661	1,041	248	206	148	111	107	115	97	81	87	64	74
SF <sub>6</sub>	3,471	4,492	821	930	189	132	123	93	62	52	50	41	46	40	52
NF <sub>3</sub>	3	17	120	1,240	1,323	1,601	1,314	1,486	965	404	432	234	58	19	15
2C. Metal industry	7,643	7,212	7,886	7,830	6,680	6,402	6,499	6,615	6,548	6,386	6,361	6,184	6,126	5,900	5,742
CO <sub>2</sub>	7,269	6,906	6,842	6,670	6,344	6,176	6,276	6,421	6,343	6,141	6,029	5,919	5,833	5,632	5,430
CH <sub>4</sub>	23	21	20	20	18	18	18	18	18	17	16	17	18	16	14
HFCs	NO	NO	NO	NO	NO	1	1	1	1	1	1	1	2	1	1
PFCs	204	171	44	36	25	25	22	16	3	NO	NO	NO	NO	NO	NO
SF <sub>6</sub>	147	114	980	1,104	294	182	182	160	182	228	315	246	274	251	296
2D. Non-energy products from fuels and solvent use (CO <sub>2</sub> )	2,040	2,377	2,659	2,865	2,748	2,701	2,551	2,685	2,527	2,486	2,583	2,689	2,658	2,561	2,344
2E. Electronic industry	1,904	5,016	8,941	6,457	3,140	2,661	2,370	2,225	2,346	2,326	2,463	2,634	2,544	2,416	2,595
HFCs	1	271	285	227	168	145	124	112	115	115	119	125	115	101	109
PFCs	1,455	4,020	6,986	4,746	2,261	1,922	1,692	1,631	1,707	1,669	1,792	1,931	1,856	1,752	1,888
SF <sub>6</sub>	419	542	1,506	1,252	494	394	356	351	366	375	349	363	349	321	324
NF <sub>3</sub>	30	184	165	232	217	199	198	131	158	167	203	216	225	242	274
2F. Product uses as ODS substitutes	4,551	15,495	9,782	14,336	24,698	27,410	30,696	33,378	37,097	40,569	43,814	46,178	48,332	51,056	52,855
HFCs	1	2,923	6,582	11,521	22,977	25,805	29,113	31,860	35,560	39,052	42,349	44,694	46,827	49,498	51,398
PFCs	4,550	12,572	3,200	2,815	1,721	1,605	1,583	1,518	1,537	1,517	1,465	1,484	1,505	1,558	1,457
SF <sub>6</sub>	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2G. Other product manufacture and use	9,105	11,749	4,096	2,109	1,701	1,789	1,854	1,841	2,065	1,829	1,894	1,861	1,796	1,828	1,836
N <sub>2</sub> O	291	449	371	368	275	270	308	359	627	402	429	420	370	390	424
PFCs	NO	NO	NO	0.3	4	6	NO	10	9	8	21	20	39	49	56
SF <sub>6</sub>	8,814	11,300	3,724	1,741	1,422	1,513	1,546	1,472	1,429	1,419	1,445	1,421	1,387	1,389	1,356
2H. Other (CO <sub>2</sub> )	65	72	87	90	77	88	100	94	91	97	107	111	105	100	87
Total	110,971	137,225	109,148	87,550	81,014	82,894	85,395	89,753	92,349	93,456	96,510	99,228	100,246	101,521	101,390

Despite the increase in HFC emissions from product uses as substitutes for ODS compared to FY1990, emissions from the industrial processes and product use sector decreased in the same period. The main driving factors for the decrease in emissions since FY1990 were the decrease in emissions of HFC-23 produced as a by-product of HCFC-22 production (chemical industry) due to regulation under the Act on the Protection of the Ozone Layer Through the Control of Specified Substances and Other Measures,

the decrease in CO<sub>2</sub> emissions from cement production (mineral industry) as the clinker production declined, and the decrease in N<sub>2</sub>O emissions from adipic acid production (chemical industry) as the N<sub>2</sub>O abatement equipment came on stream.

### 2.2.3. Agriculture

Emissions from the agriculture sector in FY2020 were 32.2 million tonnes (in CO<sub>2</sub> eq.). They decreased by 14.1% since FY1990 and increased by 0.3% compared to the previous year.

The breakdown of the FY2020 emissions from this sector showed that the largest source was the rice cultivation (CH<sub>4</sub>) accounting for 37%. It was followed by enteric fermentation (CH<sub>4</sub>) (24%), and agricultural soils (N<sub>2</sub>O) (18%) as a result of the nitrogen-based fertilizer applications.

The main driving factor for the decrease in emissions since FY1990 was the decrease in N<sub>2</sub>O emissions from agricultural soils due to the decrease in the amount of inorganic nitrogen fertilizers applied and organic fertilizers from livestock manure applied, and the decrease in CH<sub>4</sub> emissions from enteric fermentation due to the decrease in the number of cattle.

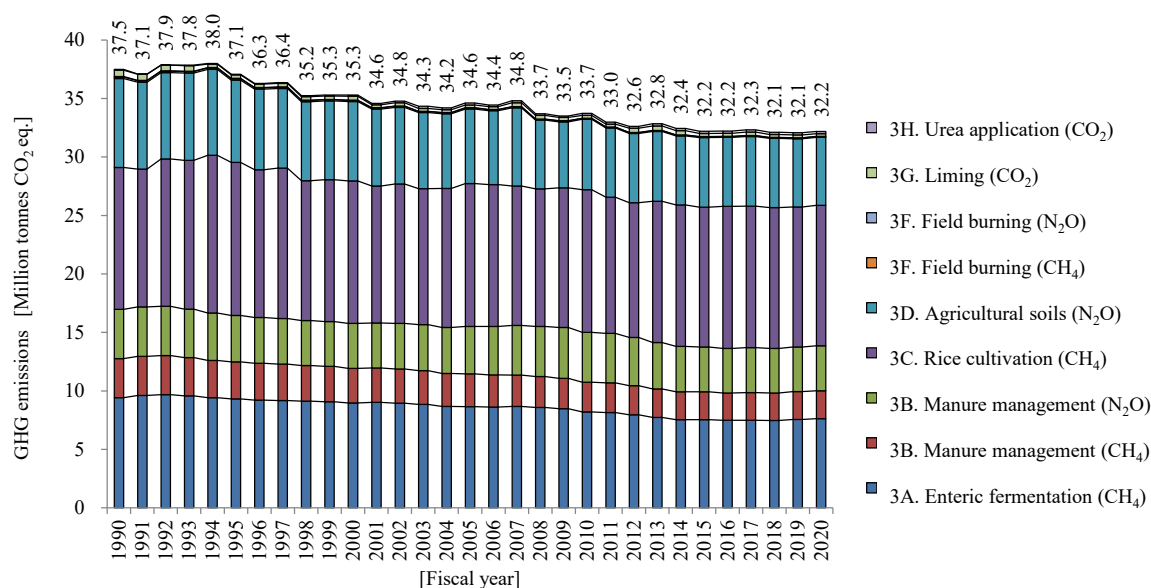


Figure 2-16 Trends in GHG emissions from the agriculture sector

Table 2-13 Trends in GHG emissions from the agriculture sector

[Thousand tonnes CO<sub>2</sub> eq.]

Category	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
3A. Enteric fermentation (CH <sub>4</sub> )	9,423	9,318	8,966	8,651	8,202	8,154	7,953	7,737	7,543	7,534	7,481	7,494	7,465	7,563	7,633
3B. Manure management	7,544	7,130	6,811	6,858	6,810	6,767	6,624	6,398	6,254	6,215	6,150	6,208	6,163	6,195	6,230
CH <sub>4</sub>	3,329	3,164	2,961	2,801	2,537	2,532	2,490	2,428	2,385	2,382	2,343	2,355	2,356	2,375	2,387
N <sub>2</sub> O	4,214	3,965	3,849	4,056	4,273	4,235	4,133	3,970	3,869	3,833	3,806	3,853	3,807	3,820	3,843
3C. Rice cultivation (CH <sub>4</sub> )	12,129	13,092	12,175	12,216	12,186	11,635	11,511	12,078	12,101	11,961	12,149	12,093	12,039	11,970	12,004
3D. Agricultural soils (N <sub>2</sub> O)	7,608	7,032	6,779	6,371	6,021	5,913	5,911	5,961	5,891	5,941	5,896	5,950	5,916	5,827	5,809
3F. Field burning of agricultural residues	166	145	126	112	96	95	93	94	92	88	88	84	85	84	84
CH <sub>4</sub>	127	111	96	86	74	73	71	72	70	67	67	64	65	64	64
N <sub>2</sub> O	39	34	30	26	23	22	22	22	22	21	21	20	20	20	20
3G. Liming (CO <sub>2</sub> )	550	304	333	231	243	247	370	380	363	259	253	294	242	242	233
3H. Urea application (CO <sub>2</sub> )	59	56	110	179	160	168	150	198	189	201	193	193	193	193	193
Total	37,479	37,076	35,300	34,618	33,719	32,980	32,612	32,847	32,433	32,198	32,209	32,316	32,103	32,075	32,186



### 2.2.4. Land Use, Land Use Change and Forestry (LULUCF)

Net removals (including CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emissions) from the LULUCF sector in FY2020 was 52.0 million tonnes (in CO<sub>2</sub> eq.). They decreased by 20.4% since FY1990 and increased by 2.1% compared to the previous year. The long-term declining trend in removals from 2003 is largely due to the maturity of Japanese forests.

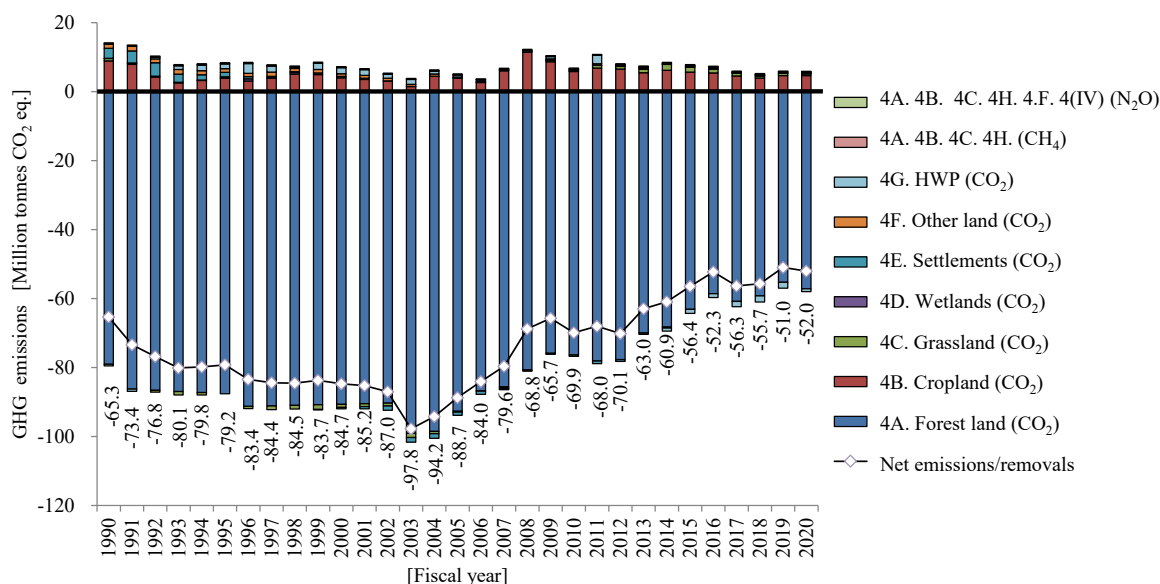


Figure 2-17 Trends in GHG emissions and removals from the LULUCF sector

Table 2-14 Trends in GHG emissions and removals from the LULUCF sector

[Thousand tonnes CO <sub>2</sub> eq.]		1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Category																
4A. Forest land		-78,931	-87,475	-90,506	-92,503	-76,218	-77,957	-77,530	-69,841	-68,110	-62,957	-58,417	-60,682	-59,106	-55,107	-57,005
CO <sub>2</sub>		-79,061	-87,606	-90,637	-92,636	-76,345	-78,085	-77,653	-69,968	-68,258	-63,088	-58,545	-60,835	-59,238	-55,243	-57,139
CH <sub>4</sub>		10	10	9	11	5	6	2	4	23	6	1	23	2	5	3
N <sub>2</sub> O		121	121	121	122	122	122	121	122.7	125.4	125.1	126.6	129.6	129.7	131.6	131.9
4B. Cropland		9,037	3,993	4,090	4,002	5,927	6,925	6,619	5,538	6,258	5,759	5,506	4,610	4,018	4,709	4,706
CO <sub>2</sub>		8,958	3,924	4,028	3,947	5,876	6,875	6,569	5,488	6,208	5,710	5,457	4,561	3,969	4,660	4,657
CH <sub>4</sub>		49	47	45	44	42	42	41	41	41	40	40	39	39	39	39
N <sub>2</sub> O		30	23	17	12	9	8	8	9	9	9	9	9	10	10	10
4C. Grassland		689	91	-866	-254	209	807	828	1,127	1,739	1,403	1,108	861	622	717	581
CO <sub>2</sub>		659	61	-896	-284	179	776	796	1,096	1,707	1,372	1,078	831	592	687	551
CH <sub>4</sub>		15	15	15	15	15	15	15	15	15	16	15	15	15	15	15
N <sub>2</sub> O		15	15	15	15	15	16	17	16	16	16	15	15	15	15	15
4D. Wetlands		91	359	426	47	112	62	71	24	24	75	75	31	31	27	27
CO <sub>2</sub>		91	359	426	47	112	62	71	24	24	75	75	31	31	27	27
CH <sub>4</sub>		NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO
N <sub>2</sub> O		IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO
4E. Settlements		2,873	1,293	-426	-936	-382	-771	-532	-423	-266	152	240	33	132	106	178
CO <sub>2</sub>		2,873	1,293	-426	-936	-382	-771	-532	-423	-266	152	240	33	132	106	178
CH <sub>4</sub>		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
N <sub>2</sub> O		IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO
4F. Other land		1,288	1,060	770	267	306	424	328	260	266	281	291	247	300	257	254
CO <sub>2</sub>		1,265	1,040	754	253	295	412	316	248	255	271	281	237	289	247	243
CH <sub>4</sub>		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
N <sub>2</sub> O		23	20	17	14	11	13	12	11	11	11	10	10	10	10	10
4G. HWP (CO <sub>2</sub> )		-450	1,401	1,765	617	101	2,443	53	304	-898	-1,210	-1,133	-1,490	-1,740	-1,720	-807
4H. Other (Organic soil in settlements)		35	27	23	20	18	17	16	16	15	15	15	15	14	14	14
CH <sub>4</sub>		32	25	21	19	17	16	15	14	14	14	14	13	13	13	13
N <sub>2</sub> O		3	2	2	2	2	2	1	1	1	1	1	1	1	1	1
4(IV) Indirect N <sub>2</sub> O		53	47	42	40	38	38	39	39	39	39	40	40	41	42	42
Total		-65,317	-79,204	-84,682	-88,699	-69,887	-68,011	-70,108	-62,957	-60,934	-56,442	-52,276	-56,336	-55,689	-50,955	-52,010

The breakdown of the FY2020 emissions and removals from this sector showed that the largest was CO<sub>2</sub> removals of 57.1 million tonnes, accounting for 110% of this sector's net total emissions / removals.

### 2.2.5. Waste

Emissions from the waste sector in FY2020 were 20.2 million tonnes (in CO<sub>2</sub> eq.). They decreased by 31.7% since FY1990 and by 0.4% compared to the previous year.

The breakdown of the FY2020 emissions from this sector showed that the largest source was waste incineration, etc (CO<sub>2</sub>), associated with waste derived from fossil fuels such as waste plastic and waste oil, accounting for 57%. It was followed by solid waste disposal (CH<sub>4</sub>) (13%) and wastewater treatment and discharge (N<sub>2</sub>O) (10%).

The main driving factor for the decrease in emissions since FY1990 was the decrease in CH<sub>4</sub> emissions from solid waste disposal on land as a result of decrease in the amount of disposal of biodegradable waste due to improvement in the volume reduction ratio by intermediate treatment under the Waste Management and Public Cleansing Act (Act No.137, 1970) and the Basic Law for Establishing the Recycling-based Society (Act No.110, 2000), and other recycling law.

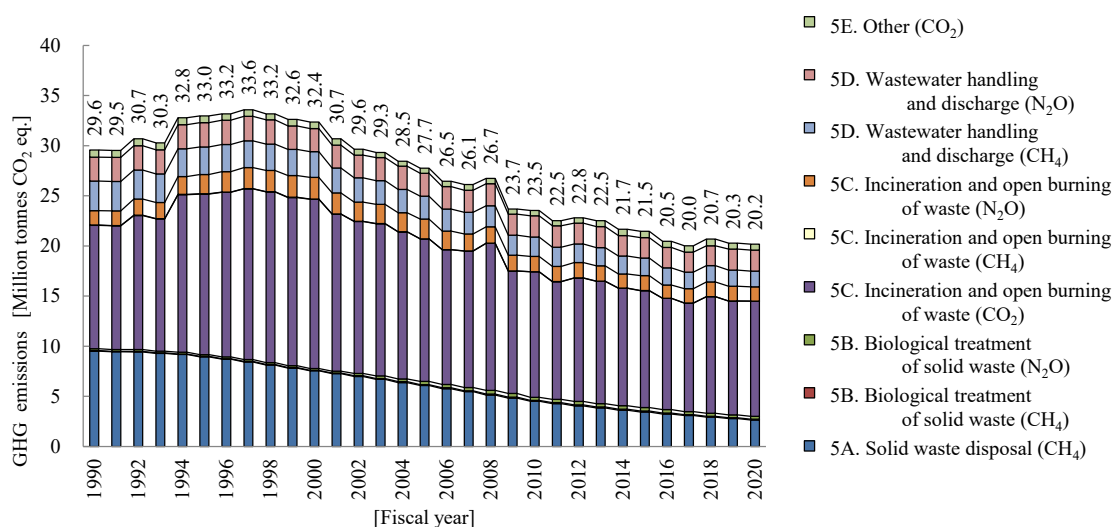


Figure 2-18 Trends in GHG emissions from the waste sector

Table 2-15 Trends in GHG emissions from the waste sector

Category	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
5A. Solid waste disposal (CH <sub>4</sub> )	9,510	8,938	7,548	6,080	4,515	4,267	4,054	3,851	3,631	3,441	3,244	3,090	2,934	2,792	2,654
5B. Biological treatment of solid waste	235	233	235	414	402	444	440	435	433	441	446	388	385	356	354
CH <sub>4</sub>	54	53	54	95	93	102	101	100	100	102	103	90	89	82	82
N <sub>2</sub> O	181	179	181	319	309	342	338	335	333	340	343	298	296	274	272
5C. Incineration and open burning of waste	13,783	17,946	19,060	16,189	14,033	13,258	13,851	13,745	13,153	13,172	12,414	12,258	13,090	12,840	12,909
CO <sub>2</sub>	12,318	16,009	16,884	14,208	12,507	11,729	12,317	12,198	11,719	11,664	11,093	10,825	11,626	11,358	11,491
CH <sub>4</sub>	28	29	21	18	12	11	11	12	10	10	9	10	11	10	10
N <sub>2</sub> O	1,438	1,908	2,156	1,963	1,515	1,518	1,523	1,535	1,423	1,498	1,312	1,423	1,453	1,473	1,408
5D. Wastewater treatment and discharge	5,329	5,189	4,857	4,560	4,069	4,037	3,925	3,893	3,825	3,777	3,742	3,640	3,618	3,703	3,668
CH <sub>4</sub>	2,942	2,750	2,556	2,280	1,954	1,908	1,855	1,811	1,779	1,749	1,714	1,648	1,629	1,607	1,578
N <sub>2</sub> O	2,387	2,439	2,301	2,280	2,115	2,129	2,069	2,082	2,045	2,027	2,028	1,992	1,990	2,096	2,091
5E. Other (CO <sub>2</sub> )	703	668	656	507	527	524	528	605	617	625	619	637	673	582	601
Total	29,559	32,973	32,357	27,750	23,546	22,530	22,798	22,529	21,658	21,456	20,465	20,014	20,700	20,275	20,186

### 2.2.6. Indirect CO<sub>2</sub>

See Section 2.1.9. above.

### 2.3. Description and Interpretation of Emission Trends for Indirect GHGs and SO<sub>x</sub>

Under the revised UNFCCC reporting guidelines on annual inventories for Parties included in Annex I to the Convention, it is required to report emissions not only of the 7 types of GHGs (CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O, HFCs, PFCs, SF<sub>6</sub>, and NF<sub>3</sub>), but also emissions of indirect GHGs (NO<sub>x</sub>, CO, and NMVOC) as well as SO<sub>x</sub>. Their emission trends are indicated below.

Nitrogen oxide (NO<sub>x</sub>) emissions in FY2020 were 1.1 million tonnes. They decreased by 41.9% since FY1990 and 5.7% compared to the previous year.

Carbon monoxide (CO) emissions in FY2020 were 2.8 million tonnes. They decreased by 35.6% since FY1990 and 11.7% compared to the previous year<sup>11</sup>.

Non-methane volatile organic compounds (NMVOC) emissions in FY2020 were 0.8 million tonnes. They decreased by 61.7% since FY1990 and 5.2% compared to the previous year.

Sulfur oxide (SO<sub>x</sub>)<sup>12</sup> emissions in FY2020 were 0.6 million tonnes. They decreased by 54.4% since FY1990 and 1.4% compared to the previous year.

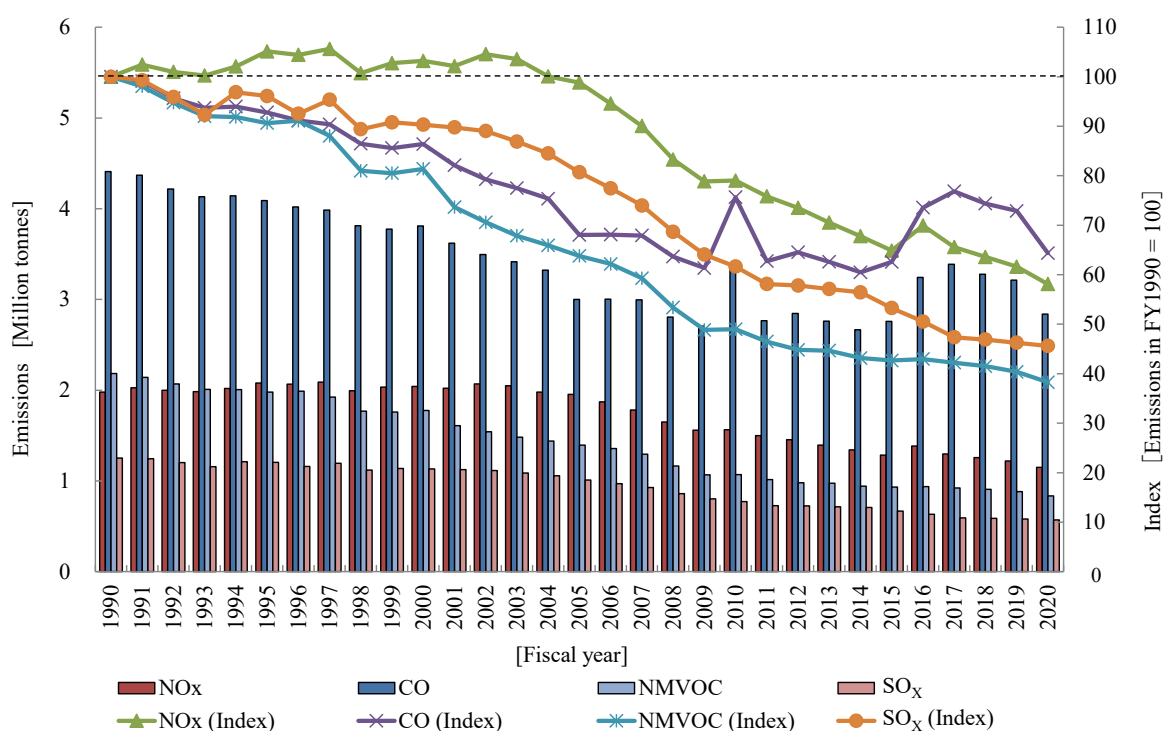


Figure 2-19 Trends in emissions of indirect GHGs and SO<sub>x</sub>

Note: The line chart shows the trend as an index of FY1990 emissions set at 100.

<sup>11</sup> The reason for the increase in CO emissions in FY2010 compared to the previous year was the change in the EF for road transportation, and the reason for the decrease in CO emissions in FY2011 compared to the previous year was the change in the share of furnace types in the iron and steel industry.

<sup>12</sup> Most SO<sub>x</sub> consists of SO<sub>2</sub>. For major sources, SO<sub>2</sub> emissions are estimated.

## 2.4. Emissions and removals from KP-LULUCF activities

The sum of emissions and removals from Kyoto Protocol Article 3.3 and 3.4 activities in FY2020 were -34.5 million tonnes (in CO<sub>2</sub> eq.). The sum of the accounting quantity (after applying the accounting rules) for the second commitment period of the Kyoto Protocol was calculated to be -376.1 million tonnes (in CO<sub>2</sub> eq.). The breakdown of emissions and removals by each activity is shown below. For detailed information, see Chapter 11.

Table 2-16 Accounting summary for activities under articles 3.3 and 3.4 of the Kyoto Protocol

GREENHOUSE GAS SOURCE AND SINK ACTIVITIES	Base Year (1990)	EMISSIONS/REMOVALS									Accounting parameters	Accounting quantity
		2013	2014	2015	2016	2017	2018	2019	2020	Total		
(kt CO <sub>2</sub> eq)												
<b>A. Article 3.3 activities</b>												
<b>A.1. Afforestation/reforestation</b>		-1,478	-1,483	-1,486	-1,488	-1,465	-1,375	-1,316	-1,245	-11,336		-11,336
Excluded emissions from natural disturbances		NA	NA	NA	NA	NA	NA	NA	NA	NA		NA
Excluded subsequent removals from land subject to natural disturbances		NA	NA	NA	NA	NA	NA	NA	NA	NA		NA
<b>A.2. Deforestation</b>		2,005	2,007	2,317	2,316	1,827	1,819	1,683	1,696	15,669		15,669
<b>B. Article 3.4 activities</b>												
<b>B.1. Forest management</b>												
Net emissions/removals		-51,174	-51,512	-49,255	-46,642	-46,353	-45,229	-41,259	-38,939	-370,363		-382,808
Excluded emissions from natural disturbances		NA	NA	NA	NA	NA	NA	NA	NA	NA		NA
Excluded subsequent removals from land subject to natural disturbances		NA	NA	NA	NA	NA	NA	NA	NA	NA		NA
Any debits from newly established forest (CEF-me)		NA	NA	NA	NA	NA	NA	NA	NA	NA		NA
Forest management reference level (FMRL)		0	0	0	0	0	0	0	0	0		0
Technical corrections to FMRL		1,044	1,220	1,366	1,499	1,635	1,762	1,899	2,019	12,446		1,556
Forest management cap												355,669
<b>B.2. Cropland management</b>	7,561	5,490	6,230	5,749	5,525	4,712	4,130	4,747	4,759	41,341		-19,147
<b>B.3. Grazing land management</b>	443	966	1,582	1,291	1,008	855	622	751	617	7,692		4,151
<b>B.4. Revegetation</b>	-80	-1,230	-1,249	-1,270	-1,287	-1,310	-1,325	-1,350	-1,360	-10,381		-9,743
<b>B.5. Wetland drainage and rewetting (not elected)</b>		NA	NA	NA	NA	NA	NA	NA	NA	NA		NA
Sum of emissions and removals from Article 3.3 and 3.4 activities for each year		-45,421	-44,425	-42,654	-40,570	-41,734	-41,357	-36,745	-34,472			
Sum of the accounting quantity for Article 3.3 and 3.4 activities of the Kyoto Protocol for the second commitment period												-376,075

Note: The total values and results of summing up each figure are not always the same because of the difference in display digit.

## References

1. Cabinet Office, Government of Japan, *Annual Report on National Accounts*.
2. IPCC, *Fourth Assessment Report*, 2007.
3. Ministry of Internal Affairs and Communications, Statistics Bureau, *Annual Report of Population Estimates*.
4. Ministry of Internal Affairs and Communications, Statistics Bureau, *Population Census*.

## Chapter 3. Energy (CRF sector 1)

### 3.1. Overview of Sector

The energy sector consist of two main categories: fuel combustion and fugitive emissions from fuels. Fuel combustion includes emissions released into the atmosphere when fossil fuels (e.g., coal, oil products, and natural gas) are combusted. Fugitive emissions are intentional or unintentional releases of gases from fossil fuels by anthropogenic activities.

In Japan, fossil fuels are used to produce energy for a wide variety of purposes (e.g., production, transportation, and consumption of energy products) and CO<sub>2</sub> (Carbon Dioxide), CH<sub>4</sub> (Methane), N<sub>2</sub>O (Nitrous Oxide), NO<sub>x</sub> (Nitrogen Oxide), CO (Carbon Monoxide), and NMVOC (Non-Methane Volatile Organic Compounds) are emitted in the process.

In FY2020, GHG emissions (CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O) from the energy sector accounted for 994,360 kt-CO<sub>2</sub> eq., and represented 86.5% of Japan's total GHG emissions (excluding LULUCF). The emissions from the energy sector had decreased by 8.9% compared to FY1990.

The methodologies are shown in the below table.

Table 3-1 Methodologies used in the energy sector

GREENHOUSE GAS SOURCE CATEGORIES	CO <sub>2</sub>		CH <sub>4</sub>		N <sub>2</sub> O	
	Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor
1.A. Fuel combustion	CS,T2	CS	CS,T1,T2,T3	CR,CS,D	CS,T1,T2,T3	CR,CS,D
1. Energy industries	CS,T2	CS	CS,T3	CS	CS,T3	CS
2. Manufacturing industries and construction	CS,T2	CS	CS,T1,T3	CR,CS,D	CS,T1,T3	CR,CS,D
3. Transport	T2	CS	T1,T2,T3	CS,D	T1,T2,T3	CS,D
4. Other sectors	CS,T2	CS	CS,T1,T3	CR,CS,D	CS,T1,T3	CR,CS,D
5. Other						
1.B. Fugitive emissions from fuels	CS,T1	CS,D	CS,T1,T2,T3	CS,D	T1	D
1. Solid fuels	CS	CS	T1,T2,T3	CS,D	T1	D
2. Oil and natural gas	CS,T1	CS,D	CS,T1	CS,D	T1	D
1.C. CO <sub>2</sub> transport and storage						

Note:

D: IPCC default, T1: IPCC Tier1, T2: IPCC Tier2, T3: IPCC Tier3, CS: country specific method or EF, CR: CORINAIR

### 3.2. Fuel Combustion (1.A.)

This category covers GHG emissions from combustion of fossil fuels such as coal, oil, and natural gas, and incineration of waste for energy purposes and with energy recovery.<sup>1</sup>

This section includes GHG emissions from five sources: energy industries (1.A.1): emissions from power generation and heat supply; manufacturing industries and construction (1.A.2): emissions from manufacturing industry and construction; transport (1.A.3): emissions from transport of passenger and freight; other sectors (1.A.4): emissions from commercial/institutional, residential, and agriculture/forestry/fishing sources; and other (1.A.5): emissions from other sources.

<sup>1</sup> The emissions from waste incineration had been reported in the waste sector in the 2008 submission, regardless of their use as energy or energy recovery. However, to comply with ERT recommendations and the requirements of the IPCC Guidelines, the emissions are reported in the energy sector since the 2009 submission.



factor for the decrease is the CO<sub>2</sub> emissions from manufacturing industries and construction (1.A.2).

By looking at the changes in CO<sub>2</sub> emissions by subcategory, emissions from the energy industries (1.A.1) increased by 18.4% since FY1990 and decreased by 2.8% compared to the previous year. The main driving factor for the increase compared to the emissions in FY1990 is the increase in thermal power generation. From FY1990 to FY2007, the emissions increased with an increase in electricity demand. From FY2011 to FY2013, the emissions increased mainly due to an increase in the share of thermal power generation as a result of the suspension of operation of the nuclear power plants triggered by the Great East Japan Earthquake. Since then, the enhancement of introduction of renewable energy and the resumption of operation of the nuclear power plants are in progress.

The CO<sub>2</sub> emissions from manufacturing industries and construction (1.A.2) decreased by 33.2% since FY1990 and decreased by 10.1% compared to the previous year. The main driving factor for the decrease compared to the emissions in FY1990 is the decreased liquid fuel consumption. The emissions are considered to have a moderate correlation with the *Indices of Industrial Production (IIP)* (Ministry of Economy, Trade and Industry (METI)). In the middle of 2000s, the CO<sub>2</sub> emissions were stable while the IIP increased, that implies the improvement of energy efficiency. (Agency for Natural Resources and Energy, 2020)

The CO<sub>2</sub> emissions from transport (1.A.3) decreased by 12.1% compared to FY1990 and decreased by 10.5% compared to the previous year. The main driving factor for the decrease compared to the emissions in FY1990 is the decrease in emissions from freight transportation, compensating for the increase in emissions from passenger vehicles. Although the emissions from road transportation increased in 1990s due to an increase in distance traveled, the emissions have decreased in the 2000s mainly due to an improvement of fuel efficiency.

The CO<sub>2</sub> emissions from other sectors (1.A.4) decreased by 12.2% since FY1990 and decreased by 1.3% compared to the previous year. The main driving factor for the decrease compared to the emissions in FY1990 is the decreased liquid fuel consumption. The CO<sub>2</sub> emissions from commercial/institutional (1.A.4.a) are considered to have a moderate correlation with the *Indices of Tertiary Industry Activity (METI)* until 2005. The emissions have decreased since then due to the decrease in the demand of liquid fuels.

On the annual review in 2012 (FCCC/ARR/2012/JPN, paragraph 33), the Expert Review Team (ERT) recommended that Japan improve the transparency of the information on the drivers of emission trends in the energy sector. In response to the recommendation, the table below provides some indicators that might have relations to the emission trends. Please note that these indicators are not used for estimating the emissions. Also, please refer to Chapter 2 for the charts of emission trends.

Table 3-3 Trends in indicators that might have relations to the GHGs emissions from fuel combustion (1.A)

No.	Related subcategories	Indicators	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
1	1.A. Fuel combustion	Final electricity consumption	TWh	765	872	973	1,025	1,035	997	991	990	974	949	951	965	946	927	914
2	1.A.2. Manufacturing	Indices of Industrial Production	CY2015=100	109.1	103.3	107.7	109.3	101.2	100.5	97.8	101.1	100.5	99.8	100.6	103.5	103.8	99.9	90.4
3	1.A.3.b. Road transportation	Vehicle kilometers traveled (VKT)	billion VKT	585	673	728	727	708	712	723	724	718	721	730	740	748	745	666
4	1.A.4.a. Commercial/institutional	Indices of Tertiary Industry Activity	CY2015=100	83.8	90.8	95.2	100.7	97.6	98.3	99.6	100.8	99.2	100.3	100.5	101.9	103.0	102.3	95.2

Reference: 1: *General Energy Statistics* by Agency for Natural Resources and Energy (ANRE), 2: Ministry of Economy, Trade and Industry (METI), 3: *Statistical Yearbook of Motor Vehicle Fuel Consumption*, etc. by Ministry of Land, Infrastructure, Transport and Tourism (MLIT), 4: METI

### 3.2.1. Comparison of the Sectoral Approach with the Reference Approach

This chapter explains a comparison between reference approach and sectoral approach in accordance with the *UNFCCC Inventory Reporting Guidelines* (Decision 24/CP.19 Annex I, paragraph 40). For the methodological issues of the sectoral approach, please refer to section 3.2.4. b).

#### 3.2.1.1. Methodological Issues of the Reference Approach

The reference approach is to calculate the CO<sub>2</sub> emissions from combustion, using a country's energy supply data. The CO<sub>2</sub> emissions estimated by the reference approach are not included in the national total and used for verification purpose. The CO<sub>2</sub> emissions by the reference approach are estimated by the following formula:

$$E = \sum_i [(A_i - N_i) \times GCV_i \times 10^{-3} \times EF_i \times OF_i] \times 44/12$$

- E* : CO<sub>2</sub> emissions from fossil fuel combustion [t-CO<sub>2</sub>]  
*A* : Apparent energy consumption (original unit [t, kL, 10<sup>3</sup>×m<sup>3</sup>])  
*N* : Non-energy use of fossil fuels (original unit)  
*GCV* : Gross calorific value (higher heating value) [MJ/original unit]  
*EF* : Carbon content of the fuel [t-C/TJ]  
*OF* : Oxidation factor  
*i* : Type of fuel

The apparent energy consumptions *A* are estimated by the following formula:

Primary fuels:  $A = P + IM - EX \pm SC - IB$

Secondary fuels:  $A = IM - EX \pm SC - IB$

Table 3-4 Sources of each term of reference approach estimation equation

Symbol	Term	Source <sup>2</sup>
<i>P</i>	Production	<ul style="list-style-type: none"> <li>Indigenously Produced (#110000) in Agency for Natural Resources and Energy's <i>General Energy Statistics</i> (Japan's Energy Balance Table)</li> <li>(Waste only) Consumption of sectoral approach<sup>3</sup></li> </ul>
<i>IM</i>	Imports	Imported (#120000) in the statistics + International bunker fuels (see section 3.2.2. )
<i>EX</i>	Exports	Export (#160000) in the statistics
<i>SC</i>	Stock change	Stockpile Change / Supply (#170000) in the statistics
<i>IB</i>	International bunkers	See section 3.2.2.
<i>N</i>	Non-energy use	Non-energy and feedstock use (#950000) in the statistics (see section 3.2.3. )

The carbon contents of the fuels, the oxidation factors and the gross calorific values are in common with the sectoral approach (refer to section 3.2.4. b).

The details of estimation results by reference approach are shown in the Common Reporting Format (CRF) table 1.A(b). The correspondence between fuels of the *General Energy Statistics* and those of the table is shown in Annex 4.

#### ➤ *Discrepancies between the figures reported in the CRF tables and the IEA statistics*

Some discrepancies exist between the fuel data of energy supply and demand in the CRF tables and the

<sup>2</sup> Numbers with # indicate the corresponding sector (row) numbers in the *General Energy Statistics* (Japan's Energy Balance Table).

<sup>3</sup> In response to the recommendation on the annual review in 2018 (FCCC/ARR/2018/JPN, E.11)



data of energy supply and demand reported in the International Energy Agency (IEA) statistics. Please refer to the details of discrepancies and their reasons in Annex 4 (A4.1).

### 3.2.1.2. Difference in Energy Consumption

As shown in Table 3-5, fluctuations of difference<sup>4</sup> of energy consumption between the reference approach and the sectoral approach during FY1990-2020 range between -1.79% (FY2012) and +1.76% (FY2004).

Energy consumption from wastes used for energy and from the incineration of wastes with energy recovery is calculated in the sectoral approach in accordance with the *2006 IPCC Guidelines for National Greenhouse Gas Inventories*.

There is a large difference between those two approaches for solid fuels in FY2004 (+10.63%). It means that, in FY2004, because stocks of the coal on the consumer side (steel making coal [\$0110<sup>5</sup>]) increased, the large difference occurred between the reference approach estimated from the provider side and the sectoral approach estimated from the consumer side. In addition, there is a large difference between those two approaches for solid fuels in FY2008 (+6.82%). This is because stocks of the coal on the consumer side (imported steam coal [\$0121]) increased, like in FY2004. It should be noted that the stock changes explained here are not 'Stockpile change / supply' in 'Primary energy supply' sector, but 'Transformation and consumption stockpile change' in 'Energy transformation & own use' sector and 'Final energy consumption' sector.

### 3.2.1.3. Difference in CO<sub>2</sub> Emissions

As shown in Table 3-6, fluctuations of a difference of CO<sub>2</sub> emissions between the reference approach and the sectoral approach during FY1990-2020 range between -0.74% (FY1990) and +3.83% (FY2004).

Emissions from wastes used for energy and from the incineration of wastes with energy recovery are not reported in waste incineration (5.C.) but reported in fuel combustion (1.A.) in accordance with the *2006 IPCC Guidelines*.

The differences between both approaches for solid fuels were large values in FY2004 and FY2008 (+9.94%, +6.24%), and small values in FY2005 and FY2009 (+2.05%, -1.92%). It is because of the same reason as the difference of energy consumption which is described in the previous section.

<sup>4</sup> Difference = [(Reference approach)-(Sectoral approach)]/(Sectoral approach)

<sup>5</sup> Numbers with \$ indicate the corresponding energy source (column) numbers in the *General Energy Statistics* (Japan's Energy Balance Table).

Table 3-5 Comparison of energy consumption<sup>6</sup>

[PJ]	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
<b>Reference Approach</b>															
Liquid fuels	9,526	10,132	9,442	8,919	7,179	7,531	7,640	7,395	6,811	6,501	6,285	6,196	5,839	5,555	5,155
Solid fuels	3,285	3,603	4,180	4,763	4,979	4,653	4,864	5,284	5,079	5,137	5,022	5,024	4,927	4,830	4,401
Gaseous fuels	2,042	2,465	3,050	3,275	3,979	4,665	4,854	4,882	4,948	4,646	4,718	4,686	4,499	4,271	4,262
Other fossil fuels	281	318	373	457	452	451	473	462	468	464	496	507	494	510	506
Peat	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
<b>Total RA</b>	<b>15,135</b>	<b>16,518</b>	<b>17,045</b>	<b>17,415</b>	<b>16,589</b>	<b>17,300</b>	<b>17,831</b>	<b>18,024</b>	<b>17,306</b>	<b>16,747</b>	<b>16,521</b>	<b>16,412</b>	<b>15,759</b>	<b>15,165</b>	<b>14,324</b>
<b>Sectoral Approach</b>															
Liquid fuels	9,459	9,973	9,451	8,949	7,261	7,704	7,850	7,463	6,839	6,544	6,308	6,139	5,903	5,646	5,244
Solid fuels	3,368	3,598	3,986	4,638	4,819	4,660	4,878	5,223	5,124	5,049	4,956	4,981	4,826	4,723	4,374
Gaseous fuels	2,209	2,667	3,226	3,355	4,093	4,772	4,954	4,939	4,981	4,744	4,850	4,731	4,535	4,341	4,319
Other fossil fuels	281	318	373	457	452	451	473	462	468	464	496	507	494	510	506
Peat	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
<b>Total</b>	<b>15,318</b>	<b>16,556</b>	<b>17,035</b>	<b>17,399</b>	<b>16,626</b>	<b>17,588</b>	<b>18,155</b>	<b>18,088</b>	<b>17,412</b>	<b>16,802</b>	<b>16,610</b>	<b>16,358</b>	<b>15,757</b>	<b>15,220</b>	<b>14,444</b>
<b>Difference (%)</b>															
Liquid fuels	0.71%	1.60%	-0.09%	-0.33%	-1.13%	-2.25%	-2.68%	-0.91%	-0.40%	-0.66%	-0.37%	0.93%	-1.08%	-1.61%	-1.69%
Solid fuels	-2.46%	0.15%	4.87%	2.70%	3.32%	-0.17%	-0.29%	1.17%	-0.87%	1.73%	1.34%	0.86%	2.11%	2.25%	0.60%
Gaseous fuels	-7.56%	-7.58%	-5.43%	-2.38%	-2.80%	-2.24%	-2.01%	-1.16%	-0.67%	-2.08%	-2.72%	-0.96%	-0.79%	-1.61%	-1.33%
Other fossil fuels	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Peat	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
<b>Total</b>	<b>-1.20%</b>	<b>-0.23%</b>	<b>0.06%</b>	<b>0.09%</b>	<b>-0.22%</b>	<b>-1.64%</b>	<b>-1.79%</b>	<b>-0.35%</b>	<b>-0.61%</b>	<b>-0.32%</b>	<b>-0.54%</b>	<b>0.33%</b>	<b>0.01%</b>	<b>-0.36%</b>	<b>-0.83%</b>

Table 3-6 Comparison of CO<sub>2</sub> emissions

[Mt-CO <sub>2</sub> ]	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
<b>Reference Approach</b>															
Liquid fuels	659.9	701.9	656.2	621.1	501.8	523.6	532.9	512.2	472.1	450.1	434.6	428.9	403.6	383.6	354.9
Solid fuels	295.7	323.8	377.9	431.1	450.8	420.8	439.9	474.5	457.2	462.1	451.1	450.8	440.8	431.6	392.3
Gaseous fuels	104.4	126.1	155.9	167.4	203.5	238.6	248.4	249.9	253.2	237.8	241.5	239.9	228.9	217.2	216.6
Other fossil fuels	10.7	12.3	15.0	17.3	16.4	16.5	17.5	17.1	16.8	17.3	18.1	18.6	18.5	19.4	19.0
Peat	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
<b>Total RA</b>	<b>1,071</b>	<b>1,164</b>	<b>1,205</b>	<b>1,237</b>	<b>1,173</b>	<b>1,199</b>	<b>1,239</b>	<b>1,254</b>	<b>1,199</b>	<b>1,167</b>	<b>1,145</b>	<b>1,138</b>	<b>1,092</b>	<b>1,052</b>	<b>983</b>
<b>Sectoral Approach</b>															
Liquid fuels	644.3	677.4	640.7	606.1	488.9	520.3	530.8	508.5	464.7	444.0	428.2	415.7	398.8	381.7	354.2
Solid fuels	309.5	327.2	364.1	422.4	438.5	423.2	442.8	473.8	465.6	458.8	449.6	451.6	435.2	425.7	393.2
Gaseous fuels	114.2	137.9	166.1	172.4	209.9	244.7	254.1	253.4	255.5	243.4	248.8	242.8	231.3	221.4	220.2
Other fossil fuels	10.7	12.3	15.0	17.3	16.4	16.5	17.5	17.1	16.8	17.3	18.1	18.6	18.5	19.4	19.0
Peat	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
<b>Total</b>	<b>1,079</b>	<b>1,155</b>	<b>1,186</b>	<b>1,218</b>	<b>1,154</b>	<b>1,205</b>	<b>1,245</b>	<b>1,253</b>	<b>1,203</b>	<b>1,163</b>	<b>1,145</b>	<b>1,129</b>	<b>1,084</b>	<b>1,048</b>	<b>987</b>
<b>Difference (%)</b>															
Liquid fuels	2.42%	3.62%	2.43%	2.47%	2.64%	0.62%	0.40%	0.74%	1.58%	1.38%	1.49%	3.17%	1.21%	0.52%	0.18%
Solid fuels	-4.47%	-1.05%	3.80%	2.05%	2.79%	-0.58%	-0.65%	0.15%	-1.80%	0.72%	0.34%	-0.18%	1.29%	1.38%	-0.22%
Gaseous fuels	-8.56%	-8.61%	-6.11%	-2.89%	-3.06%	-2.48%	-2.24%	-1.39%	-0.92%	-2.29%	-2.93%	-1.20%	-1.07%	-1.91%	-1.64%
Other fossil fuels	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Peat	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
<b>Total</b>	<b>-0.74%</b>	<b>0.80%</b>	<b>1.62%</b>	<b>1.53%</b>	<b>1.62%</b>	<b>-0.44%</b>	<b>-0.52%</b>	<b>0.07%</b>	<b>-0.28%</b>	<b>0.33%</b>	<b>0.06%</b>	<b>0.84%</b>	<b>0.73%</b>	<b>0.35%</b>	<b>-0.39%</b>

#### 3.2.1.4. Comparison between Differences in Energy Consumption and that of CO<sub>2</sub> Emissions

The difference in energy consumption and the difference in CO<sub>2</sub> emissions generally show a similar tendency for their trends.

<sup>6</sup> In this chapter, solid fuels mean coal and coal products (including coal derived gas), liquid fuels mean crude oil and oil products (including LPG, etc.), and gaseous fuels mean natural gas (including LNG, etc.) and city gas, unless otherwise specified. (cf. 2006 IPCC Guidelines, Vol.2, Table 1.1) Peat is included in solid fuels.

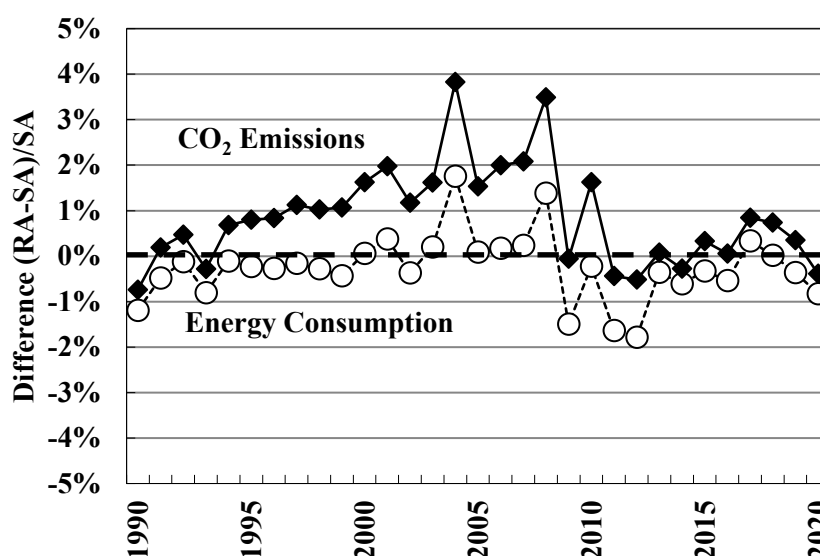


Figure 3-1 Trends in difference of energy consumption and CO<sub>2</sub> emissions

### 3.2.1.5. Causes of the difference between Reference Approach and Sectoral Approach

The difference in energy consumption and in CO<sub>2</sub> emissions can be explained mainly by the difference of the amount of non-energy use which was deducted under energy transformation & own use sector of the Energy Balance Table (*General Energy Statistics*).

#### 1) Matters not sufficiently considered in the calculation process of Reference Approach

In the current estimation of reference approach, the energy consumption amount, which is obtained by subtracting the amount of non-energy use from the amount supplied inside the country, is assumed to be completely combusted. However, in real situation, some of the energy amount is not combusted but stored, and the increase or decrease of the stored amount is not reflected in reference approach.

##### ● *Other Transformation [#289000]*

In Energy transformation & own use sector such as oil refining, energy source shipment/drawdown amounts do not necessarily match production/receipt amounts. Other than energy received through one's own imports or that produced by refining, factors involved include returns from consumption/sales sectors of products once shipped, transactions of small amounts of byproduct energy from other companies, stock buildups and drawdowns due to product storage tank installation or decommissioning at factories and business sites, and losses due to accidents or fires.

When energy source inconsistencies due to such causes in the Energy transformation & own use sector are determined, the other transformation sector represents its amount. However, this input/output are not reflected in reference approach emission calculation.

##### ● *Transformation and Consumption Stockpile Change [#350000]*

This sector represents the increase or decrease of stock in Energy transformation & own use sector and Final energy consumption sector. However, this increase/decrease was not reflected in reference approach emission calculation.

- **Other factors**

Some emissions are not calculated for the sources that the emissions are relatively low compared to total emissions in reference approach, in order not to be too complicated (cf. *2006 IPCC Guidelines*, Vol.2, page 6.12). For example, the emissions from lubricants used in two stroke engines are not accounted for in the reference approach emission calculation.

The CO<sub>2</sub> amount captured for geological storage is not subtracted in the reference approach emission calculation, although it is subtracted in the sectoral approach emission calculation.

## 2) *Matters which cannot be avoided for the characteristics of survey data*

- **Statistical Discrepancy [#400000]**

Statistical discrepancy is originally the intrinsic error arising at the sampling stage in statistical studies (source error), and mutual discrepancies among the statistics for supply, conversion, and consumption. It is sometimes difficult to guess where the discrepancies come from (relative error).

These errors induce the discrepancies among domestic supply, conversion, and final energy consumption, calculated as difference between both approaches.

## 3) *Matters related to the difference of energy and carbon balance between energy input and output*

- **'Coal Blending' [#211000], 'Oil Product Blending' [#221000], 'Coal Products Secondary Transformation' [#281000], 'Oil Products Secondary Transformation' [#282000]**

This sector represents energy conversion that does not belong to any of the sectors from Coke production [#212000] to Steel process gas [#215000] and from Oil refinery [#222000] to District heat supply [#270000], and actions considered to be energy conversion in which coal or oil product brands are changed by only simple operations such as blending or moisture adjustment.

Carbon weight is considered to be consistent before and after blending or conversions. However, given that carbon content per calorific value is changed following such as blending, in statistics, carbon weight could be varied before and after blending or conversions. This difference can generate the variation between two approaches.

## 4) *Matters related to the conversion to another fuel type*

- **Gas Conversion and Production [#231000]**

This sector represents energy conversion arising from city gas production. City gas is made from liquid and solid fuels such as liquefied petroleum gas (LPG) and coke oven gas (COG) as well as gaseous fuels such as liquefied natural gas (LNG). Thus, the fact that some liquid and solid fuels are converted to gaseous fuels is not reflected in reference approach emission calculation. The emissions calculated by the sectoral approach tend to be larger than those by reference approach for gaseous fuels and smaller for liquid and solid fuels. This sector does not affect the difference between two approaches in total.



fuel consumed for international navigation and aviation.

The emissions from bunker fuels used for international navigation and aviation are not included in the national totals but are reported as the memo item in the CRFs in accordance with the *UNFCCC Inventory Reporting Guidelines* and the *2006 IPCC Guidelines*.

## b) Methodological Issues

### ● Estimation Method

The emissions of CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O from this source are derived by multiplying the consumption of each fuel type handled by bonds by the emission factor.

### ● Emission Factors

#### ➤ CO<sub>2</sub>

The emission factors used for CO<sub>2</sub> are the same as those from 1.A.1 fuel combustion (CO<sub>2</sub>) in the energy sector (Refer to section 3.2.4. b)).

On the annual review in 2012 (FCCC/ARR/2012/JPN) and 2013 (FCCC/ARR/2013/JPN), the ERT noted that the Japanese carbon emission factor (EF) for jet kerosene (18.3 t-C/TJ based on the gross calorific value) is lower than the EF for jet kerosene included in the *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories* (18.5 t-C/TJ based on the gross calorific value<sup>7</sup>). The ERT recommended that Japan provide additional information.

The Japanese carbon emission factor for jet kerosene is obtained from actual measurement. In addition, the 95% confidence interval of EF for jet kerosene is 18.1-19.3 t-C/TJ (based on the gross calorific value) in the *2006 IPCC Guidelines* (Vol.2, Table 1.4) and the Japanese EF is inside the range. Therefore, Japan considers that this country-specific EF is appropriate value, comparing to the default value.

#### ➤ CH<sub>4</sub>, N<sub>2</sub>O

The default values given in the *2006 IPCC Guidelines* are used for CH<sub>4</sub> and N<sub>2</sub>O emission factors.

Table 3-8 Emission factors for CH<sub>4</sub> and N<sub>2</sub>O from international bunkers

Transport mode	Type of fuel	CH <sub>4</sub> emission factor [kg-CH <sub>4</sub> /TJ(NCV)]	N <sub>2</sub> O emission factor [kg-N <sub>2</sub> O/TJ(NCV)]
Aircraft	Jet fuel	0.5 <sup>1)</sup>	2 <sup>1)</sup>
Shipping	Fuel oil A, fuel oil B, fuel oil C, diesel oil, kerosene	7 <sup>2)</sup>	2 <sup>2)</sup>

Note:

1) *2006 IPCC Guidelines* Vol. 2, Table 3.6.5

2) *2006 IPCC Guidelines* Vol. 2, Table 3.5.3. According to the *2006 IPCC Guidelines* Vol. 3 page 5.7, CH<sub>4</sub> and N<sub>2</sub>O emissions from lubricants are very small in comparison to CO<sub>2</sub>, and these can be neglected for the greenhouse gas calculation. Therefore, the emissions are not estimated.

### ● Activity Data

The totals for bonded imports and bonded exports given in *Yearbook of Mineral Resources and Petroleum Products Statistics* (former *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*) (METI) are used for the emissions of CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O from the relevant source.

A and B in the diagram below correspond to the items under bonded exports and bonded imports, respectively, in the *Yearbook of Mineral Resources and Petroleum Products Statistics* (former *Yearbook*

<sup>7</sup> This value is also the default value in the *2006 IPCC Guidelines*.

of Production, Supply and Demand of Petroleum, Coal and Coke). C equals to the sum of A and B and it is used as the activity data for this source of emissions. This is considered to be approximately equivalent to the amount of the fuels sold in Japan for international aviation and navigation.

It is assumed that jet fuel is used by aircrafts, while fuel oil A, B, C, diesel oil, kerosene and lubricants are used by vessels. Fuel oil A, B, and C are used for the propulsion of international water-borne vessels. Diesel oil and kerosene are used only for fuels of private power generators (e.g. air heating). All lubricants are assumed to be oxidized during use from the viewpoint of conservativeness as lubricants consumption by type is unknown.

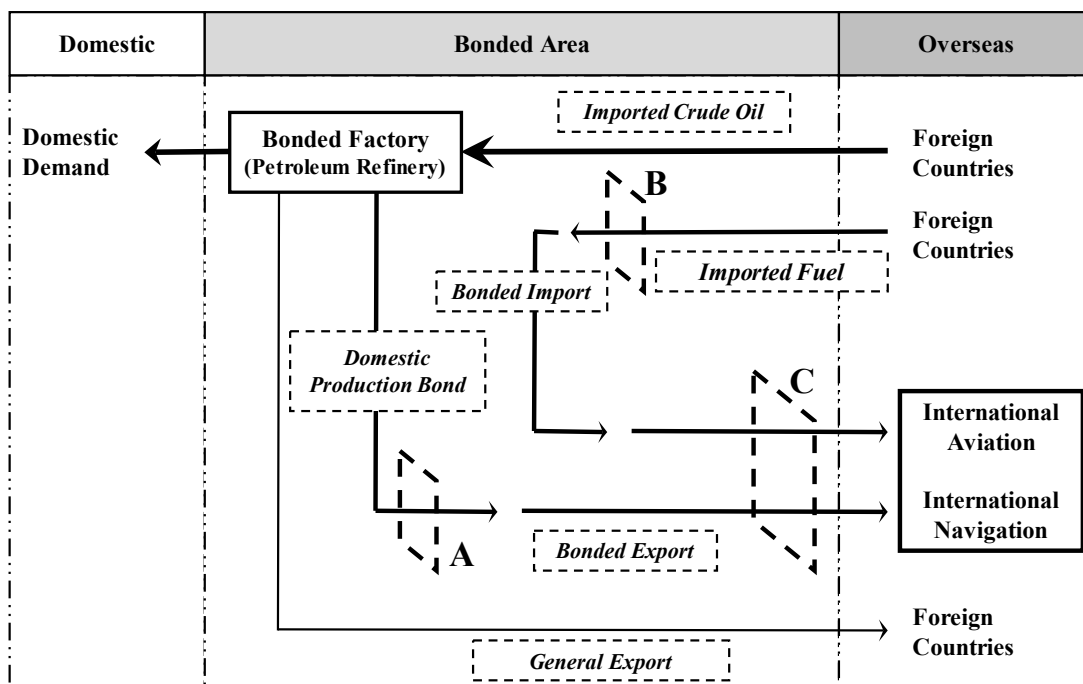


Figure 3-2 Activity data for international bunkers

➤  $CO_2$

The kiloliter-based consumption data given in the *Yearbook of Mineral Resources and Petroleum Products Statistics* (former *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*) are converted to Joule-based data using the actual calorific values given in the *General Energy Statistics*.

➤  $CH_4, N_2O$

The *2006 IPCC Guidelines* provide default emission factors that are based on net calorific values. Therefore, the activity data in gross calorific values are converted to net calorific values by multiplying them by the conversion rate.

● **Glossary**

Bonded Jet Fuel

Under the Tariff Law, aircraft (Japanese and non-Japanese) flying international routes are deemed to be “aircraft for international use”, and the fuel they consume is tariff-free, subject to the completion of the required procedures. The application of this legislation means that if fuel is refined from crude oil imported to Japanese refinery, both the crude oil import tariff and the petroleum and coal tax are waived. Similarly, if fuel has been imported as a product, the product import tariff is waived. The foregoing is termed as “bonded jet fuel”.

Bonded Fuel Oil

Vessels that ply between Japan and other countries are deemed to be “foreign trade vessels”, under the Tariff Law. The majority of their fuel is consumed outside Japanese territorial waters, and, therefore, both the tariffs and the petroleum and coal tax are waived. The foregoing is termed as “bonded fuel oil”.

Bonded Export

The demand for fuel supplied to aircraft (Japanese and non-Japanese) flying international routes and ships (Japanese and non-Japanese) that ply foreign ocean routes is termed as “bonded demand”. Jet fuel is supplied to aircraft while fuel oil is supplied to ships. Of these bonded demands, the fuel supplied from products that was produced from crude oil is counted as bonded export by *Yearbook of Mineral Resources and Petroleum Products Statistics*.

Bonded Import (Bond to Bond)

Fuel products that are imported from foreign countries, landed in a bonded area and supplied from the bonded area to bonded demand without going through domestic customs, is counted as bonded import by *Yearbook of Mineral Resources and Petroleum Products Statistics*.

**3.2.3. Feedstocks and Non-Energy Use of Fuels**

The *General Energy Statistics* is used as the activity data for estimating GHG emissions from fuel combustion (1.A.). The Total energy consumption (#500000) in the statistics includes the amount of energy used as feedstocks without the combustion and oxidation process. The energy consumption in the category of Non-energy and feedstock use (#950000) represents such amount of energy. For the purpose of estimating the emissions, the consumption in the category of Non-energy and feedstock use was deducted from Total energy consumption.

The consumption in the category of Non-energy and feedstock use includes the following: (1) Consumption which can be confirmed as clearly non-energy uses by official statistics, such as surveys of feedstock inputs according to the *Yearbook of the Current Survey of Energy Consumption* (METI) which is the reference of the *General Energy Statistics*; and (2) Amount of products which are produced for the purpose of non-energy use from the beginning. (However, the portion which is confirmed from official statistics such as the *Yearbook of the Current Survey of Energy Consumption* as having been employed for energy uses is treated as energy consumption and is excluded from non-energy use.)

The feedstocks and non-energy use of fuels are reported in “Fuel quantity for NEU” and “Carbon excluded” columns of the the Common Reporting Format (CRF) table 1.A(d). The correspondence between fuels of the *General Energy Statistics* and those of the table is shown in Annex 4.

The CO<sub>2</sub> emissions from combustion or oxidation of the fuel used for non-energy purpose such as feedstock use of products in any process of manufacturing, use and abandonment of products are separately reported in other sectors shown in Table 3-9. (For detail, see each related chapter.) The emissions are reported in “Reported CO<sub>2</sub> emissions” column of the CRF table 1.A(d).

Among emissions from manufacturing processes of iron and steel and non-ferrous metals, emissions from fuel combustion should be reported in Energy sector (1.A) and emissions from reducing agent should be reported in Industrial processes and product use sector (2.C). Both emissions are reported



together in Energy sector (1.A), because Japan considers that it is the most appropriate to grasp all emissions from manufacturing processes of iron and steel, and non-ferrous metals comprehensively from the viewpoints of accuracy, and avoiding double-counting and omissions. Each manufacturing process and category is shown in Table 3-10.

Table 3-9 Allocation of CO<sub>2</sub> emissions from fuel used for non-energy purpose such as feedstock

CO <sub>2</sub> emitting process	CRF Category	Type of fuel used for non-energy purpose such as feedstock	Emission factor	
				Calorific value
Ammonia production	2.B.1	Naphtha	See Table 3-11	See Table 3-19
		Liquefied petroleum gas (LPG), (until FY2002)		
		Refinery gas (off-gas) (until FY2011)		
		Indigenous natural gas		
		Coal (steam coal, imports)		
		Petroleum coke		
		Liquefied natural gas (LNG)		
		Coke oven gas (COG) (until FY2001)		
Silicon carbide production	2.B.5.a	Petroleum coke	2.3 [t-CO <sub>2</sub> /t] (per petroleum coke consumption amount)	
Calcium carbide production	2.B.5.b	Coke	From reducing agent in production: 1.09 [t-CO <sub>2</sub> /t] (confidential information in and after FY2008), from use: 1.10 [t-CO <sub>2</sub> /t] (both EFs per calcium carbide production amount)	
Titanium dioxide production	2.B.6	Petroleum coke, etc.	Rutile TiO <sub>2</sub> : confidential information Synthetic rutile: 1.43 [t-CO <sub>2</sub> /t] (per production amount)	
Methanol production	2.B.8.a	Natural gas (until FY1995)	0.67 [t-CO <sub>2</sub> /t] (per methanol production amount)	
Ethylene production	2.B.8.b	Naphtha, LPG, etc.	Confidential information	
Carbon black production	2.B.8.f	Coal tar, etc.	2.06 [t-CO <sub>2</sub> /t] (per carbon black production amount)	
Maleic anhydride production	2.B.8.g	LPG	1.65 [t-CO <sub>2</sub> /t] (per maleic anhydride production amount made by oxidation of n-butane)	
Hydrogen production	2.B.8.g	Natural gas, etc.	Report by member companies of the Japan Industrial and Medical Gases Association	
Automobile and marine engine oils (excluding total loss type) <sup>1)</sup>	2.D.1	Lubricants	See Table 3-11	
Paraffin wax use	2.D.2	Bitumen	See Table 3-11	

Note:

- CO<sub>2</sub> emissions from automobile and marine engine oils (total loss type) are included in Transport (1.A.3).
- CO<sub>2</sub> emissions from fuel used for non-energy purpose may occur when fossil-fuel derived waste is incinerated or decomposed, and when fossil-fuel derived chemical products are used as feedstock to produce other chemical products. These CO<sub>2</sub> emissions are reported under 1.A (other fossil fuels), 2.D.3, 2.B.8, 2.H.2, 5.C or 5.E. However, This table and "Reported CO<sub>2</sub> emissions" column of CRF table 1.A(d) do not include these emissions in accordance with the 2006 IPCC Guidelines, Vol.3, page 1.16.

Table 3-10 Reported category of CO<sub>2</sub> emissions from iron and steel and non-ferrous metals process

CO <sub>2</sub> emitting process	Main fuel used for non-energy purpose such as feedstock	Allocation as per IPCC Guidelines	Allocation used by the Party
Production of Steel and Pig iron	Coke, pulverized coal, waste plastics, coke oven gas, blast furnace gas	2.C.1	1.A.2.a (Iron and steel)
Sinter production	Coke	2.C.1	1.A.2.a (Iron and steel)
Pellet production	Coke	2.C.1	1.A.2.a (Iron and steel)
Ferroalloys production	Coke, steam coal	2.C.2	1.A.2.a (Iron and steel)
Aluminium production	Coke (Main ingredient in the anode paste)	2.C.3	1.A.2.f (Non-metallic minerals)
Lead production	Coke	2.C.5	1.A.2.b (Non-ferrous metals)
Zinc production	Coke	2.C.6	1.A.2.b (Non-ferrous metals)

### 3.2.4. CO<sub>2</sub> Emissions from Energy Industries (1.A.1.: CO<sub>2</sub>)

#### a) Category Description

This section provides the methods for estimating CO<sub>2</sub> emissions from public electricity and heat production (1.A.1.a), petroleum refining (1.A.1.b), and manufacture of solid fuels and other energy industries (1.A.1.c).

In FY2020, CO<sub>2</sub> emissions from this category accounted for 436,334 kt-CO<sub>2</sub>, and represented 37.9% of Japan's total GHG emissions (excluding LULUCF). Public electricity and heat production (1.A.1.a) accounts for 89.8% and is the largest subcategory in energy industries (1.A.1).

The IEFs (Implied Emission Factor)<sup>8</sup> of CO<sub>2</sub> emissions from solid fuels in 1.A.1.c (Manufacture of solid fuels and other energy industries) have been pulled up and down by fluctuation of carbon balances derived from the transformation of solid fuels by the manufacture of solid fuels. The apparent annual change of this category is caused by the mass-balance, energy-balance and carbon-balance between coking coal, coke and other coal products, and may be influenced by statistical error, unobserved stockpiles in the process and/or spontaneous input-output unbalance.

#### b) Methodological Issues

##### ● Estimation Method

The Tier 2 Sectoral Approach has been used in accordance with the decision tree of the *2006 IPCC Guidelines* to calculate emissions (Vol.2, Page 1.9, Fig. 1.2). Country-specific emission factors are used for all types of fuel.

$$E = \sum_{ij} [(A_{ij} - N_{ij}) \times GCV_i \times 10^{-3} \times EF_i \times OF_i] \times 44/12$$

*E* : CO<sub>2</sub> emissions from fossil fuel combustion [ t-CO<sub>2</sub> ]

*A* : Energy consumption (original unit [t, kL, 10<sup>3</sup>×m<sup>3</sup>])

*N* : Non-energy use of fossil fuels (original unit)

*GCV* : Gross calorific value [ MJ/original unit ]

*EF* : Carbon content of the fuel [ t-C/TJ ]

*OF* : Oxidation factor

*i* : Type of fuel

*j* : Sector

<sup>8</sup> Indicators obtained by dividing the emissions in the common reporting format (CRF) by the activity data in the CRF.

The energy consumption and emissions from waste incineration with energy recovery are reported in fuel combustion (1.A.) as “other fossil fuels” and “biomass” in accordance with the *2006 IPCC Guidelines*.

The estimation method, emission factors and activity data for emissions from waste incineration with energy recovery are the same as those used in the waste incineration (5.C.) in accordance with the *2006 IPCC Guidelines*. Please refer to Chapter 7 for further details on the estimation methods.

The CO<sub>2</sub> emissions from biomass are not included in the national totals<sup>9</sup> but are reported in the CRFs as reference in accordance with the *2006 IPCC Guidelines*. In the *General Energy Statistics*, the consumptions of biofuels are included in those of gasoline and diesel oil, but the CO<sub>2</sub> emissions from biofuels are not considered as fossil fuel origin by adjusting the calorific value and the carbon emission factors of gasoline and diesel oil.

CO<sub>2</sub> generated from an oil refinery plant was captured and stored from fiscal year 2004 to 2007 and 2016 onward, and it is reported under “CO<sub>2</sub> amount captured” in liquid fuels of 1.A.1.b Petroleum refining of the CRF table 1.A(a). It is subtracted from the emissions estimated by the above formula. Please refer to section 3.4.4. for details.

### ● *Emission Factors*

#### ➤ *Carbon emission factors*

The carbon content of fuels expressed as the unit of gross calorific value (higher heating value) was used for carbon emission factors (CEF). The emission factors are mostly country-specific values.

The emission factors were developed based on three different concepts; (a) Energy sources other than Blast Furnace Gas (BFG) and City gas, (b) BFG, and (c) City gas.

Table 3-11 provides the emission factors for CO<sub>2</sub> by fuel types.

Carbon emission factors for residual and straight-run fuel oil for refinery use declined by 8.0 per cent between 2012 and 2013, the GCVs were revised during the 2013 survey and, as a result, increased by around 8.3 per cent between 2012 and 2013. The crude oil for refinery use is major (99.9 per cent of input volume to atmospheric distillation units in 2018), and the straight-run fuel oil for refinery use is minor (0.1 per cent) and it is not used for direct combustion.

<sup>9</sup> The reason of non-inclusion is to avoid double counting with the CO<sub>2</sub> emissions resulting from carbon stock changes estimated in LULUCF sector. (See *2006 IPCC Guidelines*, Vol.2, Page 2.33.)



Table 3-12 References and methodologies of carbon emission factors for fuel combustion (FY1990-2012)

Fuel	Code	FY1990-2012		
Solid fuels	Coal	Steel making coal	\$0110 Same as coking coal	
		Coking coal	\$0111 Kainou (2005)	
		Pulverized coal injection (PCI) coal	\$0112 Same as coking coal	
		Imported steam coal	\$0121 Same as imported steam coal for general use	
		Imported steam coal for general use	\$0122 Environmental Agency (1992)	
		Imported steam coal for power generation use	\$0123 Same as imported steam coal for general use	
		Indigenous produced steam coal	\$0124 Environmental Agency (1992)	
	Coal Products	Hard coal, anthracite & lignite	\$0130 Kainou (2005)	
		Coke	\$0211 Environmental Agency (1992)	
		Coal tar	\$0212 Kainou (2005)	
		Coal briquette	\$0213 Environmental Agency (1992)	
		Coke oven gas	\$0221 Kainou (2005)	
		Blast furnace gas	\$0222 Values based on the carbon balance in blast furnace and converter furnace in the <i>General Energy Statistics</i>	
		Converter furnace gas	\$0225 Kainou (2005)	
	Liquid fuels	Oil	Crude oil for refinery use	\$0310 Same as crude oil for refinery use
			Crude oil for refinery use	\$0311
			Residual and straight run fuel oil for refinery use	\$0312 Weighted average of brand-specific CEFs based on the share of imports
Crude oil for power generation use			\$0320 Estimated by interpolating by approximate equation of crude oil for refinery use	
Bituminous mixture fuel			\$0321 Kainou (2005)	
Natural gas liquid (NGL) / condensate			\$0330	
NGL/condensate for refinery use			\$0331	
NGL/condensate for power generation use		\$0332 Weighted average of brand-specific CEFs based on the share of imports		
NGL/condensate for petrochemical use		\$0333		
Oil Products		Pure naphtha	\$0420 Environmental Agency (1992)	
			Reformate	\$0421 Values of gasoline
		Gasoline (crude oil origin)	\$0431	Environmental Agency (1992)
				Weighted average of CEFs of crude oil origin and biomass origin based on the share of domestic consumption
		Gasoline (biofuel blended)		
		Jet fuel oil	\$0432 Environmental Agency (1992)	
		Kerosene	\$0433 Environmental Agency (1992)	
		Gas oil or diesel oil (crude oil origin)	\$0434	
		Gas oil or diesel oil (biofuel blended)	\$0434 Weighted average of CEFs of crude oil origin and biomass origin based on the share of domestic consumption	
		Fuel oil A	\$0436 Environmental Agency (1992)	
		Fuel oil C	\$0437 Same as fuel oil C for general use	
	Fuel oil B	\$0438 Environmental Agency (1992)		
	Fuel oil C for general use	\$0439 Environmental Agency (1992)		
Fuel oil C for power generation use	\$0440 Environmental Agency (1992)			
Miscellaneous oil products	Lubricant oil	\$0451 Environmental Agency (1992)		
	Other heavy oil products	\$0452 Environmental Agency (1992)		
	Petroleum coke	\$0455 Environmental Agency (1992)		
	Galvanic furnace gas	\$0456 Values of converter furnace gas		
	Refinery gas	\$0457 Environmental Agency (1992)		
	Liquefied petroleum gas (LPG)	\$0458 Weighted average of theoretical CEFs of propane and butane based on the share of these matters in indigenous production and imports of the fuel		
Gaseous fuels	Natural Gas	Liquefied natural gas (LNG)	\$0510 Weighted average of CEFs by production area based on the share of imports by country	
		Indigenous natural gas	\$0520 Kainou (2005)	
		Indigenous natural gas	\$0521 Values of indigenous natural gas	
		Coal mining gas	\$0522 Environmental Agency (1992)	
		Boil off gas from crude oil	\$0523 Values of indigenous natural gas	
	City Gas	City gas	\$0610 Estimated from the carbon balance of "city gas conversion and production" in the <i>General Energy Statistics</i>	
		Small scale community gas	\$0620 Values of liquefied petroleum gas	
(Reference)	Biomass	Woods	SN131 Actual measurements provided by JPA	
		Waste woods	SN132	
		Bioethanol	SN134	
		Biodiesel	SN135 Theoretical carbon emission factor of ethanol in normal condition	
		Thermal use of black liquor	SN136 Actual measurements provided by JPA	
		Gas biomass	SN137 Theoretical carbon emission factor of methane in normal condition	

Note:

FEPC: Federation of Electric Power Companies of Japan, JCIA: Japan Chemical Industry Association, JGA: Japan Gas Association, JISF: Japan Iron and Steel Federation, JNGA: Japan Natural Gas Association, JPA: Japan Paper Association, PAJ: Petroleum Association of Japan, SATP: Standard ambient temperature and pressure

Table 3-13 References and methodologies of carbon emission factors for fuel combustion (FY2013-2017)

Fuel	Code	FY2013-2017			
Solid fuels	Coal	Steel making coal	S0110	Weighted average of CEFs of coking coal and PCI coal using consumptions of the fuels	
		Coking coal	S0111	Simple average of CEFs obtained from actual measurements provided by JISF	
		Pulverized coal injection (PCI) coal	S0112	Simple average of CEFs obtained from actual measurements provided by JISF	
		Imported steam coal	S0121	Same as imported steam coal for general use	
		Imported steam coal for general use	S0122	Weighted average of CEF using receipts. The CEF were estimated from actual measurements provided by FEPC.	
		Imported steam coal for power generation use	S0123	Same as imported steam coal for general use	
		Indigenous produced steam coal	S0124	Weighted average of CEF using receipts. The CEF were estimated from actual measurements provided by FEPC.	
		Hard coal, anthracite & lignite	S0130	Estimated by interpolating by the approximate equation of imported steam coal	
		Coke	S0211	Simple average of CEFs obtained from actual measurements provided by JISF	
	Coal Products	Coal tar	S0212	Continuous use of the current value	
		Coal briquette	S0213	Values of hard coal, anthracite & lignite	
		Coke oven gas	S0221	Simple average of CEFs estimated from actual measurements provided by JISF	
		Blast furnace gas	S0222	Values based on the carbon balance in blast furnace and converter furnace in the <i>General Energy Statistics</i>	
Converter furnace gas		S0225	Simple average of CEFs estimated from actual measurements provided by JISF		
Liquid fuels		Oil	Crude oil for refinery use	S0310	Same as crude oil for refinery use
	Crude oil for refinery use		S0311	Weighted average of brand-specific CEFs based on imports by brand. The brand-specific CEFs were estimated by the approximate equation of crude oil based on brand-specific GCV obtained from actual measurements provided by PAJ.	
	Residual and straight run fuel oil for refinery use		S0312	Weighted average of brand-specific CEFs based on imports by brand. The brand-specific CEFs were estimated by the approximate equation of crude oil based on brand-specific GCV obtained from actual measurements provided by PAJ.	
	Crude oil for power generation use		S0320	Weighted average of monthly CEFs using monthly receipts. The monthly CEFs were estimated by approximate equation of crude oil using GCV from <i>Electric Power Statistics</i> (ANRE).	
	Bituminous mixture fuel		S0321	Continuous use of the current value	
	Natural gas liquid (NGL) / condensate		S0330		
	NGL/condensate for refinery use		S0331	Weighted average of brand-specific CEFs based on imports and shipments by brand. The brand-specific CEFs were estimated by approximate equation of crude oil using brand-specific GCV obtained from actual measurements provided by PAJ.	
	NGL/condensate for power generation use		S0332		
	NGL/condensate for petrochemical use		S0333		
	Oil Products		Fuel oil	Pure naphtha	S0420
		Reformate		S0421	Value of premium gasoline, which is simple average of CEF obtained from actual measurements provided by PAJ
		Fuel oil	Gasoline (crude oil origin)	S0431	Weighted average of CEFs of regular and premium gasoline using domestic shipments by type. The CEF of each gasoline were obtained from actual measurements provided by PAJ.
			Gasoline (biofuel blended)		Values calculated by weighted average of emission factors of crude oil origin and biomass origin based on the share of domestic consumption
			Jet fuel oil	S0432	Weighted average of CEFs of kerosene type jet fuel and gasoline type jet fuel using the final consumptions by type in the <i>General Energy Statistics</i> . The CEFs of each type were obtained from actual measurements provided by PAJ.
			Kerosene	S0433	Simple average of CEFs obtained from actual measurements provided by PAJ
			Gas oil or diesel oil (crude oil origin)	S0434	Simple average of CEFs obtained from actual measurements provided by PAJ
			Gas oil or diesel oil (biofuel blended)		Weighted average of emission factors of crude oil origin and biomass origin based on the share of domestic consumption
Fuel oil A			S0436	Simple average of CEFs obtained from actual measurements provided by PAJ	
Fuel oil C			S0437	Same as fuel oil C for general use	
Fuel oil B			S0438	Estimated by interpolating by approximate equation of oil products using GCV obtained from actual measurements provided by PAJ	
Fuel oil C for general use			S0439	Simple average of CEFs obtained from actual measurements provided by PAJ	
Fuel oil C for power generation use		S0440	Estimated by approximate equation of oil products using GCV from <i>Electric Power Statistics</i> (ANRE).		
Miscellaneous oil products		Lubricant oil	S0451	Estimated by interpolating by approximate equation of oil products based on GCV obtained from actual measurements provided by PAJ	
		Other heavy oil products	S0452	Estimated by interpolating by approximate equation of oil products based on GCV estimated from energy balance of slack fuel oil input and fuel oil C output	
		Petroleum coke	S0455	Simple average of CEFs obtained from actual measurements provided by JCIA	
		Galvanic furnace gas	S0456	Values of converter furnace gas	
	Refinery gas	S0457	Simple average of CEFs estimated from actual measurements provided by PAJ		
	Liquefied petroleum gas (LPG)	S0458	Weighted average of theoretical CEFs of propane and butane using domestic supply amount of each gas		
	Gaseous fuels	Natural Gas	Liquefied natural gas (LNG)	S0510	Weighted average of CEFs by production area using imports by country. The CEFs by production area were estimated from <i>Gas Industry Handbook</i> (JGA).
			Indigenous natural gas	S0520	Weighted average of CEFs by gas field using productions by gas field. The CEFs by gas field were estimated from actual measurements provided by JNGA.
Indigenous natural gas			S0521	Values of indigenous natural gas (S0520)	
Coal mining gas			S0522	Weighted average of CEFs by gas field using productions by gas field. The CEFs by gas field were estimated from actual measurements provided by JNGA.	
Boil off gas from crude oil			S0523	Values of indigenous natural gas (S0520)	
City Gas		City gas	S0610	Estimated from the carbon balance of "city gas conversion and production" in the <i>General Energy Statistics</i>	
		Small scale community gas	S0620	Values of liquefied petroleum gas	
(Reference)	Biomass	Woods	SN131		
		Waste woods	SN132	Simple average of CEFs obtained by actual measurements provided by JPA	
		Bioethanol	SN134		
		Biodiesel	SN135	Theoretical carbon emission factor of ethanol in SATP condition	
		Thermal use of black liquor	SN136	Actual measurements provided by JPA	
Gas biomass	SN137	Theoretical carbon emission factor of methane in SATP condition			

Note:

FEPC: Federation of Electric Power Companies of Japan, JCIA: Japan Chemical Industry Association, JGA: Japan Gas Association,

JISF: Japan Iron and Steel Federation, JNGA: Japan Natural Gas Association, JPA: Japan Paper Association,

PAJ: Petroleum Association of Japan, SATP: Standard ambient temperature and pressure

Table 3-14 References and methodologies of carbon emission factors for fuel combustion (FY2018 onward)

Fuel	Code	FY2018 onward			
Solid fuels	Coal	Steel making coal	\$0110	Weighted average of CEFs of coking coal and PCI coal using consumptions of the fuels	
		Coking coal	\$0111	Simple average of CEFs obtained from actual measurements provided by JISF	
		Pulverized coal injection (PCI) coal	\$0112	Simple average of CEFs obtained from actual measurements provided by JISF	
		Imported steam coal	\$0121	Same as imported steam coal for general use	
		Imported steam coal for general use	\$0122	Weighted average of CEF using receipts. The CEF were estimated from actual measurements provided by FEPC.	
		Imported steam coal for power generation use	\$0123	Same as imported steam coal for general use	
		Indigenous produced steam coal	\$0124	Weighted average of CEF using receipts. The CEF were estimated from actual measurements provided by FEPC.	
	Coal Products	Hard coal, anthracite & lignite	\$0130	Continuous use of the current value	
		Coke	\$0211	Simple average of CEFs obtained from actual measurements provided by JISF	
		Coal tar	\$0212	Continuous use of the current value	
		Coal briquette	\$0213	Continuous use of the current value	
		Coke oven gas	\$0221	Simple average of CEFs estimated from actual measurements provided by JISF	
		Blast furnace gas	\$0222	Values based on the carbon balance in blast furnace and converter furnace in the <i>General Energy Statistics</i>	
		Converter furnace gas	\$0225	Simple average of CEFs estimated from actual measurements provided by JISF	
Liquid fuels	Oil	Crude oil for refinery use	\$0310	Same as crude oil for refinery use	
		Crude oil for refinery use	\$0311	Weighted average of brand-specific CEFs based on imports by brand. The brand-specific CEFs were estimated by the approximate equation of crude oil based on brand-specific GCV obtained from actual measurements provided by PAJ.	
		Residual and straight run fuel oil for refinery use	\$0312	Weighted average of brand-specific CEFs based on imports and shipments by brand. The brand-specific CEFs were estimated by approximate equation of crude oil using GCV from <i>Electric Power Statistics</i> (ANRE).	
		Crude oil for power generation use	\$0320	Continuous use of the current value	
		Bituminous mixture fuel	\$0321	Continuous use of the current value	
		Natural gas liquid (NGL) / condensate	\$0330	Weighted average of brand-specific CEFs based on imports and shipments by brand. The brand-specific CEFs were estimated by approximate equation of crude oil using brand-specific GCV obtained from actual measurements provided by PAJ.	
		NGL/condensate for refinery use	\$0331		
		NGL/condensate for power generation use	\$0332		
	NGL/condensate for petrochemical use	\$0333			
	Oil Products	Fuel oil	Pure naphtha	\$0420	Continuous use of the current value
			Reformate	\$0421	Continuous use of the current value
Gasoline		Gasoline (crude oil origin)	\$0431	Weighted average of CEFs of regular and premium gasoline using domestic shipments by type. The CEF of each gasoline were obtained from actual measurements provided by PAJ.	
		Gasoline (biofuel blended)		Values calculated by weighted average of emission factors of crude oil origin and biomass origin based on the share of domestic consumption	
Jet fuel oil		\$0432	Weighted average of CEFs of kerosene type jet fuel and gasoline type jet fuel using the final consumptions by type in the <i>General Energy Statistics</i> . The CEFs of each type were obtained from actual measurements provided by PAJ.		
Fuel oil		Kerosene	\$0433	Continuous use of the current value	
		Gas oil or diesel oil (crude oil origin)	\$0434	Continuous use of the current value	
		Gas oil or diesel oil (biofuel blended)		Values calculated by weighted average of emission factors of crude oil origin and biomass origin based on the share of domestic consumption	
		Fuel oil A	\$0436	Continuous use of the current value	
		Fuel oil C	\$0437	Same as fuel oil C for general use	
		Fuel oil B	\$0438	Continuous use of the current value	
		Fuel oil C for general use	\$0439	Continuous use of the current value	
Fuel oil C for power generation use		\$0440	Estimated by approximate equation of oil products using GCV from <i>Electric Power Statistics</i> (ANRE).		
Miscellaneous oil products	Lubricant oil	\$0451	Continuous use of the current value		
	Other heavy oil products	\$0452	Estimated by interpolating by approximate equation of oil products based on GCV estimated from energy balance of slack fuel oil input and fuel oil C output		
	Petroleum coke	\$0455	Continuous use of the current value		
	Galvanic furnace gas	\$0456	Values of converter furnace gas		
	Refinery gas	\$0457	Continuous use of the current value		
Liquefied petroleum gas (LPG)	\$0458	Weighted average of theoretical CEFs of propane and butane using domestic supply amount of each gas			
Gaseous fuels	Natural Gas	Liquefied natural gas (LNG)	\$0510	Weighted average of CEFs by production area using imports by country. The CEFs by production area were estimated from actual measurements provided by FEPC and JGA.	
		Indigenous natural gas	\$0520	Weighted average of CEFs by gas field using productions by gas field. The CEFs by gas field were estimated from actual measurements provided by JNGA.	
		Indigenous natural gas	\$0521	Values of indigenous natural gas (\$0520)	
		Coal mining gas	\$0522	Continuous use of the current value	
		Boil off gas from crude oil	\$0523	Values of indigenous natural gas (\$0520)	
	City Gas	City gas	\$0610	Estimated from the carbon balance of "city gas conversion and production" in the <i>General Energy Statistics</i>	
	Small scale community gas	\$0620	Values of liquefied petroleum gas		
(Reference)	Biomass	Woods	\$N131	Continuous use of the current value	
		Waste woods	\$N132		
		Bioethanol	\$N134	Continuous use of the current value	
		Biodiesel	\$N135	Continuous use of the current value	
		Thermal use of black liquor	\$N136	Continuous use of the current value	
		Gas biomass	\$N137	Continuous use of the current value	

Note:

FEPC: Federation of Electric Power Companies of Japan, JCIA: Japan Chemical Industry Association, JGA: Japan Gas Association, JISF: Japan Iron and Steel Federation, JNGA: Japan Natural Gas Association, JPA: Japan Paper Association, PAJ: Petroleum Association of Japan, SATP: Standard ambient temperature and pressure

*(a) Energy sources other than Blast Furnace Gas (BFG) and City gas*

The carbon emission factors of energy sources other than blast furnace gas (BFG) and city gas were established based on Environmental Agency (1992), Ministry of the Environment (2002a), Kainou (2005), Kainou (2014), and Agency for Natural Resources and Energy (2020).

- ***Methodological issues of carbon emission factors from FY1990 to FY2012***

The evaluation results in Kainou (2005) were adopted for setting emission factors. In the choice of carbon emission factors, an adequacy assessment of emission factors was conducted in Environmental Agency (1992), which were used in the inventories submitted up to 2005. These were assessed based on the following three criteria. The values assessed as adequate continue to be used in this inventory.

- 1) Evaluation and analysis by comparison of theoretical upper and lower limits
- 2) Evaluation and analysis by comparison with the *Revised 1996 IPCC Guidelines* default values
- 3) Group evaluation and analysis by carbon balance using the *General Energy Statistics*

The summaries of evaluations are indicated below.

1) Evaluation and analysis by comparison of theoretical upper and lower limits

The validity of carbon emission factors is evaluated by comparing the intended emission factor and the emission factor calculated theoretically from standard enthalpy change of the formation of pure matter, such as hydrogen, methane and carbon monoxide, because most of the fuels for which carbon emission factors are required to be evaluated are hydrocarbons containing a few impurities, and because a physicochemical correspondence exists between the gross calorific values of pure hydrocarbons and carbon emission factors.

2) Evaluation and analysis by comparison with the *Revised 1996 IPCC Guidelines* default values

The validity of carbon emission factors is judged by using the *Revised 1996 IPCC Guidelines* default values or the *2006 IPCC Guidelines* reference values<sup>10</sup> and their statistical reliability (uncertainty) information. However, because the average properties of fuels envisaged in the IPCC Guidelines and those of the fuels used in Japan are not necessarily the same, carbon emission factors can be evaluated based on the statistical examination of the group evaluation and analysis mentioned below even when figures deviate, as long as a valid reason for the deviation exists.

3) Group evaluation and analysis by carbon balance using the *General Energy Statistics*

The validity of fuel-specific carbon emission factors for some petroleum and coal product factor groups can be evaluated using the *General Energy Statistics* to analyze the carbon balance in coal and oil products.

With regard to those judged there is no validity, the values shown in Ministry of the Environment (2002a) and *2006 IPCC Guidelines* were compared and verified, and values considered valid were used.

- ***Methodological issues of carbon emission factors from FY2013 to FY2017***

The values through the survey conducted by METI and the Ministry of the Environment (MOE) on the

<sup>10</sup> When *Evaluating and Analyzing the Validity of Carbon Emission Factors for Different Fuels* was submitted, the *2006 IPCC Guidelines* had not been published yet. These values were reference values, and some of these reference values were revised.



calorific values (CV) and carbon emission factors (CEF) in FY2013 and FY2014 were adopted. The outline is described below.

### 1) Outline of the Survey

The METI and MOE collected the data such as physical properties of various energy sources that relevant industrial associations had, and conducted the survey on the actual measurements of physical properties of samples provided by relevant industrial associations in FY2013 and FY2014. The CVs and CEFs from FY2013 were established using the methodologies presented in Kainou (2014) based on the physical properties of various energy sources obtained from the survey.

### 2) Basic Methodology of Estimation of Carbon Emission Factors

The CVs and CEFs by energy source were established, based on the properties and priority in accuracy of various energy sources, by the following methods: (1) estimation from theoretical values; (2) estimation from the actual measurements provided by the relevant industrial associations and the actual measurements by the METI and MOE; (3) estimation from the values of major energy sources, and from the weighted average and/or regression analysis using those values; (4) continuous use of the current values.

The estimation methods of the CVs and CEFs of solid, liquid and gaseous fuels based on the theoretical values and the actual measurements (corresponding to the methods (1) and (2)) are as follows:

#### *Gaseous fuels*

In the cases where component composition can be measured by such techniques as gas chromatography in some energy sources like gaseous fuels, CVs and CEFs are derived by weighted average of those of pure matters by composition. Theoretical CVs and CEFs of pure matters such as methane and propane are estimated from physical properties like standard enthalpy change of the formation.

#### *Solid and liquid fuels*

In the cases where energy sources are solid fuels or liquid fuels that the weighted average by pure matters are not feasible, CVs and carbon contents are estimated by statistical treatment of the actual measurements of physical properties such as gross calorific values and carbon contents.

The method (3) is that the CVs and CEFs of subject energy sources are estimated by interpolating by the approximate equations. The equations were established based on the actual measurements of steam coal, crude oil and oil products, and they can estimate CVs and CEFs from the physical properties such as density and water content.

### 3) Quality Control

The CVs and CEFs estimated above were compared with the current values and the default values of the *2006 IPCC Guidelines*, and then the validity is confirmed.

#### **- *Methodological issues of carbon emission factors from FY2018 onward***

The CEFs from FY2018 onward were established in combination of the CVs, based on the survey conducted by METI and MOE on the CV and CEF in FY2017 through FY2019. The fuels to be revised were selected, considering that the major revision of the CV and CEF has already been done in FY2013, the composition of some fuels does not significantly change during five years or so, the balance between cost and work load of the measurements and impact on emissions.

The CV and CEF were established basically by the following methods: (1) They were established in place of the current values using the data provided by industry organizations; (2) They were established in place of the current values using the existing statistics and references, the estimation equations, and other means; (3) The current values were used continuously. For (1) and (2), Kainou (2014) was referred to if the same estimation methodologies and references were adopted as in FY2013 values.

The CV and CEF estimated above were compared with the FY2013 values and the default values of the 2006 IPCC Guidelines to evaluate the validity. In addition, the balance of energy and carbon in the coal products manufacturing and petroleum product manufacturing categories was confirmed: the output did not exceed the input due to the establishment of the CV and CEF described above.

### (b) Blast Furnace Gas (BFG)

During the iron and steel production process, in the blast furnace and converter furnace, the amount of energy and carbon contained in coke and Pulverized Coal Injection (PCI) coal which are injected to the processes and those contained in BFG and Converter Furnace Gas (CFG, or Linz-Donawitz converter gas (LDG)) which are calculated should be theoretically balanced. Since the composition of BFG is unstable, the emission factors for BFG were established with annually calculated values in order to keep the carbon balance in the blast furnace and converter furnace during the iron and steel production process.

The amount of carbon (excluding the carbon contained in CFG from the carbon contained in 'Coke' and 'PCI coal') injected to the blast furnace indicated under 'Steel process gas' is considered to be carbon contained in BFG. The emission factor for BFG was established as the carbon described above divided by the calorific value of the BFG generated. The equation for the emission factor, the overview of the carbon flow for iron and steel and the calculation process are shown below.

The calculation to establish the emission factor for BFG is conducted every year.

$$EF_{BFG} = [(A_{coal} \times EF_{coal} + A_{coke} \times EF_{coke}) - A_{CFG} \times EF_{CFG}] / A_{BFG}$$

*EF* : Carbon emission factor [t-C/TJ]

*A* : Fuel consumption [TJ]

*BFG* : Blast Furnace Gas

*coal* : PCI coal

*coke* : Coke

*CFG* : Converter Furnace Gas

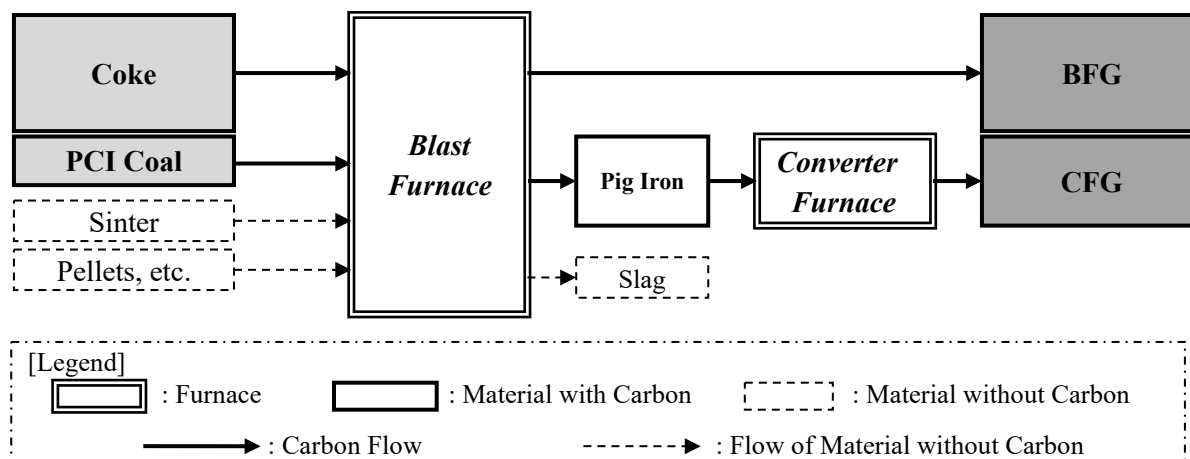


Figure 3-3 Overview of carbon flow for iron & steel manufacturing

Table 3-15 Calculation process of emission factors for BFG

Steel process gas		1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Note
Input																	
PCI coal	kt-C	1,650	2,619	3,351	3,014	3,444	3,669	4,019	4,401	4,283	4,180	4,206	4,250	4,094	4,043	2,965	A
Coke	kt-C	12,739	11,400	12,221	11,497	11,194	10,137	10,187	10,870	10,917	10,270	10,196	9,739	9,586	9,273	7,833	B
Input total	kt-C	14,389	14,019	15,572	14,511	14,637	13,806	14,206	15,271	15,200	14,449	14,402	13,989	13,680	13,316	10,799	C: A + B
Output																	
CFG (LDG)	kt-C	2,541	2,359	2,726	2,804	2,798	2,502	2,612	2,955	2,941	2,778	2,770	2,589	2,552	2,478	2,066	D
Difference	kt-C	11,848	11,660	12,846	11,707	11,839	11,304	11,594	12,316	12,260	11,671	11,632	11,400	11,127	10,838	8,733	E: C - D
Output																	
BFG	PJ	434.8	433.5	481.8	441.4	448.7	429.6	442.8	464.5	461.7	440.1	438.9	429.8	423.2	412.4	331.1	F
EF BFG	t-C/TJ	27.2	26.9	26.7	26.5	26.4	26.3	26.2	26.5	26.6	26.5	26.5	26.5	26.3	26.3	26.4	E / F

## (c) City gas

“City gas” consists of “city gas” provided by gas retailers, general gas pipeline companies, and specified gas pipeline companies (former general gas supplier, etc.) and “small-scale community gas” provided by gas retailers that generate gas in specified gas generation facilities and supply it through conduits (former small-scale community gas supplier).

*Small-scale community gas suppliers:*

Because most of the small-scale community gas is LPG, the same emission factor was adopted as for LPG.

*General gas suppliers:*

City gas (general gas) is produced from a mixture of raw materials and air dilution. In order to calculate the city gas emission factors, the total carbon contained in fossil fuel used as raw materials was divided by the total calorific value of the produced city gas. The emission factors for city gas were established based on the carbon balance in “city gas production”. To calculate the city gas emission factors, the total carbon in fossil fuel inputs used as raw materials (COG, Kerosene, Refinery gas, LPG, LNG and Indigenous natural gas) was divided by the total calorific value of the city gas production.

The calculation to establish the emission factor for city gas is conducted every year.

$$EF_{CG} = \sum_i (A_i \times EF_i) / P_{CG}$$

$EF$  : Carbon emission factor [ t-C/TJ ]

$A$  : Fuel consumption [TJ]

$P$  : Calorific value of the city gas production [TJ]

$CG$  : City gas

$i$  : Feedstocks (COG, Kerosene, Refinery gas, LPG, LNG, Indigenous natural gas, Gas biomass)

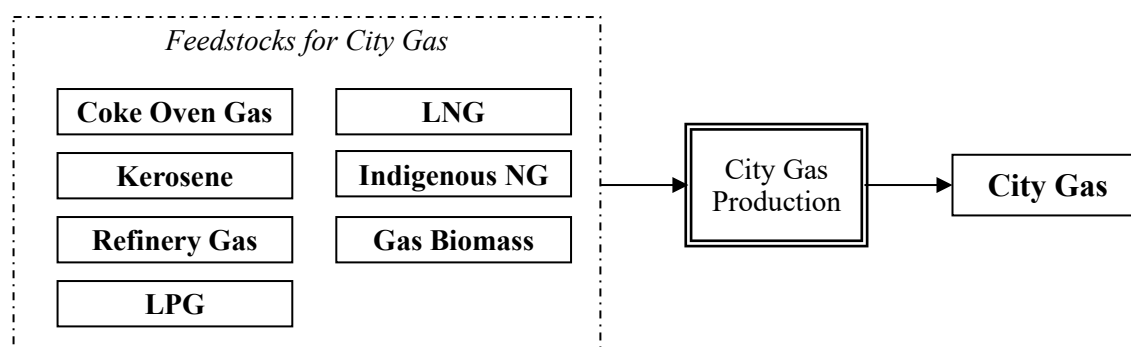


Figure 3-4 Manufacturing flow for city gas

Table 3-16 Calculation process of emission factors for city gas

City gas		1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Note
<b>Input</b>																	
COG	kt-C	211	134	105	22	0	0	0	0	0	0	0	0	0	0	0	a1
Kerosene	kt-C	200	275	69	6	0	0	0	0	0	0	0	0	0	0	0	a2
Refinery gas	kt-C	186	199	186	145	89	83	82	67	56	37	48	43	46	77	81	a3
LPG	kt-C	1,957	2,129	1,809	1,092	786	869	891	930	992	818	837	947	965	942	932	a4
LNG	kt-C	6,473	9,429	12,051	17,146	21,357	21,957	22,216	21,709	21,863	21,868	22,907	23,252	22,682	21,960	21,239	a5
Indigenous NG	kt-C	551	661	848	1,190	1,603	1,635	1,557	1,498	1,479	1,435	1,415	1,347	1,187	1,048	991	a6
Input total	kt-C	9,577	12,827	15,068	19,601	23,834	24,544	24,746	24,205	24,390	24,159	25,205	25,589	24,879	24,028	23,243	A: Σa
<b>Output</b>																	
City gas	PJ	664.7	892.3	1,061.1	1,392.0	1,700.3	1,750.3	1,764.1	1,724.3	1,737.3	1,722.1	1,796.5	1,822.5	1,781.9	1,720.8	1,664.7	B
EF City gas	t-C/TJ	14.4	14.4	14.2	14.1	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	A/B

### ➤ Oxidation factor

For each type of energy, country-specific oxidation factors were established considering the actual conditions of fuel combustion in Japan based on survey on related industrial associations, manufacturing corporations and experts.

#### Gaseous Fuels

Every measurement result of soot concentration of boilers to generate power by the Federation for Electric Power Companies Japan (FEPC) in 2004 for gaseous fuels combustion showed that no soot was emitted; therefore, it is assumed that gaseous fuels are completely combusted. The results of questionnaires also showed that gaseous fuels were completely combusted. Hence, the oxidation factor for gaseous fuel combustion was set to 1.0.

#### Liquid Fuels

The carbon contained in liquid fuels is considered to be almost completely combusted; however, unburned fuel loss, about 0.5%, may occur depending on its fired condition. Because data of actual measurements were not available, considering meticulous combustion management and smoke treatment in Japan, the oxidation factor for liquid fuels combustion was set to 1.0.

#### Solid Fuels

The oxidation factor for solid fuels varies depending on the fired condition, type of furnace, and coal property; therefore, it is quite difficult to obtain a representational data set of actual measurements of unburned fuel loss. Meanwhile, almost all the unburned carbon generated during combustion in furnace is considered to be contained in coal ash. Coal ash is effectively utilized or landfilled. Carbon contained in coal ash which is used as raw material of cement is oxidized to CO<sub>2</sub> and emitted into the atmosphere during the calcinations process.

The average oxidation factor from 1990 to 2003 considering unburned carbon oxidized in the firing process of coal ash was 0.996, expressed as 3 digits. Usually 2 digits are considered to be adequate in the view of other coefficients' accuracy; therefore, the oxidation factor for solid fuels was set to 1.0 rounded off to two digits.

### ● Activity Data

The fuel consumption data given in the *General Energy Statistics* were used for the activity data. Table 3-17 shows the trend of energy consumption.

Table 3-17 Energy consumptions in Energy Industries (1.A.1) (unit: PJ)

Fuel	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Liquid fuels	2,596	2,198	1,618	1,669	1,352	1,885	2,166	1,866	1,465	1,312	1,168	1,032	895	795	680
Solid fuels	1,235	1,542	1,951	2,586	2,757	2,655	2,835	3,121	3,061	3,038	3,039	3,096	2,917	2,850	2,744
Gaseous fuels	1,564	1,786	2,167	2,021	2,624	3,266	3,475	3,488	3,552	3,300	3,394	3,218	3,033	2,846	2,925
Other fossil fuels	IE	IE	0.3	5	5	5	5	0.1	1	1	1	1	1	1	1
Biomass	0.04	0.1	0.1	26	28	28	28	31	32	32	48	84	92	140	156
Total	5,395	5,526	5,737	6,308	6,766	7,838	8,510	8,506	8,111	7,683	7,649	7,432	6,938	6,632	6,507

Note: Fuel type is in accordance with the Common Reporting Format (CRF).

The *General Energy Statistics* (Energy Balance Table) provides a comprehensive overview of domestic energy supply and demand to grasp what are converted from energy sources, such as coal, oil, natural gas and others, provided in Japan, and what are consumed in what sectors. The objective of this *General Energy Statistics* is to help to quantitatively understand energy supply and demand and to make judgments about the situation, in addition to helping with planning for energy and environmental policy, and with measuring, assessing, and otherwise gauging policy effectiveness.

The *General Energy Statistics* shows the main energy sources used in Japan as “Columns” and the supply, conversion and consumption sectors as “Rows” in a matrix. Specifically, the columns comprise 13 major categories (coal, coal products, crude oil, oil products, natural gas, city gas, renewable energy (excl. hydro), hydraulic power generation (excl. pumped), pumped storage, effective recovery use of wasted energy, nuclear power generation, electricity, and heat) and the necessary sub-categories and a more detailed breakdown of the sub-categories. The rows comprise 3 major sectors: primary energy supply (primary supply), energy transformation & own use (conversion), and final energy consumption (final consumption). The rows also contain the necessary sub-categories and a more detailed breakdown of the sub-categories.

In calculating the energy supply and demand amounts for the *General Energy Statistics*, it is assumed that each energy source, such as gasoline or electricity, is homogeneous in terms of gross calorific value per original unit (MJ/kg, MJ/l, MJ/m<sup>3</sup>), and that homogeneous energy sources are supplied, converted and consumed. The values for supply, conversion and consumption in original units as determined from official statistical sources are multiplied by the gross calorific value per original unit to obtain energy supply and demand amounts.

The calculation process in the *General Energy Statistics* is as follows:

- (1) Setting calorific values and carbon emission factors.
- (2) Building an energy supply and demand module.
- (3) Preparing original unit tables (preparing a detailed table, a main table and a summary table through the module from relevant official statistics) (units in t, kL, 10<sup>3</sup> m<sup>3</sup>, etc.).
- (4) Preparing energy unit tables (unit in J).
- (5) Preparing energy-derived carbon tables (carbon content).

The *General Energy Statistics* adopts “actual calorific values” calculated based on annual official statistics for some fuel types which can be recalculated. For other fuel types which cannot be recalculated and whose composition is stable, “standard calorific values” based on latest measurement data available at the time, relevant official statistics and documents are adopted.

The complete Energy Balance Tables for the years since FY1990 are available on the following internet

site:

[https://www.enecho.meti.go.jp/statistics/total\\_energy/results.html#headline2](https://www.enecho.meti.go.jp/statistics/total_energy/results.html#headline2) (Japanese version only)

Please refer to the simplified energy balance tables provided in Annex 4 (A4.2).

For the activity data for energy industries, the data reported in the following sectors in the *General Energy Statistics* were used: “manufacture of coal products” [#210000]; “oil products” [#220000]; “gas conversion and production” [#230000]; “power generation” [#240000] which reports energy consumption associated with electric power generation by electric power suppliers; “district heat supply” [#270000] which provides energy consumption associated with heat energy and cold energy by thermal energy suppliers; “own use, coal products” [#301100] which reports energy consumption associated with captive (own) use of energy industries; “own use, oil products” [#301200]; “own use, gas conversion and production” [#301300]; “own use, power generation” [#301400]; “own use, district heat supply” [#301500].

In addition, fossil fuel consumption of “Auto power production” in “production, transmission and distribution of electricity” [#255330] is also included in the energy industries from FY1990 to FY2015. This is because electricity utilities whose main business is power generation should be included in public electricity and heat production (1.A.1.a) in accordance with the *2006 IPCC Guidelines*, and “production, transmission and distribution of electricity” until FY2015 mainly includes independent power producers (IPP) whose main business is power generation. Since the definition and coverage of the sector of “Electric Utilities” was changed due to the enforcement of the revised Electricity Business Act, which stipulates the full liberalization of the electricity retail market in April 2016, electricity utilities whose main business is power generation such as IPP from FY2016 onwards are included in not “production, transmission and distribution of electricity” [#255330] but “power generation” [#240000].

Table 3-18 shows the correspondence between the sectors of Japan’s Energy Balance Table from the *General Energy Statistics* and those of the CRF.

Table 3-18 Correspondence between sectors of Japan’s Energy Balance Table and those of the CRF (1.A.1)

CRF		General Energy Statistics	
1A1	Energy industries		
	1A1a Public electricity and heat production	Public Power generation	#240000
		Own use; Public Power generation	#301400
		District heat supply	#270000
		Own use; District heat supply	#301500
		Auto power generation; Production, transmission and distribution of electricity (until 2015)	#255330
	1A1b Petroleum refining	Oil products	#220000
		Own use; Oil products	#301200
		Auto power generation; Manufacture of petroleum products	#253171
		Auto steam generation, Manufacture of petroleum products	#263171
		Final energy consumption, Manufacture of petroleum products	#626510
		Non-energy and feedstock use; Manufacture of petroleum products	#951540
	1A1c Manufacture of solid fuels and other energy industries	Manufacture of coal products	#210000
		Own use; Coal products	#301100
		Auto power generation; Manufacture of coal products and miscellaneous	#253175
		Auto steam generation, Manufacture of coal products and miscellaneous	#263175
		Final energy consumption; Manufacture of coal products and miscellaneous	#626550
		Gas conversion and production	#230000
		Own use; Gas conversion and production	#301300

Note: #95xxxx items are subtracted as non-energy use activities.

➤ *Gross calorific value*

The gross calorific values used in *General Energy Statistics* are adopted. Table 3-19 shows the trends

in gross calorific value for each fuel type. *General Energy Statistics* adopts actual calorific values calculated based on annual official statistics for some fuel types which can be recalculated. For other fuel types which cannot be recalculated and whose composition is stable, “standard calorific values” based on latest measurement data available at the time, relevant official statistics and documents are adopted.

The "standard calorific values" are revised approximately once in every 5 years. The revision was conducted to the values of FY2000, 2005, 2013 and 2018.

The gross calorific value (GCV) trends for solid fuels are declining since 1990. From 1970 to 1990, Japanese steel manufacturers used conventional coking coal for feedstock for coke, but due to the shortage of coking coal and the increase of price, they developed a new coke making technology to use steam coal with pre-treatment as feedstock for coke instead. Similarly, they changed PCI coal from coking coal and steam coal mixture to steam coal with pre-treatment. The Japanese steel manufacturers have been trying to make high-quality coke from cheap coal for economic reasons. Because conventional coking coal has a higher carbon content and GCV than steam coal, and because the new technology was introduced gradually, the apparent GCV gradually decreased in these years.





derived from the actual measurements of carbon emission factors. The upper and lower limits of uncertainties of activity data are set by the standard deviations of the statistical discrepancies [#400000] divided by domestic primary energy supply [#190000] from 1990 to 2017 for solid, liquid and gaseous fuels respectively, taking account of difficulty to set the uncertainties of energy consumption by each fuel and sector from the *General Energy Statistics*, or the reference of activity data. As a result, the uncertainty was determined to be -4% to +2% for CO<sub>2</sub> emissions from combustion of solid, liquid and gaseous fuels as a whole for the fuel combustion category. See section 7.4.3 for the uncertainty of CO<sub>2</sub> emissions from waste incineration for energy purposes and with energy recovery.

● **Time-series Consistency**

The emissions were calculated in a consistent manner in all time-series.

The carbon emission factors of all energy sources have been calculated by a consistent estimation method in all time-series.

The activity data was used from data in the *General Energy Statistics* in all time-series, and the statistics were made by a consistent estimation method in all time-series.

The fossil fuel consumption of “Production, Transmission and Distribution of Electricity” [#255330] under “Auto power production” of the *General Energy Statistics* for the period of FY1990 through FY2015 are included in the activity data of Public electricity and heat production subcategory (1.A.1.a) in light of time-series consistency. See the Activity Data section under 3.2.4. b).

**d) Category-specific QA/QC and Verification**

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

**e) Category-specific Recalculations**

Due to the updates of the activity data and the emission factors based on the update of the *General Energy Statistics*, the emissions for the period of FY1990-FY1992 and FY1995-FY2019 were recalculated.

Updating the statistical data and improving the estimation methodology in the waste sector, CO<sub>2</sub> emissions from other fossil fuels for the period of FY2005-FY2019 were recalculated. See section 7.4.3 for details.

See Chapter 10 for impact on trend.

**f) Category-specific Planned Improvements**

It is necessary to consider the development of the carbon emission factor of petroleum coke with the sufficient number of samples because the number of samples are insufficient to reflect Japan's circumstances during the development work of the calorific values and the carbon emission factors.

### 3.2.5. CH<sub>4</sub> and N<sub>2</sub>O Emissions from Energy Industries (1.A.1.: CH<sub>4</sub>, N<sub>2</sub>O)

**a) Category Description**

This section provides the methods for estimating CH<sub>4</sub> and N<sub>2</sub>O emissions from public electricity and

heat production (1.A.1.a), petroleum refining (1.A.1.b), and manufacture of solid fuels and other energy industries (1.A.1.c).

CH<sub>4</sub> is generated as a result of incomplete combustion, and as such, if sufficient care is taken to ensure complete combustion, CH<sub>4</sub> will not be generated. N<sub>2</sub>O is generated through the reaction of NO, which is generated by combustion, with nitrogen-containing volatile components in fuels. Consequently, the higher the nitrogen content of the fuel used, the more likely it is that N<sub>2</sub>O will be generated. However, the reaction that produces N<sub>2</sub>O is also dependent on temperature, with N<sub>2</sub>O more likely to be generated at lower temperatures. More N<sub>2</sub>O will accordingly be generated by furnaces such as fluidized bed boilers that burn fuel at low temperatures (800–900°C). N<sub>2</sub>O can also be generated when NO<sub>x</sub> contacts catalysts for NO<sub>x</sub> removal.

The contribution of CH<sub>4</sub> and N<sub>2</sub>O emissions from this category relative to total GHG emissions is small in Japan. The N<sub>2</sub>O emissions from fluidized bed boilers are relatively large in this category. The N<sub>2</sub>O emissions from fluidized bed boilers contribute to the increase of GHG emissions from this category, since fluidized bed boilers have been introduced in Japan from 1990.

The N<sub>2</sub>O emissions from solid fuel in 1.A.1.a (Public electricity and heat production) increased between FY1994 and FY1995. The reason for the increase was that a new large sized fluidized-bed boiler for power generation was introduced in FY1995. As a result, the solid fuel consumption of fluidized-bed boilers for public power generation increased in FY1995, resulting in an increase of N<sub>2</sub>O emissions from solid fuels in this category.

CH<sub>4</sub> emitted in coke production is reported in this category. We have no measurements of the concentration of N<sub>2</sub>O in the gas leaking from coking furnace lids, but we decided that N<sub>2</sub>O emissions from this source are not applicable the reason being that experts say that N<sub>2</sub>O is likely not produced because the atmosphere in a coke oven is normally at least 1,000°C, and is reducing.

## b) Methodological Issues

### ● Estimation Method

#### ➤ Furnaces

Because it is possible to use fuel-specific, sector-specific and furnace-specific activity data, and also to set country-specific emission factors by furnace, CH<sub>4</sub> and N<sub>2</sub>O emissions from fuel combustion in this category are calculated by using Tier 3 method in accordance with the decision tree of the *2006 IPCC Guidelines* (Vol.2, Page 1.9, Fig. 1.2).

The estimation equation is as follows. The emissions were calculated by multiplying fuel-specific, furnace-specific and sector-specific activity data by fuel-specific and furnace-specific emission factors.

$$E = \sum_{ij} (EF_{ij} \times A_{ijk})$$

$E$  : Emissions from combustion of fuel by stationary sources [kg-CH<sub>4</sub>, kg-N<sub>2</sub>O]

$EF_{ij}$  : Emission factor for fuel type  $i$ , furnace type  $j$  [kg-CH<sub>4</sub>/TJ, kg-N<sub>2</sub>O/TJ]

$A_{ijk}$  : Fuel consumption for fuel type  $i$ , furnace type  $j$ , sector  $k$  [TJ]

$i$  : Fuel type

$j$  : Furnace type

$k$  : Sector

#### ➤ Biomass boilers

Because it is possible to use country-specific emission factors of power generation facility and heat

utilization facility, CH<sub>4</sub> and N<sub>2</sub>O emissions from combustion in biomass boilers are calculated by using Tier 3 method in accordance with the decision tree of the *2006 IPCC Guidelines* (Vol.2, Page 1.9, Fig. 1.2). However, CH<sub>4</sub> and N<sub>2</sub>O emissions of gas biomass are calculated by using Tier 1, as country-specific emission factors are not available.

➤ *Coke Production*

CH<sub>4</sub> emissions from coke production were calculated by multiplying coke production amount by Japan's country-specific emission factor, based on the method given in the *2006 IPCC Guidelines*.

➤ *Incineration of waste for energy purposes and with energy recovery*

See section 7.4.3

● **Emission Factors**

➤ *Furnaces*

Chimney flue CH<sub>4</sub>, N<sub>2</sub>O and O<sub>2</sub> concentrations, theoretical (dry) exhaust gas volumes, theoretical air volumes, and higher heating values (gross calorific values (GCV)) shown in Table 3-20 were employed based on data obtained from surveys conducted in Japan (Table 3-21) to establish emission factors for each kind of facility using the following combustion calculation formula.

$$EF = C_{CH_4, N_2O} \times \{G_0' + (m - 1) \times A_0\} \times MW / V_m / GCV$$

<i>EF</i>	: Emission factor [kg-CH <sub>4</sub> /TJ, kg-N <sub>2</sub> O/TJ]
<i>C<sub>CH<sub>4</sub> or N<sub>2</sub>O</sub></i>	: CH <sub>4</sub> or N <sub>2</sub> O concentration in exhaust gas [ppm]
<i>G<sub>0</sub>'</i>	: Theoretical exhaust gas volume for each fuel combustion (dry) [m <sup>3</sup> N/ original unit]
<i>A<sub>0</sub></i>	: Theoretical air volume for each fuel combustion [m <sup>3</sup> N/ original unit]
<i>m</i>	: Air ratio = actual air volume/ theoretical air volume [-]
<i>MW</i>	: Molecular weight of CH <sub>4</sub> (constant)=16 [g/mol] Molecular weight of N <sub>2</sub> O(constant)=44 [g/mol]
<i>V<sub>m</sub></i>	: One mole ideal gas volume in standardized condition (constant) =22.4 [10 <sup>-3</sup> m <sup>3</sup> /mol]
<i>GCV</i>	: Gross calorific value for each fuel combustion [MJ/ original unit]

However, the air ratio “*m*” is approximately provided with O<sub>2</sub> concentration in exhaust gas, as shown in the equation below.

$$m = \frac{21}{21 - C_{O_2}}$$

<i>C<sub>O<sub>2</sub></sub></i>	: O <sub>2</sub> concentration in exhaust gas [%]
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CH<sub>4</sub> and N<sub>2</sub>O emission factors by each fuel and furnace types were averaged after dividing the emission factor of each kind of facilities according to fuel and furnace types (Table 3-22, Table 3-23). Anomalous values were excluded according to t-testing or expert judgment when calculating the average values. Please refer to MOE (2006a) for the actual measurement data to establish the emission factors.

- **Emission Factors with Air-Intake Adjustment**

In Japan, until the GHG inventory was submitted in 2005, based on the results of past discussions (e.g., Japan Society for Atmospheric Environment (1996) relating to methodologies for calculating emissions, the non-CO<sub>2</sub> emission factors from stationary combustion were established after accounting for the differences between emission gas concentrations and intake gas concentrations (i.e., air-intake adjustment). With this methodology, it was possible to obtain negative emission factors for some

emission sources if the measurement data showed that concentrations in emission gas were lower than those in intake gas, possibly because CH<sub>4</sub> and N<sub>2</sub>O present in the intake gas had been either oxidized or decomposed through the combustion process.

However, during the in-country review that was conducted in 2003, the Expert Review Team recommended Japan to replace negative emission factors by the corresponding positive ones, because, in the interest of enabling better international comparisons, the *Revised 1996 IPCC Guidelines* as well as *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (hereinafter referred to as *GPG (2000)*) indicate that positive emission factors should be used for calculations of emissions based on actual emissions of CH<sub>4</sub> and N<sub>2</sub>O in the flue gases, though air-intake adjustments might enable accurate determination of emissions. Thus, in the inventories submitted in 2006 and thereafter, the air-intake adjustments were not made, and emission factors were determined by using the actual measured CH<sub>4</sub> and N<sub>2</sub>O concentrations in emission gases.

Table 3-20 Theoretical exhaust gas and air volumes, and higher heating values for different fuels

Fuel type	Original unit	Theoretical exhaust gas volume (dry)	Gross calorific value	Theoretical air volume	Remarks
		$G_0^{1)}$	$GCV^{2)}$	$A_0^{1)}$	
		m <sup>3</sup> N/L, kg, m <sup>3</sup> N	kJ/L, kg, m <sup>3</sup> N, kWh	m <sup>3</sup> N/L, kg, m <sup>3</sup> N	
Fuel oil A	L	8.900	39,100	9.500	a
Fuel oil B	L	9.300	40,400	9.900	a
Fuel oil C	L	9.500	41,700	10.100	a
Diesel oil	L	8.800	38,200	9.400	a
Kerosene	L	8.400	36,700	9.100	a
Crude oil	L	8.747	38,200	9.340	a
Naphtha	L	7.550	34,100	8.400	a
Other liquid fuels	L	9.288	37,850	9.687	b
Other liquid fuels (heavy)	L	9.064	37,674	9.453	b
Other liquid fuels (light)	L	9.419	35,761	9.824	b
Steam coal	kg	7.210	26,600	7.800	a
Coke	kg	7.220	30,100	7.300	a
Harvested wood	kg	3.450	14,367	3.720	b
Charcoal	kg	7.600	30,500	7.730	c
Other solid fuels	kg	7.000	33,141	7.000	b
City gas	m <sup>3</sup>	9.850	46,047	10.949	b
Coke oven gas (COG)	m <sup>3</sup>	4.500	21,100	4.800	a
Blast furnace gas (BFG)	m <sup>3</sup>	1.460	3,410	0.626	a
Liquefied natural gas (LNG)	kg	11.766	54,500	13.093	a
Liquefied petroleum gas (LPG)	kg	11.051	50,200	12.045	a
Converter furnace gas (CFG) (Linz-Donawitz gas: LDG)	m <sup>3</sup>	2.200	8,410	1.500	a
Refinery gas (off-gas)	m <sup>3</sup>	11.200	44,900	12.400	a
Other gaseous fuels	m <sup>3</sup>	4.587	28,465	4.096	b
Other gaseous fuels (petroleum)	m <sup>3</sup>	7.889	40,307	7.045	b
Other gaseous fuels (steel)	m <sup>3</sup>	2.812	19,097	2.511	b
Other gaseous fuels (mining)	m <sup>3</sup>	3.396	38,177	3.032	b
Other gaseous fuels (other)	m <sup>3</sup>	4.839	23,400	4.321	b
Pulping waste liquor	kg	3.245	13,898	3.499	b
Electricity	kWh		3,600		a

Note:

- 1) Theoretical exhaust gas and air volumes are the standard values given in the *General Survey of the Emissions of Air Pollutants* (MOE), except for city gas, LNG, and LPG, for which values calculated from constituent data were used. For city gas, the constituents of city gas (13A) were considered to be representative.
- 2) Regarding higher heating value, the standard calorific values given in the *General Energy Statistics* were used for items marked a, and the standard values given in *General Survey of the Emissions of Air Pollutants* (based on the 1992 survey) for items marked b in the Remarks column. The higher heating value for steam coal (imported) was used as the higher heating value of steam coal. The item marked c in the Remarks column was set by the 2005 Committee for the Greenhouse Gases Emissions Estimation Methods based on reference materials.

Table 3-21 References for measurement data used in the establishment of emission factors

	References
1	Hokkaido Prefecture, <i>Report of GHG Emissions Intensity from Stationary Combustion</i> , 1991
2	Hyogo Prefecture, <i>Report of GHG Emissions Intensity from Stationary Combustion</i> , 1991
3	Osaka Prefecture, <i>Study of GHG Emissions Intensity from Stationary Combustion</i> , 1991
4	Hokkaido Prefecture, <i>Report of GHG Emissions Intensity from Stationary Combustion</i> , 1992
5	Hyogo Prefecture, <i>Report of GHG Emissions Intensity from Stationary Combustion</i> , 1992
6	City of Kitakyushu, <i>Report of GHG Emissions Intensity from Stationary Combustion</i> , 1992
7	Hyogo Prefecture, <i>Study of GHG Emission Factors from Stationary Combustion</i> , 1993
8	Hyogo Prefecture, <i>Report of GHG Emissions Intensity from Stationary Combustion</i> , 1994
9	Kanagawa Prefecture, <i>Study of GHG Emission Factors from Stationary Combustion</i> , 1995
10	Niigata Prefecture, <i>Study of GHG Emission Factors from Stationary Combustion</i> , 1995
11	Osaka Prefecture, <i>Study of GHG Emission Factors from Stationary Combustion</i> , 1995
12	Hiroshima Prefecture, <i>Study of GHG Emission Factors from Stationary Combustion</i> , 1995
13	Fukuoka Prefecture, <i>Report of GHG Emission Factors from Stationary Combustion</i> , 1995
14	City of Osaka, <i>Study of GHG Emission Factors from Stationary Combustion</i> , 1995
15	City of Kobe, <i>Study of GHG Emission Factors from Stationary Combustion</i> , 1995
16	Hokkaido Prefecture, <i>Study of GHG Emission Factors from Stationary Combustion</i> , 1996
17	Ishikawa Prefecture, <i>Study of GHG Emission Factors from Stationary Combustion</i> , 1996
18	Kyoto Prefecture, <i>Study of GHG Emission Factors from Stationary Combustion</i> , 1996
19	Osaka Prefecture, <i>Study of GHG Emission Factors from Stationary Combustion</i> , 1996
20	Hyogo Prefecture, <i>Study of GHG Emission Factors from Stationary Combustion</i> , 1996
21	Hiroshima Prefecture, <i>Study of GHG Emission Factors from Stationary Combustion</i> , 1996
22	Fukuoka Prefecture, <i>Report of GHG Emission Factors from Stationary Combustion</i> , 1996
23	Kyoto Prefecture, <i>Report of GHG Emission Factors from Stationary Combustion</i> , 1997
24	Hyogo Prefecture, <i>Study of GHG Emission Factors from Stationary Combustion</i> , 1997
25	Fukuoka Prefecture, <i>Report of GHG Emission Factors from Stationary Combustion</i> , 1997
26	Japan Society for Atmospheric Environment, <i>Report on Emission Factor Results for Combustion Facilities</i> , 1996
27	Osaka Prefecture, <i>Study of GHG Emission Factors from Stationary Combustion</i> , 1999
28	Hyogo Prefecture, <i>Report of GHG Emission Factors from Stationary Combustion</i> , 2000
29	The Institute of Applied Energy, <i>Report for Trend of Fuel Quality in Lowering Environmental Atmospheric Quality</i> , 2000
30	MOE, Measurement Data prepared by the Committee for the Greenhouse Gases Emissions Estimation Methods in FY1999, 1999
31	Data prepared by the Federation of Electric Power Companies of Japan
32	IPCC, <i>2006 IPCC Guidelines</i> , 2006
33	Forestry Agency Wood Use Promotion Division, <i>Promotion of Wood Use and Energy-saving and CO<sub>2</sub> Reduction Demonstration Project Fiscal Year 2014</i> , 2015
34	MOE, <i>Survey on Grasp of the Actual Condition of Greenhouse Gas Emissions from Biomass Boilers Fiscal Year 2017</i> , 2018

Table 3-22 CH<sub>4</sub> emission factors for different fuels and furnaces in GCV basis (unit: kg-CH<sub>4</sub>/TJ)

Fuel	Code	Boilers		Industrial furnaces								Internal combustion engines					
		Boiler	Sintering furnace for smelting of metals (except copper, lead, and zinc)	Pelletizing furnace (steel and non-ferrous metal)	Blast furnace, converter furnace and open-hearth furnace (steel and non-ferrous metal)	Metal rolling furnace, metal treating furnace, metal forging furnace	Petroleum and gas furnaces	Catalytic regenerator	Brick kiln, ceramic kiln, and other kiln	Aggregate drying kiln, cement raw material drying kiln, brick raw material drying kiln	Other drying kilns	Other industrial furnaces	Gas turbine	Diesel engine	Gas engine, petrol engine		
Coal	Steel Making Coal	S0110	0.13	31	1.7	NA	13	13	NA	1.5	29	6.6	13	NA	NA	NA	
	Coking Coal	S0111															
	Pulverized Coal Injection Coal	S0112															
	Imported Steam Coal	S0121															
	Imported Coal for General Use	S0122															
	Imported Coal for Power Generation	S0123															
	Indigenous Produced Steam Coal	S0124															
Hard Coal, Anthracite & Lignite	S0130																
Coal Products	Coke	S0211	0.13	31	1.7	NA	13	13	0.054	1.5	29	6.6	13	NA	NA	NA	
	Coal Tar	S0212															
	Coal Briquette	S0213															
	Coke Oven Gas	S0221															
	Blast Furnace Gas	S0222															
	Converter Furnace Gas	S0225															
Oil	Crude Oil for Refinery	S0310	0.10	31	1.7	NA	0.43	0.16	NA	1.5	29	6.6	0.83	0.81	0.70	54	
	Crude Oil for Power Generation	S0320															
	Bituminous Mixture Fuel	S0321															
	Natural Gas Liquid & Condensate	S0330															
Oil Products	Pure Naphtha	S0420	0.26	31	1.7	NA	0.43	0.16	NA	1.5	29	6.6	0.83	0.81	0.70	54	
	Reformate	S0421															
	Gasoline	S0431															
	Jet Fuel Oil	S0432															
	Kerosene	S0433															
	Gas Oil / Diesel Oil	S0434															
	Fuel Oil A	S0436															
	Fuel Oil C	S0437															
	Fuel Oil B	S0438															
	Fuel Oil C for General Use	S0439															
	Fuel Oil C for Power Generation	S0440															
	Lubricant Oil	S0451															
	Other Heavy Oil Products	S0452															
	Petroleum Coke	S0455															
Natural Gas	Liquefied Natural Gas	S0510	0.23	31	1.7	NA	0.43	0.16	NA	1.5	29	6.6	2.3	0.81	0.70	54	
	Indigenous Natural Gas	S0520															
	Indigenous Natural Gas	S0521															
	Coal Mining Gas	S0522															
	Boil Off Gas from Crude Oil	S0523															
	Galvanic Furnace Gas	S0456															
Refinery Gas	S0457																
Liquified Petroleum Gas	S0458																
City Gas	City Gas	S0610	0.23	31	1.7	NA	0.43	0.16	NA	1.5	29	6.6	2.3	0.81	0.70	54	
	Small Scale Community Gas	S0620															
Biomass Energy	Woods	Power generation	SN131	0.2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
		Heat utilization		16	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Waste Wood	Power generation	SN132	0.2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		Heat utilization		16	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Thermal Use of Black Liquor	SN136	4.3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Gas Biomass	SN137	0.9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Non Specified Biomass	SN138	16	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 3-23 N<sub>2</sub>O emission factors for different fuels and furnaces in GCV basis (unit: kg-N<sub>2</sub>O/TJ)

Fuel	Code	Boilers			Industrial furnaces					Internal-combustion engines																						
		Boiler (other than fluidized-bed boiler)	Normal pressure fluidized-bed boiler	Pressurized fluidized-bed boiler	Blast furnace	Petroleum and gas furnaces	Catalytic regenerator	Coke oven	Other industrial furnace	Gas turbine	Diesel engine	Gas engine, petrol engine																				
Coal	Steel Making Coal	\$0110	0.85	54	0.85	NA	1.1	NA	NA	1.1	NA	NA	NA																			
	Coking Coal	\$0111																														
	Pulverized Coal Injection Coal	\$0112																														
	Imported Steam Coal	\$0121																														
	Imported Coal for General Use	\$0122																														
	Imported Coal for Power Generation	\$0123																														
	Indigenous Produced Steam Coal	\$0124																														
Hard Coal, Anthracite & Lignite	\$0130	0.85																														
Coal Products	Coke	\$0211	0.85	54	0.85	NA	1.1	7.3	NA	1.1	NA	NA	NA																			
	Coal Tar	\$0212																														
	Coal Briquette	\$0213																														
	Coke Oven Gas	\$0221																														
	Blast Furnace Gas	\$0222												0.17	0.17	0.17	0.047	0.21	NA	0.14	1.2	0.58	2.2	0.85								
	Converter Furnace Gas	\$0225												NA																		
Oil	Crude Oil for Refinery	\$0310	0.22	0.22	0.22	NA	0.21	NA	NA	1.8	0.58	2.2	0.85																			
	Crude Oil for Power Generation	\$0320																														
	Bituminous Mixture Fuel	\$0321																														
	Natural Gas Liquid & Condensate	\$0330																														
Oil Products	Pure Naphtha	\$0420	0.19	0.19	0.19	NA	0.21	NA	NA	1.8	0.58	2.2	0.85																			
	Reformate	\$0421																														
	Gasoline	\$0431																														
	Jet Fuel Oil	\$0432																														
	Kerosene	\$0433																														
	Gas Oil / Diesel Oil	\$0434																														
	Fuel Oil A	\$0436																														
	Fuel Oil C	\$0437												0.22	0.22	0.22	NA	1.15	7.3	1.1	NA	NA	NA									
	Fuel Oil B	\$0438																														
	Fuel Oil C for General Use	\$0439																														
	Fuel Oil C for Power Generation	\$0440																														
	Lubricant Oil	\$0451												0.19	0.19	0.19	NA	0.21	NA	0.14	1.2	0.58	2.2	0.85								
	Other Heavy Oil Products	\$0452												0.85	54	0.85																
	Petroleum Coke	\$0455																														
Galvanic Furnace Gas	\$0456																															
Refinery Gas	\$0457	0.17	0.17	0.17																												
Liquefied Petroleum Gas	\$0458	0.17	0.17	0.17	NA	0.21	NA	0.14	1.2	0.58	2.2	0.85																				
Liquefied Natural Gas	\$0510																															
Indigenous Natural Gas	\$0520																															
Indigenous Natural Gas	\$0521																															
Coal Mining Gas	\$0522																															
Boil Off Gas from Crude Oil	\$0523																															
City Gas	City Gas												\$0610	0.17	0.17	0.17									NA	0.21	NA	0.14	1.2	0.58	2.2	0.85
	Small Scale Community Gas												\$0620																			
Biomass Energy	Woods												Power generation	\$N131	0.87	0.87									0.87	NA	NA	NA	NA	NA	NA	NA
													Heat utilization	\$N131	1.60	1.60	1.60	NA	NA	NA	NA	NA	NA	NA	NA							
	Waste Wood												Power generation	\$N132	0.87	0.87	0.87	NA	NA	NA	NA	NA	NA	NA	NA							
													Heat utilization	\$N132	1.60	1.60	1.60	NA	NA	NA	NA	NA	NA	NA	NA							
	Thermal Use of Black Liquor												\$N136	0.17	0.17	0.17	NA	NA	NA	NA	NA	NA	NA	NA								
	Gas Biomass												\$N137	0.09	0.09	0.09	NA	NA	NA	NA	NA	NA	NA	NA								
	Non Specified Biomass	\$N138	1.60	1.60	1.60	NA	NA	NA	NA	NA	NA	NA	NA																			

➤ *Biomass boilers*

CH<sub>4</sub> and N<sub>2</sub>O emission factors by each fuel and each facility in biomass boilers are shown in Table 3-22 and Table 3-23.

The country-specific emission factors of woods, waste woods and non-specified biomass were established based on the actual measurements from MOE (2018) and Forestry Agency (2015), considering the utilization situation of woody biomass.

The emission factors of black liquor were established by using theoretical (dry) exhaust gas volumes, theoretical air volumes, and higher heating values shown in Table 3-20.

For the emission factors of gas biomass, the default values of the *2006 IPCC Guidelines* (Vol.2, page 2.16-2.23, table 2.2-2.5) were adopted. As the default values are based on net calorific values, they were converted to the GCV basis by multiplying them by 0.9 (for fuels with gaseous state) (*2006 IPCC Guidelines*, Vol.2, page 1.16).

➤ *Coke production*

CH<sub>4</sub> emissions from coke production come from two sources: CH<sub>4</sub> in combustion exhaust gas from gas leakage from the carbonization chamber to the combustion chamber, and CH<sub>4</sub> emitted from the coking furnace lid, the desulfurization tower, or the desulfurization recycling tower, in the carbonization process of coal.

- *Combustion exhaust gas*

The concentration of CH<sub>4</sub> in the exhaust gas from coking furnaces operated by five companies at seven operating sites (surveyed by the Japan Iron and Steel Federation, actual results for FY1999) was weighted by the production amount of coke to derive a weighted average, which was established as the emission factor. The emission factor is 0.089 [kg-CH<sub>4</sub>/t].

- *Coking furnace lid, desulfurization tower, and desulfurization recycling tower*

The Japan Iron and Steel Federation has had a voluntary plan in place since fiscal year 1997 to manage noxious atmospheric pollutants, and CH<sub>4</sub> emissions have been estimated from emissions of other substances from the lid of coking furnaces. The emission factor has been established by taking a weighted average using this data and the amount of production of coke.

Table 3-24 Emission factor of CH<sub>4</sub> from coking furnace lids, desulfurization towers, and desulfurization recycling towers

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
CH <sub>4</sub> EFs	kgCH <sub>4</sub> /t	0.238	0.238	0.119	0.043	0.031	0.042	0.045	0.039	0.038	0.036	0.033	0.031	0.027	0.030	0.030

Reference: Japan Iron and Steel Federation data

Note: Emission factor change is assumed to be small for FY1990-1996. Therefore, actual data values for FY1995 is used for other years with no data. For FY1997-1999, it is assumed that values for 1998 and 1999 are the same as those of 1997 (0.18). For FY2000 and on, actual data values are adopted.

- *CH<sub>4</sub> emission factor for coke production*

The aforementioned Combustion Exhaust Gas and Coking Furnace Lids, Desulfurization Towers, and Desulfurization Recycling Towers have been added, and the resulting figure has been used as the emission factor.



## ● Activity Data

### ➤ Furnaces

In the estimation of the activity data, data on the *General Survey of the Emissions of Air Pollutants* (MOE) (see next page for the outline of this survey), which provides details of the fuel consumption for each type of furnace and fuel, and data on each fuel consumption statistics (*Yearbook of the Current Survey of Energy Consumption in the Selected Industries* (METI), *Structural Survey of Energy Consumption* (ANRE), *Electric Power Statistics* (ANRE), and *Current Survey of Production Concerning Gas Industry* (ANRE)) are used, because data on stationary combustion fuel consumption for each type of furnace are not available in the *General Energy Statistics*.

The fuel consumption by each sector (energy conversion, industry, commercial & others, and residential) for each type of fuels as presented in the *General Energy Statistics* was further divided among each furnace type proportionally to the fuel consumption ratio for each furnace type estimated from the *General Survey of the Emissions of Air Pollutants* and from the fuel consumption statistics to obtain the activity data for each sector, each fuel type and each furnace type. However, because the data in the *General Survey of the Emissions of Air Pollutants* do not differentiate between pressurized fluidized-bed boilers, normal pressure fluidized-bed boilers, and other boilers, the fuel consumption of these fluidized-bed boilers is calculated separately. The fuel consumption data of pressurized fluidized-bed furnaces were provided by the Federation of Electric Power Companies. The fuel consumption data of normal pressure fluidized-bed furnaces were provided from companies which had past operation records of normal pressure fluidized-bed furnaces since 1990.

The data of solid fuel boilers excluding fluidized-bed furnaces were estimated by subtracting the data of fluidized-bed furnace from the data of whole solid fuel boilers.

The *General Survey of the Emissions of Air Pollutants* for all facilities emitting soot and smoke is exhaustively carried out approximately every three years. The fuel consumption ratio for each furnace type and each fiscal year is assumed as shown in Table 3-25.

Table 3-25 Setting method of fuel consumption ratio for each furnace type

Fiscal year	Setting method
1990 – 1991	Set by linear interpolation using the FY1989 and FY1992 survey results
1992	FY1992 survey result is used
1993 – 1994	Set by linear interpolation using the FY1992 and FY1995 survey results
1995	FY1995 survey result is used
1996	FY1996 survey result is used
1997 – 1998	Set by linear interpolation using the FY1996 and FY1999 survey results
1999	FY1999 survey result is used
2000 – 2007	Set by linear interpolation using the FY1999 and FY2008 survey results
2008	FY2008 survey result is used
2009 – 2010	FY2008 survey result is intentionally used <sup>1)</sup>
2011	FY2011 survey result is used
2012 – 2013	Set by linear interpolation using the FY2011 and FY2014 survey results
2014	FY2014 survey result is used
2015 – 2016	Set by linear interpolation using the FY2014 and FY2017 survey results
2017	FY2017 survey result is used
2018 –	FY2017 survey result is intentionally used

Note:

1) The survey result of FY2011 is quite different from that of FY2008 because of the influence of the Great East Japan Earthquake which occurred on March 2011, thus the FY2008 data is intentionally used without interpolation.

The procedure for calculating activity data is as follows:

- 1) Fuel consumption data from the *General Survey of the Emissions of Air Pollutants* is collated respectively for each fuel type, furnace type and sector.
- 2) The percentage of fuel consumption accounted for by each furnace type is calculated for each fuel type and sector.
- 3) Fuel consumption for different fuel types and sectors provided in the *General Energy Statistics* is multiplied by the percentage calculated in (2) to obtain fuel-specific, furnace-specific, and sector-specific activity data.

$$A_{ijk} = A_{EBik} \times w_{ijk}$$

$$w_{ijk} = A_{MAPijk} / \sum_m A_{MAPijk}$$

$A_{EBik}$  : Fuel consumption for fuel type  $i$ , sector  $k$  from the *General Energy Statistics* [TJ]

$w_{ijk}$  : Ratio of furnace type  $j$  associated with consumption of fuel type  $i$  in sector  $k$

$i$  : Fuel type

$j$  : Furnace type

$k$  : Sector

$A_{MAPijk}$  : Fuel consumption for fuel type  $i$ , furnace type  $j$ , sector  $k$  according to the *General Survey of the Emissions of Air Pollutants* [TJ]

#### - **Outline of the General Survey of the Emissions of Air Pollutants**

The *General Survey of the Emissions of Air Pollutants* is a statistical survey conducted to (1) promote a reasonable and effective atmospheric environmental policy, (2) obtain information on current activities within the context of the Air Pollutant Control Law (e.g., the current status of regulation of stationary sources that emit soot and smoke in facilities registered to a local government and in facilities emitting ordinary soot or particular soot, and the current status of air pollutant control), (3) develop the submitted data on facilities emitting soot and smoke, and (4) estimate the amounts of air pollutant emissions from facilities that emit soot and smoke. This survey is conducted in the form of questionnaires. The response sheets and this survey's explanations are distributed to the target facilities mentioned above.

#### - **Influence of Great East Japan Earthquake on Fuel Consumption Ratio by Furnace Type**

The Great East Japan Earthquake which occurred on March 2011 largely influences the result of the *General Survey of the Emissions of Air Pollutants* in FY2011. It leads to the fluctuation of the fuel consumption ratio by furnace type in some categories in the previous and following fiscal years.

In the recommendation by UNFCCC inventory review on Japan's inventory submission in 2018 (FCCC/ARR/2018/JPN, paragraph E.12), the ERT noted that the IEFs of gaseous fuels for oil refinery category (1.A.1.b) largely reduced in CH<sub>4</sub> emissions from FY2010 (6.32 kg/TJ) to FY2011 (0.28 kg/TJ) and also in N<sub>2</sub>O emissions from FY2010 (0.42 kg/TJ) to FY2011 (0.20 kg/TJ). This is because the fuel consumption ratio by furnace type in this survey has been reflected in the activity data, and the gaseous fuel consumption by the furnaces with high emission factors such as "Gas Engine" (CH<sub>4</sub> EF: 54 kg/TJ, N<sub>2</sub>O EF: 0.85 kg/TJ) and "Other Industrial Furnaces" (CH<sub>4</sub> EF: 2.29 kg/TJ, N<sub>2</sub>O EF: 1.2 kg/TJ) is significantly reduced from FY2010 to FY2011.

On the other hand, in the same recommendation, the ERT also pointed out that the recalculated IEFs of gaseous fuels for the same category submitted in 2018 are larger than those in 2017 for FY2012-2015.

Specifically, the CH<sub>4</sub> IEFs increased by 15.3% in FY2012, by 33.9% in FY2013, by 50.7% in FY2014 and by 36.5% in FY2015 respectively, and the N<sub>2</sub>O IEFs increased by 15.1% in FY2012, by 33.0% in FY2013, by 49.4% in FY2014 and by 37.6% in FY2015 respectively. This is because, on the contrary to the former case, the fuel consumption ratio by furnace type in the *General Survey of the Emissions of Air Pollutants* in FY2014 has been adopted to the inventory in the same fiscal year. In FY2014 survey, the consumption of some gaseous fuels by furnaces with high emission factors such as “Gas Turbine” (CH<sub>4</sub> EF: 0.81 kg/TJ, N<sub>2</sub>O EF: 0.58 kg/TJ) and “Other Industrial Furnaces” (see above for EFs) have significantly increased from the FY2011 survey conducted right after the Earthquake. In the 2017 inventory submission, the fuel consumption ratio by furnace type in FY2011 survey was applied to the FY2011-2015 activity data. In the 2018 inventory submission, the fuel consumption ratio by furnace type in FY2014 survey has been reflected to the FY2014 activity data by furnace type at first, then the interpolation of fuel consumption ratio by furnace type has been adopted to FY2012-2013 activity data and FY2014 survey data has been used for FY2015 activity data. As a result of the recalculation, the emissions and the IEFs from FY2012 to FY2015 have largely increased.

➤ *Biomass boilers*

As the activity data of woods, waste woods, black liquor, gas biomass and non-specified biomass for the biomass boilers, the fuel consumption by each sector in the *General Energy Statistics* was used. It was assumed that woods and waste woods under “power generation sector” and “Auto power generation sector” of the *General Energy Statistics* were used in the power generation facilities, while those under the rest of the sectors were used in the heat utilization facilities.

➤ *Coke production*

As the activity data of CH<sub>4</sub> emissions from coke production, the coke production amount was given in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products Statistics*, and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics*.

Table 3-26 Coke production amount

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Coke production	kt	47,338	42,279	38,511	38,009	37,036	34,875	35,024	35,082	33,785	32,439	33,138	32,587	32,659	32,640	29,287

c) *Uncertainties and Time-series Consistency*

● *Uncertainties*

➤ *Furnaces (including biomass boilers)*

In case of using the default emission factor of the *2006 IPCC Guidelines*, the default uncertainties were applied. In case of using country specific emission factor, country specific uncertainties were established.

Since the uncertainty by fuel and sector of energy consumption in the *General Energy Statistics* were not available, upper value and lower value of uncertainty were established from standard deviation of the rate of statistics error of “Coal, Coal Products”, “Oil, Oil Products”, Natural Gas, LPG” and “Biomass Energy” from 1990 to 2016.

The uncertainties at furnaces were estimated to be -33% to +46% for CH<sub>4</sub> emissions and -33% to +33% for N<sub>2</sub>O emissions as a whole for the fuel combustion category.

➤ *Coke production*

For the uncertainty of the emission factor for coke production, the uncertainty of fuel combustion emissions from the coking furnace and coking furnace lids were estimated separately. The uncertainty of fuel combustion emissions from the coking furnace and coking furnace lids was estimated as 98.5% and 61.8%, respectively. For the uncertainty of activity data, the standard value of 5% given by MOE (2006a) was used.

➤ *Incineration of waste for energy purposes and with energy recovery*

See section 7.4.3

● **Time-series Consistency**

➤ *Furnaces (including biomass boilers)*

The emissions were calculated in a consistent manner in all time-series.

The emission factors for CH<sub>4</sub> and N<sub>2</sub>O have been calculated by a consistent estimation method since FY1990.

The activity data was used from data in the *General Energy Statistics* in all time-series, and the statistics were made by a consistent estimation method in all time-series. For the activity data of “Production, Transmission and Distribution of Electricity” under “Auto power generation” of the *General Energy Statistics*, see section 3.2.4. c) (1.A.1).

➤ *Coke production*

The activity data for coke production are calculated using the data from the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products Statistics*, and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics*, by a consistent method throughout the time-series from FY1990 to the most recent year. The emission factor is based on the information provided by the Japan Iron and Steel Federation estimated using a consistent methodology throughout the time-series. Therefore, CH<sub>4</sub> emissions from coke production have been estimated in a consistent manner throughout the time-series.

➤ *Incineration of waste for energy purposes and with energy recovery*

See section 7.4.3

**d) Category-specific QA/QC and Verification**

● **QA/QC**

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

● **Verification**

N<sub>2</sub>O emission factors of fuel combustion currently used are established based on the actual measurements conducted in 1990s. Since then, the change of combustion conditions due to the progress of energy saving may change the emission factors, and the necessity of periodical review of the emission factors were pointed out by the Committee for the Greenhouse Gases Emissions Estimation Methods in FY2009. In addition, the Expert Review Team strongly recommended that Japan provided additional

information in its annual submission to transparently justify the appropriateness of the measurements to the current boiler types/technologies in the individual review of the 2013 submission. (FCCC/ARR/2013/JPN)

In response to this, the actual measurement conducted in FY2009 is described here. The object of measurement was the N<sub>2</sub>O emission factor of fluidized-bed boilers combusting solid fuels. As a result, the validity of measurements in 1990s is confirmed because the result of the measurement in FY2009 is almost the same level of the emission factor based on the measurements in the 1990s.

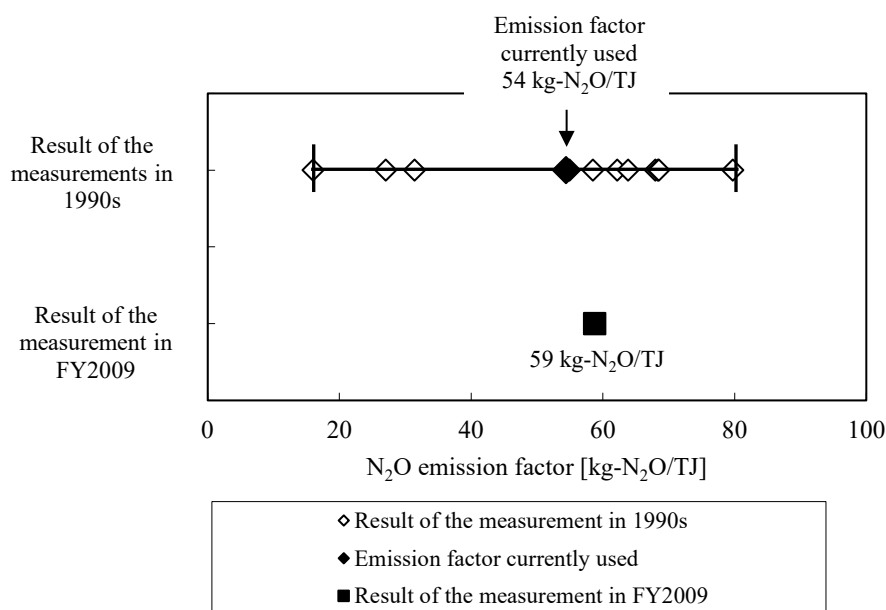


Figure 3-5 Comparison of the 1990s and FY2009 measurement results

Note: The result of the measurement in FY2009 in the figure is the average of three measurements in a boiler.

#### e) Category-specific Recalculations

Since the activity data for FY1990-1992 and FY1995-2019 in the *General Energy Statistics* were revised, the CH<sub>4</sub> and N<sub>2</sub>O emissions in those years were recalculated.

See Chapter 10 for impact on trend.

#### f) Category-specific Planned Improvements

There are no major planned improvements in this category.

### 3.2.6. CO<sub>2</sub> Emissions from Manufacturing Industries and Construction (1.A.2.: CO<sub>2</sub>)

#### a) Category Description

This section provides the estimation methods for determining CO<sub>2</sub> emissions from iron and steel (1.A.2.a); non-ferrous metals (1.A.2.b); chemicals (1.A.2.c); pulp, paper, and print (1.A.2.d); food processing, beverages, and tobacco (1.A.2.e); non-metallic minerals (1.A.2.f) and other (1.A.2.g).

In FY2020, CO<sub>2</sub> emissions from this category accounted for 233,834 kt-CO<sub>2</sub>, and represented 20.3% of Japan's total GHG emissions (excluding LULUCF). The iron and steel (1.A.2.a) accounts for 47.9%, and is the largest source within the manufacturing industries and construction category in FY2020.

## b) Methodological Issues

### ● Estimation Method

The Tier 2 Sectoral Approach has been used in accordance with the decision tree of the *2006 IPCC Guidelines* (Vol.2, Page 1.9, Fig. 1.2) to calculate emissions, as was the case for the energy industries (1.A.1). See section 3.2.4. b) (1.A.1).

The energy consumption and emissions from waste incineration with energy recovery are reported in fuel combustion (1.A.) as “other fossil fuels” and “biomass” in accordance with the *2006 IPCC Guidelines*.

The estimation method, emission factors and activity data for emissions from waste incineration with energy recovery are the same as those used in the waste incineration (5.C.) in accordance with the *2006 IPCC Guidelines*. Please refer to Chapter 7 for further details on the estimation methods.

The CO<sub>2</sub> emissions from biomass are not included in the national totals but are reported in the CRFs as reference in accordance with the *2006 IPCC Guidelines*.

### ● Emission Factors

The emission factors elaborated in the energy industries (1.A.1) are also used in this category. See section 3.2.4. b) (1.A.1).

### ● Activity Data

The data presented in the *General Energy Statistics* were used for activity data, as was the case for the energy industries (1.A.1).

Table 3-27 Energy consumptions in Manufacturing Industries and Construction category (1.A.2) (unit: PJ)

Fuel	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Liquid fuels	1,960	2,114	1,909	1,544	1,050	1,099	1,043	1,020	962	891	837	811	822	767	746
Solid fuels	2,130	2,054	2,034	2,051	2,043	1,990	2,031	2,087	2,051	2,000	1,889	1,863	1,828	1,802	1,560
Gaseous fuels	227	344	408	599	629	654	648	611	594	595	603	601	630	601	578
Other fossil fuels	86	99	115	174	203	204	210	214	221	224	221	228	233	241	244
Biomass	227	227	240	273	298	291	286	309	303	300	272	281	286	286	259
Total	4,629	4,837	4,705	4,641	4,224	4,238	4,218	4,241	4,131	4,010	3,821	3,785	3,799	3,697	3,387

The activity data for the manufacturing industry sectors were calculated by totaling the energy consumption from production activities in factories and offices (final energy consumption: #6xxxx<sup>11</sup>), energy consumption related to non-utility power generation for use in one’s own factories and offices (auto power generation: #25xxxx), and energy consumption related to steam production for use in own factories and offices (auto steam generation: #26xxxx) shown in the *General Energy Statistics*. Because the energy consumption for production activities in factories and offices contained a certain amount used as raw materials (non-energy and feedstock use: #95xxxx), this amount was subtracted.

The auto power generation and auto steam generation sectors are included in the energy transformation & own use sector in the *General Energy Statistics*. However, the *2006 IPCC Guidelines* allocates CO<sub>2</sub> emissions from energy consumption for power or steam generation to the sectors generating that power or steam. As such, these CO<sub>2</sub> emissions are added to those from each industry in the final energy consumption sector and are reported in 1.A.2.

Table 3-28 shows the correspondence between the sectors of Japan’s Energy Balance Table and those

<sup>11</sup> x indicates any number.

of the CRF (1.A.2).

Table 3-28 Correspondence between sectors of Japan's Energy Balance Table and of the CRF (1.A.2)

CRF	General Energy Statistics	
1A2 Manufacturing industries and construction		
1A2a Iron and steel	Auto power generation; Manufacture of iron and steel	#253250
	Auto steam generation; Manufacture of iron and steel	#263220
	Final energy consumption; Manufacture of iron and steel	#629100
	Non-energy and feedstock use; Manufacture of iron, steel and steel products	#951560
1A2b Non-ferrous metals	Auto power generation; Manufacture of non-ferrous metals and products	#253230
	Auto steam generation; Manufacture of non-ferrous metals and products	#263260
	Final energy consumption; Manufacture of non-ferrous metals and products	#629300
	Non-energy and feedstock use; Primary smelting and refining of copper, lead, zinc and aluminium	#951570
1A2c Chemicals	Auto power generation; Manufacture of chemical and allied products	#253160
	Auto steam generation; Manufacture of chemical and allied products	#263160
	Final energy consumption; Manufacture of chemical and allied products	#626100
	Non-energy and feedstock use; Manufacture of petrochemical, ammonia, soda products	#951530
1A2d Pulp, paper and print	Auto power generation; Manufacture of pulp, paper and paper products	#253140
	Auto power generation; Printing and allied industries	#253150
	Auto steam generation; Manufacture of pulp, paper and paper products	#263140
	Auto steam generation; Printing and allied industries	#263150
	Final energy consumption; Manufacture of pulp, paper and paper products	#624000
	Final energy consumption; Printing and allied industries	#625000
	Non-energy and feedstock use; Manufacture of pulp, paper and paper products, large scale	#951520
1A2e Food processing, beverages and tobacco	Auto power generation; Manufacture of food	#253090
	Auto power generation; Manufacture of beverages, tobacco and feed	#253100
	Auto steam generation; Manufacture of food	#263090
	Auto steam generation; Manufacture of beverages, tobacco and feed	#263100
	Final energy consumption; Manufacture of food, beverages, tobacco and feed	#621000
1A2f Non-metallic minerals	Auto power generation; Manufacture of ceramic, stone and clay products	#253210
	Auto steam generation; Manufacture of ceramic, stone and clay products	#263210
	Final energy consumption; Manufacture of ceramic, stone and clay products	#628100
	Non-energy and feedstock use; Manufacture of ceramic, stone and clay products	#951550
1A2g Other	Auto power generation; Agriculture, fishery, mining and construction (except for Agriculture, forestry and fishery [#251010-#251040])	#251000
	Auto power generation; Manufacturing (except for the industries listed in 1A1b, 1A1c, 1A2a through 1A2f)	#252000
	Auto steam generation; Agriculture, fishery, mining and construction (except for Agriculture, forestry and fishery [#261010-#261040])	#261000
	Auto steam generation; Manufacturing (except for the industries listed in 1A1b, 1A1c, 1A2a through 1A2f)	#262000
	Final energy consumption; Agriculture, fishery, mining and construction (except for Agriculture, forestry and fishery [#611000])	#610000
	Final energy consumption; Manufacturing (except for the industries listed in 1A1b, 1A1c, 1A2a through 1A2f)	#620000
	Non-energy and feedstock use; Agriculture, fishery, mining and construction (except for agriculture, forestry and fishery)	#951100
	Non-energy and feedstock use; Manufacturing industry, large scale (except for the industries listed in 1A1b, 1A1c, 1A2a through 1A2f)	#951500
	Non-energy and feedstock use; Manufacturing industry, small and medium scale	#951700

Note: #95xxxx items are subtracted as non-energy use activities.

**c) Uncertainties and Time-series Consistency**

Same as 3.2.4 Energy Industries (1. A. 1). See section 3.2.4. c).

**d) Category-specific QA/QC and Verification**

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

**e) Category-specific Recalculations**

Due to the updates of the activity data and the emission factors based on the update of the *General Energy Statistics*, the emissions for the period of FY1990-FY1992 and FY1994-FY2019 were recalculated.

Updating the statistical data and improving the estimation methodology in the waste sector, CO<sub>2</sub> emissions from other fossil fuels in FY2005-FY2019 were recalculated. See section 7.4.3 for details.

See Chapter 10 for impact on trend.

**f) Category-specific Planned Improvements**

There are no major planned improvements in this category.

**3.2.7. CH<sub>4</sub> and N<sub>2</sub>O Emissions from Manufacturing Industries and Construction (1.A.2.: CH<sub>4</sub>, N<sub>2</sub>O)****a) Category Description**

This section provides the estimation methods for determining CH<sub>4</sub> and N<sub>2</sub>O emissions from iron and steel (1.A.2.a); non-ferrous metals (1.A.2.b); chemicals (1.A.2.c); pulp, paper, and print (1.A.2.d); food processing, beverages, and tobacco (1.A.2.e); non-metallic minerals (1.A.2.f); and other (1.A.2.g).

This category also provides the estimation methods for determining CH<sub>4</sub> and N<sub>2</sub>O emissions from off-road vehicles, work ships and other machineries.

**b) Methodological Issues**● **Estimation Method**➤ *Furnaces*

Same with Energy Industries (1.A.1), CH<sub>4</sub> and N<sub>2</sub>O emissions from fuel combustion in this category are calculated by using Tier 3 method in accordance with the decision tree of the *2006 IPCC Guidelines* (Vol.2, Page 1.9, Fig. 1.2). See section 3.2.5. b) (1.A.1).

➤ *Biomass boilers*

See section 3.2.5. b) (1.A.1).

➤ *Off-road vehicles and other machinery*

The emissions from off-road vehicles, work ships and other machinery of manufacturing industries and construction are estimated by Tier 1 in accordance with the decision tree of the *2006 IPCC Guidelines* (Vol.2, Page 3.34, Fig. 3.3.1) to calculate emissions and reported in each sub-category of manufacturing



industries and construction (1.A.2).

➤ *Incineration of waste for energy purposes and with energy recovery*

See section 7.4.3.

● **Emission Factors**

➤ *Furnaces*

The emission factors which were established in Energy Industries (1.A.1) were used. See Table 3-22 and Table 3-23, See section 3.2.5. b) (1.A.1).

➤ *Biomass boilers*

See section 3.2.5. b) (1.A.1).

➤ *Off-road vehicles and other machinery*

The emission factors of fuel oil A of work ships were estimated using the default values of Ocean-going Ships which were provided in the *2006 IPCC Guidelines* (Vol.2, page 3.50, Table 3.5.3) after conversion to the gross calorific value by multiplying them by 0.95 (*2006 IPCC Guidelines*, Vol.2, page 1.16). The emission factors of gasoline, diesel oil and fuel oil A for other than work ships were estimated from the values of European Environment Agency (EEA, 2016) (Table 3-1, 1.A.2.g.vii) after conversion to the gross calorific value.

Table 3-29 Emission factors of CH<sub>4</sub> and N<sub>2</sub>O for off-road vehicles and other machinery in manufacturing industries and construction (1.A.2)

Fuel	Unit	CH <sub>4</sub> emission factor	N <sub>2</sub> O emission factor	Reference
Gasoline	g/t	665	59	EEA (2016), Non-road mobile sources and machinery, Table 3-1
Diesel oil (includes fuel oil A used for other than ships)	g/t	83	135	
Fuel oil A used for ships	kg/TJ(NCV)	7	2	<i>2006 IPCC Guidelines</i> , Vol.2, Table 3.5.3

● **Activity Data**

➤ *Furnaces*

The fuel consumption of mobile combustion and stationary combustion are estimated by multiplying the fuel consumption of each category and each fuel type in the *General Energy Statistics* by the ratios of mobile and stationary combustion on the Table 3-30, which are the survey results executed by MOE in FY2014 and FY2015.

In addition, the fuel consumption, which is estimated by multiplying the fuel consumption of stationary combustion obtained as described above by the fuel consumption ratio of each furnace type, is assumed as the activity data for the stationary combustion (namely combustion in furnaces). Same with Energy Industries (1.A.1), the ratio of fuel consumption of each furnace type was estimated from data on the *General Survey of the Emissions of Air Pollutants* and data on each fuel consumption statistics (*Yearbook of the Current Survey of Energy Consumption in the Selected Industries*, *Structural Survey of Energy Consumption*, *Electric Power Statistics*, and *Current Survey of Production Concerning Gas Industry*). See section 3.2.5. b) (1.A.1).

➤ *Biomass boilers*

As the activity data from the biomass boilers, the inventory used the fuel consumption for each sector, each fuel type in the *General Energy Statistics*. However, the consumption of non-specified biomass for

each industry type before FY2001 under “Auto steam generation sector” in the *General Energy Statistics* was not available because it was not investigated. Therefore, for this period, it was estimated on the assumption that it is proportional to the amount of steam generation for each industry type before FY2001, based on the amount of steam generation in FY2002.

➤ *Off-road vehicles and other machinery*

The fuel consumption, which is estimated by multiplying the fuel consumption of each category and each fuel type in the *General Energy Statistics* by the fuel consumption ratio in the Table 3-30, is assumed to be the activity data of the mobile combustion, namely the off-road vehicles and other machinery.

In relation to the Table 3-30, all fuel consumption of fuel oil A and diesel oil of construction in the *General Energy Statistics* were used for activity data of mobile combustion. According to Japan Federation of Construction Contractors, the fuel consumption of electric generator as stationary combustions is included in the value of fuel oil A and diesel oil of construction, however the emission factors of mobile combustion are applied for electric generator, because a combustion engine of electric generator is similar with diesel engine.

Table 3-30 Fuel consumption ratio of mobile combustion and stationary combustion in manufacturing industries and construction (1.A.2)

CRF code	Category in General Energy Statistics	Gasoline		Diesel oil		Fuel oil A		
		Mobile combustion	Stationary combustion	Mobile combustion	Stationary combustion	Mobile combustion (ships)	Mobile combustion	Stationary combustion
1A2a	Manufacture of iron and steel	1%	99%	16%	84%			
1A2b	Manufacture of non-ferrous metals and products	24%	76%	1%	99%			
1A2c	Manufacture of chemical and allied products	100%	0%	1%	99%			
1A2d	Manufacture of pulp, paper and paper products	74%	26%	10%	90%			
	Printing and Allied Industries			0%	100%			
1A2e	Manufacture of food, beverages, tobacco and feed			1%	99%			
1A2f	Manufacture of Ceramic, Stone and Clay Products	7%	93%	1%	99%			
1A2g	Manufacture of Fabricated Metal Products			1%	99%			
	Manufacture of Machinery	2%	98%	1%	99%			
	Mining, Quarrying of Stone and Gravel			100%	0%	17%	25%	58%
	Manufacture of Lumber and Wood Products, except Furniture and Fixtures			2%	98%			
	Construction Work Industry			100%	0%	0%	100%	0%
	Manufacture of Textile Mill Products	100%	0%					
	Manufacture of Leather Tanning, Leather Products and Fur Skins			0%	100%			
	Manufacture of Furniture and Fixtures			0%	100%			
	Manufacture of Rubber Products			0%	100%			
	Manufacture of Plastic Products, except Otherwise Classified			0%	100%			
	Miscellaneous Manufacturing Industry			4%	96%			

Reference: Estimated based on MOE (2015b) and MOE (2016).

### c) Uncertainties and Time-series Consistency

#### ➤ Furnaces (including Biomass boilers)

Same as Energy Industries (1.A.1). See section 3.2.5. c).

The consumption of non-specified biomass for each industry type before FY2001 was not available because it was not investigated. Therefore, time-series consistency is ensured by estimating the consumption on the assumption that it is proportional to the amount of steam generation for each industry type before FY2001, based on the amount of steam generation in FY2002.

#### ➤ Off-road vehicles and other machinery

The default values of the 2006 IPCC Guidelines were substituted for the uncertainties of emission factors. The uncertainties of the activity data were established from the standard deviation of the rate of statistical discrepancy of liquid and gaseous fuels of the *General Energy Statistics*. For the activity data obtained from the fuel consumption ratio of mobile combustion, the uncertainties of the ratio were

estimated from the survey conducted by MOE in FY2014 and FY2015 and they were combined by the error propagation formula. As a result, the uncertainties were determined to be  $-29\%$  to  $+41\%$  for CH<sub>4</sub> emissions and  $-23\%$  to  $+91\%$  for N<sub>2</sub>O emissions from off-road vehicles and other machinery as a whole for the fuel combustion category.

➤ *Incineration of waste for energy purposes and with energy recovery*

See section 7.4.3.

**d) Category-specific QA/QC and Verification**

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

**e) Category-specific Recalculations**

Since the activity data for FY1990-2019 in the *General Energy Statistics* were revised, the CH<sub>4</sub> and N<sub>2</sub>O emissions in those years were recalculated.

Updating the statistical data in the waste sector, CH<sub>4</sub> and N<sub>2</sub>O emissions for FY2019 were recalculated. See section 7.4.3 for details.

See Chapter 10 for impact on trend.

**f) Category-specific Planned Improvements**

Same as Energy Industries (1.A.1). See section 3.2.5. f).

### 3.2.8. CO<sub>2</sub> Emissions from Transport (1.A.3.: CO<sub>2</sub>)

**a) Category Description**

This section provides the methods used to estimate CO<sub>2</sub> emissions from domestic aviation (1.A.3.a), road transportation (1.A.3.b), railways (1.A.3.c), domestic navigation (1.A.3.d), and other transportation (1.A.3.e). The emissions from mobile sources that the main purpose is other than transport of passenger or freight (e.g. off-road vehicles, work ships and fishing boats) are included in manufacturing industries and construction (1.A.2) and other sectors (1.A.4).

In FY2020, CO<sub>2</sub> emissions from this category accounted for 177,643 kt-CO<sub>2</sub>, and represented 15.4% of Japan's total GHG emissions (excluding LULUCF). The road transportation (1.A.3.b) accounts for 91.1% and is the largest within the Transport category in FY2020.

**b) Methodological Issues**

● **Estimation Method**

➤ *Fuels such as gasoline and diesel oil*

The Tier 2 Sectoral Approach has been used in accordance with the decision tree of the *2006 IPCC Guidelines* to calculate emissions (Vol.2, Page 1.9, Fig. 1.2), as was the case for the energy industries (1.A.1). See section 3.2.4. b)). In the CRFs, the CO<sub>2</sub> emissions from biofuels are estimated from domestic supply [#190000] of biofuels from the *General Energy Statistics* and reported in Road transportation (1.A.3.b) as reference values. (The CO<sub>2</sub> emissions from biomass are not included in the

national totals in accordance with the 2006 IPCC Guidelines.)

➤ *Lubricants*

CO<sub>2</sub> is emitted by oxidation of lubricants in engines during use. According to the 2006 IPCC Guidelines (Vol.3, page 5.6), in the case of 2-stroke (2-cycle) engines, where the lubricant is mixed with another fuel and thus on purpose co-combusted in the engine, the emissions should be estimated and reported as part of the combustion emissions in the energy sector. 2-stroke engine oil for automobile and marine diesel engine oil correspond to be reported in the energy sector. The emissions are estimated by the following equation. The emissions from 2-stroke engine oil are reported in 1.A.3.b and those from marine diesel oil are reported in 1.A.3.d.

$$E = \sum_i (LC_i \times CC_i \times ODU_i \times 44/12)$$

$E$  : CO<sub>2</sub> emissions from lubricants oxidized during use [kt-CO<sub>2</sub>]

$LC_i$  : Consumption of lubricant [TJ]

$CC_i$  : Carbon content of lubricant [kt-C/TJ]

$ODU_i$  : Oxidized During Use (ODU) factor

$i$  : Lubricant type (2-stroke engine oil for automobile and marine diesel engine oil)

● **Emission Factors**

➤ *Fuels such as gasoline and diesel oil*

The emission factors elaborated in the energy industries (1.A.1) are also used in this category. See section 3.2.4. b).

The carbon emission factor for liquid fuels (diesel oil) in 1.A.3.b (Road transportation) is the lowest in Annex I Parties for two reasons. One is because the quality standard for diesel oil in Japan is different from other countries. Crude oil with high sulfur content imported from the Middle East must be decomposed and go through ultra-deep desulfurization to become low-sulfur diesel oil (<10 ppm) according to Japanese automobile exhaust gas regulations. The other reason is because gas oil used for purposes other than road transport is called "fuel oil A" to distinguish it from diesel oil. The carbon balance of Japanese petroleum refineries including diesel oil and fuel oil A nearly matches according to statistics, so these carbon emission factors are not irregular.

Please refer to the quality standard for diesel oil in Japan provided in Annex 4 (A4.3).

➤ *Lubricants*

The carbon content  $CC$  is the carbon emission factor of lubricants elaborated in the energy industries (1.A.1). The ODU factor is 1.0 assuming that all lubricants are combusted.

● **Activity Data**

Table 3-31 Energy consumptions in Transport (1.A.3.) (unit: PJ)

Fuel	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Liquid fuels	2,982	3,581	3,735	3,514	3,286	3,215	3,228	3,135	3,065	3,049	3,024	2,999	2,967	2,901	2,597
Solid fuels	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gaseous fuels	0	0	1	4	5	5	4	4	4	3	3	2	2	2	1
Other fossil fuels	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Biomass	NO	NO	NO	0	9	9	9	10	12	15	18	19	20	19	20
Total	2,983	3,581	3,736	3,518	3,299	3,228	3,241	3,149	3,081	3,067	3,045	3,021	2,988	2,922	2,618

➤ *Fuels such as gasoline and diesel oil*

The data given in the *General Energy Statistics* were used for activity data.

The values subtracting final energy consumption reported under ‘non-energy and feedstock use’ [#953000] from energy consumption reported under ‘air transport’ [#815000] [#854000], ‘road transport’ [#811000] [#851000] [#811500] [#812000], ‘railway transport’ [#813000] [#852000] and ‘water transport’ [#814000] [#853000] in Japan’s Energy Balance Table (*General Energy Statistics*) are used for activity data. Because energy consumption reported under ‘non-energy and feedstock use’ was used for purposes other than combustion and was considered not emitting CO<sub>2</sub>, these values were deducted. (see Table 3-32)

Table 3-32 Correspondence between sectors of Japan’s Energy Balance Table and those of the CRF (1.A.3)

CRF		General Energy Statistics	
1A3	Transport		
1A3a	Domestic aviation	Final energy consumption; Passenger; Air passenger transport	#815000
		Final energy consumption; Freight; Air freight transport	#854000
		Non-energy and feedstock use; Transportation (air)	#953000
1A3b	Road transportation		
i	Cars	Final energy consumption; Passenger; Passenger vehicle	#811000
		Non-energy and feedstock use; Transportation (passenger vehicle)	#953000
ii	Light duty trucks	IE (1A3biii)	-
iii	Heavy duty trucks and buses	Final energy consumption; Passenger; Bus	#811500
		Final energy consumption; Freight; Freight truck and lorry	#851000
		Non-energy and feedstock use; Transportation (bus, freight truck and lorry)	#953000
iv	Motorcycles	Final energy consumption; Passenger; Motorcycles	#812000
		Non-energy and feedstock use; Transportation (Motorcycles)	#953000
v	Other	IE (1A3biii)	-
1A3c	Railways	Final energy consumption; Passenger; Railway passenger transport	#813000
		Final energy consumption; Freight; Railway freight transport	#852000
		Non-energy and feedstock use; Transportation (railways)	#953000
1A3d	Domestic navigation	Final energy consumption; Passenger; Water passenger transport	#814000
		Final energy consumption; Freight; Water freight transport	#853000
		Non-energy and feedstock use; Transportation (water)	#953000
1A3e	Other transportation	NO	-

Note: #95xxxx items are subtracted as non-energy use activities.

### ➤ Lubricants

The sales of engine oils for automobiles and navigation are estimated from the total sales of lubricants, and then they are used to estimate the consumptions of total loss type engine oils.

The sales of engine oils for automobile (gasoline engine oil and diesel engine oil) and marine diesel engine oil in cubic volume basis are estimated by multiplying  $DS$ , or the domestic sales of all lubricants shown in *Yearbook of Mineral Resources and Petroleum Products Statistics* and *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, by  $R_i$ , or the proportion of each of engine oil to all lubricants sold to consumers, wholesalers and retailers<sup>12</sup> estimated from these yearbooks. They are multiplied by  $R_{TLi}$ , or the proportions of total loss type lubricants to each of engine oil, to obtain the consumptions of total loss type engine oils.  $R_{TLi}$  is derived by dividing the productions and imports of 2-stroke engine oils and marine cylinder oil in fiscal year 2011 shown in Japan Lubricating Oil Society (2013) by the domestic sales of engine oils for automobiles and marine diesel engine oil estimated above, respectively (0.92% for engine oils for automobiles and 83% for marine diesel engine oil).

$LC_i$ , or the consumptions of total loss type engine oils in quantity of heat basis, are obtained by converting the consumptions in cubic volume basis by using the gross calorific values of lubricants shown in the *General Energy Statistics*, and they are set as activity data.

<sup>12</sup> Lubricants sold to consumers, for FY1990-2001.

$$LC_i = DS \times R_i \times R_{TLi} \times GCV$$

- $LC_i$  : Consumption of each of engine oil [TJ]  
 $DS$  : Domestic sales of all lubricants [1,000 kL]  
 $R_i$  : Proportion of each of engine oil to all lubricants sold to consumers, wholesalers and retailers  
 $R_{TLi}$  : Proportions of total loss type lubricants to each of engine oil  
 $i$  : Lubricant type (engine oils for automobile and marine diesel engine oil)  
 $GCV$  : Gross calorific values of lubricants [GJ/kL]

Table 3-33 Consumption of total loss type engine oils

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
Two stroke engine oil for automobiles	$LC_1$	TJ	207	215	210	194	183	172	157	158	154	142	135	137	149	144	
Cylinder oil for navigation	$LC_2$	TJ	5,318	5,503	7,144	6,250	4,627	4,016	3,638	3,502	3,301	3,124	2,843	2,766	3,095	3,036	2,831
Total sales of lubricants	$DS$	1000 kL	2,439	2,335	2,192	2,047	1,763	1,695	1,538	1,531	1,511	1,460	1,414	1,433	1,590	1,548	1,430
Proportion of sales of engine oils for automobiles	$R_1$	-	23%	25%	26%	26%	28%	28%	28%	28%	26%	26%	26%	26%	26%	27%	
Proportion of sales of marine diesel engine oils	$R_2$	-	6.5%	7.1%	9.8%	9.1%	7.9%	7.1%	7.1%	6.8%	6.5%	6.4%	6.0%	5.8%	5.8%	5.9%	
Gross calorific value of lubricants	$GCV$	GJ/kL	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2	

### c) Uncertainties and Time-series Consistency

Same as 3.2.4 Energy Industries (1. A. 1). See section 3.2.4. c).

### d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

### e) Category-specific Recalculations

Due to the updates of the activity data and the emission factors based on the update of the *General Energy Statistics*, the emissions for the period of FY2011-FY2019 were recalculated. In addition, due to the updates of the activity data based on the revision of the *Yearbook of Mineral Resources and Petroleum Products Statistics*, the emissions from lubricants for FY2019 were recalculated.

See Chapter 10 for impact on trend.

### f) Category-specific Planned Improvements

There are no major planned improvements in this category.

## 3.2.9. CH<sub>4</sub> and N<sub>2</sub>O Emissions from Transport (1.A.3.: CH<sub>4</sub>, N<sub>2</sub>O)

This section provides the estimation methods for CH<sub>4</sub> and N<sub>2</sub>O emissions from domestic aviation (1.A.3.a), road transportation (1.A.3.b), railways (1.A.3.c), domestic navigation (1.A.3.d), and other transportation (1.A.3.e). The emissions from mobile sources that the main purpose is other than transport of passenger or freight (e.g. off-road vehicles, work ships and fishing boats) are included in manufacturing industries and construction (1.A.2) and other sectors (1.A.4).

### 3.2.9.1. Domestic Aviation (1.A.3.a.)

#### a) Category Description

This section provides the estimation methods for CH<sub>4</sub> and N<sub>2</sub>O emissions from energy consumption in

domestic aviation. Greenhouse gases associated with the domestic operation of Japanese airliners are mainly emitted from jet fuels. In addition, a small amount of aviation gasoline used by light aircraft and helicopters is also a source of CH<sub>4</sub> and N<sub>2</sub>O emissions.

## b) Methodological Issues

### ● Estimation Method

In accordance with the decision tree of the *2006 IPCC Guidelines* (Vol. 2, page 3.60, Fig. 3.6.1), the emissions from jet fuel for jet aircraft are estimated using the Tier 2 method by each operation phase: Landing/Take-Off (LTO) cycle and cruise. For LTO phase, the emissions by aircraft type are estimated by multiplying the emission factor per LTO 1 cycle by the number of LTO cycles for each aircraft type on domestic routes, and then they are aggregated. However, the emissions prior to FY2000 are estimated by multiplying the weighted average emission factor for all type of aircraft in FY2001 by the total activity data due to lack of activity data by aircraft type prior to FY2000. For cruise phase, the emissions are estimated from the total jet fuel consumption during cruising on domestic routes.

The emissions from aviation gasoline, which is used for light aircraft and helicopters, are estimated by the Tier 1 method from the total domestic fuel consumption.

$$E_{jet} = \sum_i (EF_{LTO,i} \times AD_{LTO,i}) + EF_{cruise} \times AD_{cruise}$$

- $E_{jet}$  : CH<sub>4</sub> and N<sub>2</sub>O emissions from domestic airliners using jet fuel  
 $EF_{LTO,i}$  : Emission factor per LTO 1 cycle by aircraft type of domestic airliner  
 $AD_{LTO,i}$  : Number of LTO cycles by aircraft type on domestic routes  
 $EF_{cruise}$  : Emission factor associated with jet fuel consumption  
 $AD_{cruise}$  : Jet fuel consumption during cruising on domestic routes  
 $i$  : Aircraft type

$$E_{gasoline} = EF_{gasoline} \times AD_{gasoline}$$

- $E_{gasoline}$  : CH<sub>4</sub> and N<sub>2</sub>O emissions associated with flight of gasoline-powered domestic aircraft  
 $EF_{gasoline}$  : Emission factor associated with the consumption of aviation gasoline  
 $AD_{gasoline}$  : Consumption of aviation gasoline by aircraft on domestic routes

### ● Emission Factors

#### ➤ Jet fuel

The default values given in the *2006 IPCC Guidelines* (Vol. 2, page 3.70, Table 3.6.9) are used for the emission factors of CH<sub>4</sub> and N<sub>2</sub>O during LTO. As for during cruising, the default values given in the *2006 IPCC Guidelines* (Vol. 2, page 3.64, Table 3.6.5) are used. (See Table 3-34)

#### ➤ Aviation gasoline

The default values given in the *2006 IPCC Guidelines* (Vol. 2, page 3.64, Table 3.6.5) are used for emission factors of CH<sub>4</sub> and N<sub>2</sub>O (see Table 3-34).

Table 3-34 CH<sub>4</sub> and N<sub>2</sub>O emission factors for aircraft

Type of aircraft (fuel)	Flight phase	CH <sub>4</sub>	N <sub>2</sub> O
Jet aircraft (Jet fuel)	LTO	Varies per aircraft type (see Table 3-35)	
	Cruise	- <sup>1)</sup>	2 [kg-N <sub>2</sub> O/TJ(NCV)]
Other than jet aircraft (Aviation gasoline)	-	0.5 [kg-CH <sub>4</sub> /TJ(NCV)]	2 [kg-N <sub>2</sub> O/TJ(NCV)]

Reference: *2006 IPCC Guidelines*, Volume 2, page 3.64, Table 3.6.5

Note:

LTO: Landing and take-off



1) Excluded from calculations, as the emissions are assumed as negligible in the guidelines.

Table 3-35 CH<sub>4</sub> and N<sub>2</sub>O emission factors and fuel consumption for major types of jet aircraft

Aircraft type	CH <sub>4</sub> emission factor [kg/CH <sub>4</sub> /LTO] <sup>1)</sup>	N <sub>2</sub> O emission factor [kg/N <sub>2</sub> O/LTO] <sup>1)</sup>	Fuel consumption [kg/LTO] <sup>1)</sup>
B737-300/400/500	0.08	0.1	780
B737-800	0.07	0.1	880
B747SR (B747-100, -200, -300)	4.84 <sup>2)</sup>	0.4 <sup>2)</sup>	3,440 <sup>3)</sup>
B747-400	0.22	0.3	3,240
B767-300	0.12	0.2	1,780
B777-200/300	0.07	0.3	2,560
A320	0.06	0.1	770
Average of emission factors of all aircraft types in FY 2001 (adopted for the emission factor of all types of aircraft before 2001)	0.34	0.15	—

Reference: 2006 IPCC Guidelines, Vol. 2, page 3.70, Table 3.6.9

Note:

1) LTO: Landing and take-off

2) Maximum value of B747-100, -200, and -300 is used

3) Average value of B747-100, -200, and -300 is used

### ● Activity Data

#### ➤ Jet fuel

The number of LTO (landing and take-off) by aircraft type given in the *PRTR Outside Notification Emissions Estimated Data* (MOE) is used as activity data for LTO. However, these data involve the international flights LTO, thus the number of international flights LTO is subtracted for each aircraft type used for both domestic and international flights in same ratio of domestic and international flights from total LTO, so as to keep the total number of domestic LTO in the *Airport Management Status Study Report* (MLIT).

The fuel consumption during LTO is calculated by multiplying the fuel amount consumed per one LTO, which is given in the 2006 IPCC Guidelines for each aircraft type, by the number of LTO given above.

The fuel consumption for cruising is estimated by subtracting the amount of jet fuel consumed during LTO from the total jet fuel consumption in the *Statistical Yearbook of Air Transport* (MLIT).

#### ➤ Aviation gasoline

The consumption of gasoline in the domestic aviation, which is taken from the *General Energy Statistics*, is used for activity data.

Table 3-36 Activity data used for emission estimates of aircraft

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Number of LTO cycle	1000 LTO	669	783	865	895	882	882	938	993	1,006	997	994	999	1,003	1,002	628
Jet fuel consumption during cruise	1000 kL	1,621	2,425	2,742	3,031	2,629	2,589	2,758	2,933	2,996	3,005	3,072	3,145	3,172	3,407	1,917
Aviation gasoline consumption	1000 kL	5.3	6.0	4.3	7.7	1.9	1.7	1.9	1.9	1.7	1.7	1.7	1.9	2.6	2.8	2.4

Table 3-37 Number of LTO cycle of major types of jet aircraft since FY2001

Aircraft type	Unit	2001	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
B737-300/400/500	1000 LTO	123	103	84	130	129	131	132	80	68	38	54	15	1
B737-800		NO	NO	97	89	97	118	130	166	165	178	210	157	10
B747SR		43	30	3	2	1	1	NO	1	1	NO	NO	NO	NO
B747-400		56	54	22	15	16	14	8	5	7	5	2	1	0
B767-300		146	103	101	105	95	87	79	75	73	80	82	52	3
B777-200/300		69	76	89	86	91	93	87	78	74	71	74	46	3
A320		59	47	48	55	88	95	102	103	97	54	54	63	4

### c) *Uncertainties and Time-series Consistency*

#### ● *Uncertainties*

As for the uncertainty of emission factors, the default values by each aircraft type per one LTO given in the *2006 IPCC Guidelines* (Tier 2) are applied for the emission factors, and the estimation is considered to be more accurate than Tier 1. Therefore, the values of the Tier 1 default uncertainty in the guideline (CH<sub>4</sub>: -57% to +100%, N<sub>2</sub>O: -70% to +150%) are considered to be the upper limit, and are adopted. As for the uncertainty of activity data, because the *Airport Management Status Study Report* is a complete survey executed by MLIT, the values in the *2006 IPCC Guidelines* (-5% to +5%) are used. As a result, the uncertainty of the emissions from domestic aviation is evaluated as -57% to +100% for CH<sub>4</sub>, and -70% to +150% for N<sub>2</sub>O.

#### ● *Time-series Consistency*

For the emission factors per LTO, the same value is used for every fiscal year since FY2001 by each aircraft type. For the emission factors prior to FY2000, because the activity data by each aircraft type are not available, the average emission factor for all aircraft type is established from the FY2001 data, and it is used for the fiscal years back to FY1990. In addition, the jet fuel consumption in the *Statistical Yearbook of Air Transport* and the aviation gasoline consumption in the *General Energy Statistics* are used as activity data consistently from FY1990 to the nearest year.

### d) *Category-specific QA/QC and Verification*

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

### e) *Category-specific Recalculations*

The CH<sub>4</sub> and N<sub>2</sub>O emissions from jet fuel for FY2019 were recalculated due to an update of the number of LTO in the *PRTR Outside Notification Emissions Estimated Data* and the total jet fuel consumption in the *Statistical Yearbook of Air Transport*. See Chapter 10 for impact on trend.

### f) *Category-specific Planned Improvements*

There are no major planned improvements in this category.

### 3.2.9.2. Road Transportation (1.A.3.b.)

This section provides the estimation methods for CH<sub>4</sub> and N<sub>2</sub>O emissions from the following vehicle categories:

Table 3-38 Reporting categories and definitions of emissions from automobiles

Vehicle type	Definition	Fuel type for emission reporting			
		Gasoline	Diesel	LPG	Natural gas
Light passenger vehicle	Light vehicle used for transportation of people.	Yes	-	-	-
Passenger vehicle	Regular vehicle or small vehicle used for transportation of people, with a capacity of 10 persons or less.	Yes	Yes	Yes	Yes
Bus	Regular vehicle or small vehicle used for transportation of people, with a capacity of 11 persons or more.	Yes	Yes	-	Yes
Light cargo truck	Light vehicle used for transportation of cargo	Yes	-	-	-
Small cargo truck	Small vehicle used for transportation of cargo.	Yes	Yes	-	Yes
Regular cargo truck	Regular vehicle used for transportation of cargo.	Yes	Yes	-	(Cargo truck)
Special-purpose vehicle	Regular, small or light vehicle used for special purposes, including flushers, advertising vans, hearses, and others.	Yes	Yes	-	Yes
Motorcycle	Two-wheeled vehicle	Yes	-	-	-

Table 3-39 Correspondence between vehicle type and sectors of the CRF (1.A.3.b)

CRF	Vehicle type, or notation key
1A3b Road transportation	
i. Cars	Light passenger vehicle and passenger vehicle
ii. Light duty trucks	IE (included in iii. Heavy duty trucks and buses)
iii. Heavy duty trucks and buses	Bus, light cargo truck, small cargo truck, regular cargo truck, and special-purpose vehicle
iv. Motorcycles	Motorcycle
v. Other	IE (included in iii. Heavy duty trucks and buses)

Different estimation methods are used between motorcycles and other road transportation vehicles, Road transportation vehicles other than motorcycles (3.2.4.2.a) and Motorcycles (3.2.4.2.b) are separately described in the following sections.

### 3.2.9.2.a. Road transportation: vehicles other than motorcycles

#### a) Category Description

This section provides the estimation methods for CH<sub>4</sub> and N<sub>2</sub>O emissions from road transportation vehicles other than motorcycles, namely light passenger vehicles, light cargo trucks, passenger vehicles, buses, small cargo trucks, regular cargo trucks, and special-purpose vehicles.

#### b) Methodological Issues

##### ● Estimation Method

The emissions are calculated by using the Tier 3 method, in accordance with the decision tree of the 2006 IPCC Guidelines (Vol. 2, page 3.14, Fig. 3.2.3).

$$E = \sum_i (EF_i \times AD_i)$$

$E$  : CH<sub>4</sub> and N<sub>2</sub>O emissions from road transportation (vehicles other than motorcycles)

$EF_i$  : Emission factor per distance traveled by vehicle type

$AD_i$  : Distance traveled by vehicle type

$i$  : Vehicle type

### ● Emission Factors

The emission factors for CH<sub>4</sub> and N<sub>2</sub>O are established for each fuel type for each vehicle type, using the data shown in Table 3-40.

For “JAMA etc. data”, the emission factors are established on the basis of the raw emission factors data provided by Japan Automobile Manufacturers Association (hereinafter referred to as JAMA) and other organizations<sup>13</sup>. For “JAMA data”, the emission factors are established on the basis of the raw emission factors data provided by JAMA only. The raw emission factors are arranged as combined mode emission factors<sup>14</sup> by vehicle exhaust gas regulation<sup>15</sup> year. The emission factors are estimated by averaging the arranged emission factors weighted by the number of vehicles of each regulation year of each car type. The main reference of the number of vehicles is *Statistics of AIRIA/ Number of Motor Vehicle* compiled by the Automobile Inspection and Registration Information Association (AIRIA). (See Table 3-41, Table 3-42.)

For “Measured data”, the emission factors are established on the basis of actual Japanese data. The emission factors are developed as weighted averages calculated from emission factors estimated by each class of running speed and proportion of distance traveled for each class of running speed given in *Road Transport Census* (MLIT). The emission factors reflect the actual operation of vehicles in Japan because the proportion of distance traveled by each class of running speed during rush hour was applied.

The N<sub>2</sub>O emission factors for natural gas trucks are established from actual measurement data. The emission factors are developed as weighted averages calculated from emission factors of each class of running speed based on actual measurements taken in Japan and the proportion of distance traveled for each class of running speed reported in the *Road Transport Census*. However, N<sub>2</sub>O emission factors for passenger vehicles, buses, and special-purpose vehicles, and CH<sub>4</sub> emission factors for special-purpose vehicles are established by the method indicated in Table 3-40, because of the absence of actual measurement data in Japan.

The detailed method for establishing the emission factors is described in the *GHGs Estimation Methods Committee Report Part 2 – Transportation* (MOE, August 2006).

<sup>13</sup> MOE, Bureau of Environment of Tokyo Metropolitan Government, NIES, National Traffic Safety and Environment Laboratory (NTSEL), and Japan Petroleum Energy Center (JPEC)

<sup>14</sup> The data were provided by test mode. The emission factors were calculated using “combined driving mode”. “Combined JC08 driving mode” = “hot start driving mode” × 0.75 + “cold start driving mode” × 0.25

<sup>15</sup> The regulated gases include CO, non-methane hydrocarbons (NMHC), NO<sub>x</sub> and particulate matter (PM).

Table 3-40 Data source of the emission factors of vehicle

Vehicle type	Fuel	Gasoline		Diesel		Natural gas	
		CH <sub>4</sub>	N <sub>2</sub> O	CH <sub>4</sub>	N <sub>2</sub> O	CH <sub>4</sub>	N <sub>2</sub> O
Light passenger vehicle		JAMA etc. data	JAMA etc. data				
Passenger vehicle		JAMA etc. data	JAMA etc. data	JAMA etc. data	JAMA etc. data	JAMA data	The EF of small cargo truck is used considering the standard of vehicle type
Bus		2006GL	2006GL	Measured data	2006GL	JAMA data	Established by correcting the EF of regular cargo truck by the equivalent inertial weight ratio considering vehicle weight.
Light cargo truck		JAMA etc. data	JAMA etc. data				
Small cargo truck		JAMA etc. data	JAMA etc. data	JAMA etc. data	JAMA etc. data		Established based on the actual measured data (classified as cargo truck)
Regular cargo truck		2006GL	2006GL	JAMA etc. data	JAMA etc. data	JAMA data	
Special-purpose vehicle		2006GL	2006GL	Measured data	2006GL		Established using the corrected travel distance ratio by each running speed, considering the EFs by each speed of regular cargo truck and running pattern of special-purpose vehicle.

Note:

- 1) JAMA etc. data: Calculated by using driving mode test data provided by Japan Automobile Manufacturers Association (JAMA) and other organizations
- 2) JAMA data: Calculated by using driving mode test data provided by JAMA
- 3) Measured data: Using actual Japanese data other than the above JAMA data
- 4) 2006GL: Using the default values in the *2006 IPCC Guidelines*.
- 5) EFs of LPG vehicle are the same as those of gasoline passenger vehicle.

Table 3-41 CH<sub>4</sub> emission factors for road transportation

Fuel	Vehicle type	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
Gasoline	Light passenger vehicle	mg-CH <sub>4</sub> /km	8.3	8.3	8.2	6.9	5.0	4.8	4.5	4.2	4.0	3.8	3.6	3.5	3.4	3.3	3.2	
	Passenger vehicle (non-hybrid)		14.5	14.5	14.3	11.3	8.0	7.5	7.1	6.6	6.3	6.0	5.7	5.5	5.3	5.1	5.0	
	Passenger vehicle (hybrid)		NO	NO	NO	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.2	2.4
	Bus		14															
	Light cargo truck		18.7	18.7	18.0	11.7	7.2	6.7	6.3	5.8	5.5	5.2	4.9	4.7	4.5	4.3	4.2	
	Small cargo truck		21.2	21.2	21.2	14.5	8.7	8.0	7.4	6.8	6.2	5.8	5.4	5.0	4.7	4.4	4.2	
	Regular cargo truck		14															
	Special-purpose vehicle		14															
Diesel	Passenger vehicle	11.3	12.2	12.6	12.8	12.8	12.7	12.8	12.9	12.7	12.4	12.1	12.1	11.8	11.1	10.5		
	Bus	19.0	18.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0		
	Small cargo truck	9.6	10.7	10.1	8.7	8.3	8.2	8.1	7.9	7.8	7.7	7.6	7.5	7.4	7.3	7.2		
	Regular cargo truck	17.0	16.0	15.0	13.9	11.1	10.6	10.1	9.6	9.0	8.4	7.9	7.3	6.8	6.3	5.8		
	Special-purpose vehicle	17.0	15.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0		
LPG	Passenger vehicle	14.5	14.5	14.3	11.3	8.0	7.5	7.1	6.6	6.3	6.0	5.7	5.5	5.3	5.1	5.0		
	Passenger vehicle																	
Natural gas	Bus																	
	Cargo truck																	
	Special-purpose vehicle																	
	Special-purpose vehicle																	

Table 3-42 N<sub>2</sub>O emission factors for road transportation

Fuel	Vehicle type	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
Gasoline	Light passenger vehicle	mg-N <sub>2</sub> O/km	14.2	14.2	13.9	9.3	5.2	4.7	4.1	3.6	3.2	2.9	2.6	2.4	2.2	2.0	1.9	
	Passenger vehicle (non-hybrid)		23.7	23.7	20.3	12.2	6.3	5.6	5.0	4.4	4.0	3.7	3.4	3.2	3.0	2.9	2.8	
	Passenger vehicle (hybrid)		NO	NO	NO	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.8
	Bus		25															
	Light cargo truck		23.7	23.7	21.7	12.8	7.3	6.8	6.2	5.7	5.3	5.0	4.7	4.4	4.2	4.0	3.8	3.8
	Small cargo truck		21.1	21.6	21.8	13.1	7.8	7.2	6.6	6.1	5.6	5.2	4.9	4.6	4.3	4.1	3.9	3.9
	Regular cargo truck		25															
	Special-purpose vehicle		25															
Diesel	Passenger vehicle		5.7	4.7	4.4	4.4	4.9	5.0	5.2	5.4	5.3	5.1	4.9	4.8	4.7	4.5	4.3	4.3
	Bus		3.0															
	Small cargo truck		9.3	10.3	11.1	11.7	12.2	12.3	12.4	12.5	12.6	12.7	12.8	12.8	12.9	13.0	13.0	13.0
	Regular cargo truck		15.0	15.0	14.9	16.9	31.8	33.3	35.0	36.9	38.8	40.7	42.4	43.6	44.4	44.7	44.8	44.8
LPG	Special-purpose vehicle		3.0															
	Passenger vehicle		23.7	23.7	20.3	12.2	6.3	5.6	5.0	4.4	4.0	3.7	3.4	3.2	3.0	2.9	2.8	2.8
Natural gas	Passenger vehicle		0.2															
	Bus		38															
	Cargo truck		13															
	Special-purpose vehicle		15															

### ● Activity Data

The estimates of annual distance traveled by each vehicle type and by each fuel type are used as activity data.

As for gasoline, diesel and LPG vehicles, the method of estimating the distance traveled by each vehicle type and by each fuel type up to FY2009 is to multiply the proportion of distance traveled for each fuel type, which is calculated from fuel consumption and fuel efficiency, by the distance traveled for each vehicle type given in *Statistical Yearbook of Motor Vehicle Transport* (MLIT). To separate out hybrid passenger vehicle (PV) from gasoline PV, the distance traveled by hybrid PV is estimated by multiplying the number of the vehicle by the annual distance traveled per vehicle. Before estimating the distance traveled, the values of *Statistical Yearbook of Motor Vehicle Transport* are converted to be consistent with the activity data since FY2010, using the overlap factors given by MLIT.

The annual distance traveled by vehicle type and by fuel type since FY2010 for gasoline, diesel and LPG vehicles is given in *Statistical Yearbook of Motor Vehicle Fuel Consumption* (MLIT). *Monthly Report of Motor Vehicle Transport Statistics* (MLIT) are also used supplementarily to estimate the annual distance for some vehicle types.

As for the natural gas vehicle, the annual distance traveled per vehicle type is determined by multiplying the number of natural gas-powered vehicles by the annual distance traveled per vehicle. From FY1990 to FY1996, the number of these vehicles is taken from the number of introduced natural gas-powered vehicles per type in the data compiled by the Japan Gas Association, and from FY1997, the number of registered natural gas-powered vehicles reported in the *Statistics of AIRIA/ Number of Motor Vehicle*. For the annual distance traveled per vehicle, the activity data are calculated using the annual total distance traveled by natural gas-powered vehicles, reported in the *Statistical Yearbook of Motor Vehicle Fuel Consumption*, the annual distance traveled by each vehicle type reported in the *Statistical Yearbook of Motor Vehicle Transport*, and the number of registered vehicle by each vehicle type reported in the *Statistics of AIRIA/ Number of Motor Vehicle*.

Table 3-43 Distance traveled of automobile

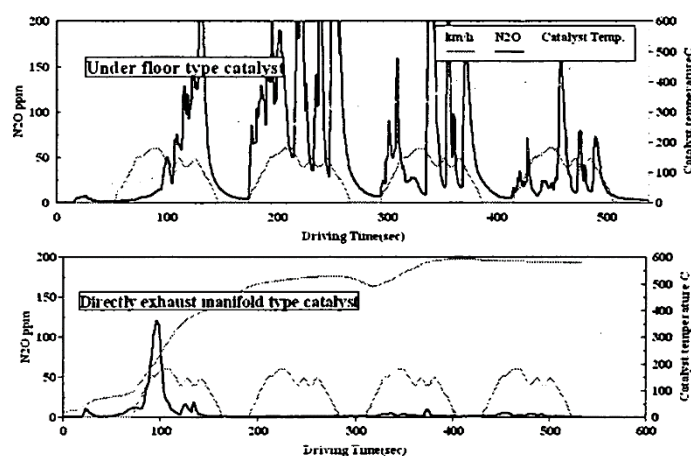
Fuel	Vehicle type	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Gasoline	Light passenger vehicle	Billion vehicle-km	16	41	72	106	137	138	146	150	157	161	170	176	180	181	163
	Passenger vehicle (non-hybrid)		273	304	343	349	319	323	316	303	282	273	267	260	255	244	209
	Passenger vehicle (hybrid)		NO	NO	NO	3	14	20	29	38	48	58	67	78	88	97	91
	Bus		0.09	0.03	0.02	0.04	0.31	0.23	0.18	0.19	0.19	0.21	0.21	0.21	0.22	0.23	0.17
	Light cargo truck		91	90	80	78	75	73	75	77	78	76	76	75	73	71	66
	Small cargo truck		29	20	20	21	22	23	23	23	23	23	21	21	21	21	20
	Regular cargo truck		0	0	0	1	1	1	2	1	1	1	1	1	1	1	1
	Special-purpose vehicle		1	1	1	1	3	3	3	3	2	2	2	2	3	3	2
Diesel	Passenger vehicle	Billion vehicle-km	40	63	55	29	10	9	8	8	8	9	9	11	12	14	13
	Bus		7	7	6	7	6	6	6	6	6	6	6	6	6	5	4
	Small cargo truck		44	49	45	33	23	23	23	22	22	20	20	19	19	18	
	Regular cargo truck		58	68	72	69	63	61	59	59	59	59	59	60	60	60	56
	Special-purpose vehicle		9	14	17	17	21	20	21	21	21	21	21	21	21	21	19
LPG	Passenger vehicle	Billion vehicle-km	18	17	15	14	12	11	11	10	10	9	8	8	7	6	4
Passenger vehicle	0.05		0.10	1.93	5.91	6.00	5.03	3.99	3.01	2.17	1.57	1.17	0.70	0.28	0.19	0.09	
Natural gas	Bus	Million vehicle-km	NO	1.9	15	48	52	49	47	39	34	28	22	15	11	9	5
	Cargo truck		0.22	10	79	254	303	305	283	265	254	230	198	170	141	110	85
	Special-purpose vehicle		0.05	2.2	18	57	67	66	65	62	56	49	39	33	27	23	17

### ● $N_2O$ emissions from gasoline passenger vehicles in Japan

With the enhancement of the regulation of exhaust emissions of air pollutants on gasoline passenger vehicles in 1978, the under-floor type three-way catalyst started to be installed in Japan, leading to an increase in  $N_2O$  emissions per distance traveled until around 1986 when the three-way catalyst became widely used. New emission regulations on gasoline passenger vehicles were not stipulated for the time being. Therefore,  $N_2O$  emissions per distance traveled were stable from 1986 to 1997. From 1997, low emission vehicles were introduced. From 2000, with the stipulation of the “2000 Emission Regulation”,  $N_2O$  emissions per distance traveled started to decrease in response to the introduction of the close-coupled catalytic converter (or directly exhaust manifold type catalyst). Since 1997, the trend of  $N_2O$  emissions per distance traveled is on the decrease.

The purification of toxic gas by catalyst does not start if the catalyst temperature has not exceeded a certain threshold level. Therefore, the early activation (or quick temperature raise) of catalyst at cold start has been projected, and the catalyst was relocated directly under the exhaust manifold, and this structure is introduced to close-coupled catalytic converter.  $N_2O$  is produced at medium temperature range, however the temperature of close-coupled catalytic converter reaches over this range in a short time period, thus the  $N_2O$  emissions can be reduced. (Goto et al., 2003; Yoda et al., 2010)

The figure below shows the  $N_2O$  emissions from a vehicle with the under-floor type catalyst and a vehicle with the directly exhaust manifold type catalyst on the condition of the same test mode.

Figure 3-6 Difference of  $N_2O$  emissions by catalyst fitting position

Note: Test mode is 11 mode. Reference: Goto et al. (2003)

- **Completeness**

- *Biofuels*

Biofuels have been used in recent years, however the CH<sub>4</sub> and N<sub>2</sub>O emissions are estimated from activity data, which are not fuel consumption but mileage by vehicle type, and it is impossible to extract mileage only for biofuels. Therefore, CH<sub>4</sub> and N<sub>2</sub>O emissions from biofuels are reported as “IE”, assuming those emissions are already included in the existing emissions from gasoline or diesel oil.

- *Methanol*

The number of methanol vehicles owned in Japan was only 9 at the end of March 2016 (data surveyed by AIRIA). Therefore, activity data is negligible, and is not reported, as it is assumed that the emissions are also negligible.

- *Lubricants*

Since CH<sub>4</sub> and N<sub>2</sub>O emissions from use of lubricants are very small in comparison to CO<sub>2</sub>, these can be neglected for the greenhouse gas calculation according to the *2006 IPCC Guidelines* (Vol.3, page 5.7). Therefore, the emissions are reported as “NE”.

### c) *Uncertainties and Time-series Consistency*

- **Uncertainties**

The emission factors of road transportation vehicle are established from the data provided by JAMA and other organizations. For the emission factors established from the samples more than five, the uncertainty is calculated from 95% confidence interval with the assumption of logarithmic standard deviation. For the emission factors established from the samples less than five, the default values of uncertainty in the *2006 IPCC Guidelines* are adopted. As for the uncertainty of activity data, because the *Statistical Yearbook of Motor Vehicle Fuel Consumption* is used for the activity data, the sample error rate of the Motor Vehicle Fuel Consumption Survey shown at the Service Statistics and Business Statistics Section Meeting by Cabinet Office, Government of Japan is used for the uncertainty. As a result, the uncertainty of emissions from road transportation vehicles including motorcycles is evaluated as -36% to +104% for CH<sub>4</sub>, and -37% to +107% for N<sub>2</sub>O.

- **Time-series Consistency**

The emission factors are developed by using the same method throughout the time-series. The activity data of gasoline, diesel and LPG vehicles by FY2009 are estimated using the overlap factors given by MLIT, to be consistent with the activity data since FY2010. The activity data of natural gas vehicle are estimated based on the number of registered vehicles reported in the *Statistics of AIRIA/ Number of Motor Vehicle* after the accurate data has become available in 1997, and using the Japan Gas Association data for the total number of vehicles introduced before 1996 when the natural gas-powered vehicle was not popular. As for other activity data of natural vehicle, the data are estimated based on the *Statistical Yearbook of Motor Vehicle Transport* and the *Statistics of AIRIA/ Number of Motor Vehicle* by a consistent method throughout the time-series from FY1990 to the nearest year.

### d) *Category-specific QA/QC and Verification*

- **QA/QC**

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission



factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

### ● Verification

On the annual review in 2014 (FCCC/ARR/2014/JPN, paragraph 40), the ERT recommended to provide additional information on the annual number of vehicles by type, the annual mileage per vehicle and the fuel efficiency per vehicle type. The ERT also recommended to compare the annual mileage and fuel efficiency by vehicle category with the fuel consumption reported by the energy balance to ensure that no discrepancies occur.

The following tables show the annual number of vehicles by type, the annual mileage per vehicle and the fuel efficiency per vehicle type. Please note that not all these data are used for the estimation of the activity data as stated in the previous section.

Table 3-44 Annual number of vehicles by type

Fuel	Vehicle type	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Gasoline	Light passenger vehicle	1000 vehicles	2,715	5,966	10,084	14,350	18,004	18,586	19,348	20,230	21,026	21,477	21,761	22,051	22,325	22,528	22,736
	Passenger vehicle (non-hybrid)		29,140	33,891	37,794	40,104	37,594	37,099	36,178	35,023	33,793	32,685	31,733	30,688	29,525	28,413	27,469
	Passenger vehicle (hybrid) <sup>1)</sup>		NO	NO	NO	253	1,404	2,017	2,851	3,823	4,685	5,559	6,544	7,513	8,453	9,281	10,014
	Bus		8	3	2	5	9	10	11	13	14	15	16	16	17	18	18
	Light cargo truck		12,312	11,377	9,958	9,548	8,923	8,873	8,784	8,708	8,624	8,520	8,421	8,345	8,322	8,279	8,284
	Small cargo truck		2,820	2,144	1,901	1,988	1,826	1,813	1,788	1,772	1,760	1,750	1,750	1,747	1,742	1,725	1,709
	Regular cargo truck		41	38	39	90	128	134	138	140	146	150	153	155	157	160	162
	Special-purpose vehicle		141	198	393	330	287	287	290	291	293	297	299	302	304	309	313
	Passenger vehicle		2,994	4,924	4,254	2,126	905	796	744	730	761	855	953	1,063	1,197	1,318	1,437
Diesel	Bus	238	240	233	225	216	214	212	212	214	215	215	214	211	202		
	Small cargo truck	3,711	4,002	3,480	2,545	1,954	1,896	1,853	1,824	1,801	1,780	1,767	1,755	1,749	1,746	1,748	
	Regular cargo truck	2,164	2,544	2,534	2,350	2,105	2,091	2,086	2,100	2,116	2,130	2,151	2,169	2,197	2,223	2,243	
	Special-purpose vehicle	628	804	994	903	820	814	814	818	822	829	840	850	856	862	869	
LPG	All types	318	303	286	295	257	248	239	232	224	216	207	194	178	161	145	
	Passenger vehicle	0.01	0.01	0.2	0.6	0.7	0.6	0.4	0.3	0.2	0.2	0.1	0.1	0.03	0.02	0.01	
Natural gas	Bus	NO	0.04	0.3	1.1	1.2	1.2	1.1	0.9	0.8	0.7	0.6	0.4	0.3	0.2	0.2	
	Cargo truck	0.01	0.5	3.9	12.8	15.0	14.5	13.7	12.9	12.1	11.0	9.5	8.2	7.0	5.7	4.9	
	Special-purpose vehicle	0.004	0.2	1.5	4.8	5.6	5.4	5.2	4.9	4.4	3.9	3.3	2.8	2.3	1.9	1.5	

Reference: *Statistics of AIRIA/ Number of Motor Vehicle* and Japan Gas Association

Table 3-45 Annual mileage per vehicle

Fuel	Vehicle type	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Gasoline	Light passenger vehicle	1000 km /vehicle	5.8	6.8	7.2	7.4	7.6	7.4	7.6	7.4	7.5	7.5	7.8	8.0	8.1	8.0	7.1
	Passenger vehicle (non-hybrid)		9.4	9.0	9.1	8.7	8.5	8.7	8.7	8.6	8.3	8.3	8.4	8.5	8.6	8.6	7.6
	Passenger vehicle (hybrid) <sup>1)</sup>		NO	NO	NO	10.1	10.2	9.7	10.3	10.0	10.3	10.5	10.3	10.4	10.5	10.5	9.0
	Bus		11.9	9.3	9.0	8.6	34.7	22.8	15.8	14.9	14.2	14.5	13.6	12.9	12.7	12.5	9.3
	Light cargo truck		7.4	7.9	8.0	8.2	8.4	8.2	8.6	8.9	9.0	8.9	9.1	9.0	8.8	8.6	8.0
	Small cargo truck		10.3	9.5	10.3	10.5	12.2	12.7	13.0	13.1	13.2	13.1	12.3	12.2	12.3	12.3	11.7
	Regular cargo truck		8.8	7.7	6.9	6.7	11.0	10.7	10.9	9.9	9.2	9.4	9.0	8.7	8.7	8.7	7.4
	Special-purpose vehicle		4.7	3.5	3.3	3.9	9.9	9.5	9.4	8.9	8.4	8.3	8.1	8.2	8.3	8.2	7.4
	Passenger vehicle		13.3	12.8	13.0	13.7	11.4	11.7	11.4	11.1	10.4	10.1	9.7	10.0	10.2	10.5	9.2
Diesel	Bus	28.9	27.6	27.9	28.9	28.6	28.1	28.4	28.2	27.9	27.4	26.5	26.0	25.8	25.3	18.7	
	Small cargo truck	11.8	12.2	12.9	12.9	11.8	11.9	12.2	12.4	12.3	12.1	11.5	11.3	11.1	11.1	10.2	
	Regular cargo truck	26.7	26.8	28.6	29.5	29.9	29.2	28.5	28.1	27.9	27.9	27.5	27.4	27.2	26.8	24.9	
	Special-purpose vehicle	14.6	16.9	17.2	18.9	25.3	25.1	25.6	25.9	25.9	25.9	25.2	24.8	24.6	24.2	22.4	
LPG	All types	56.6	55.5	52.7	46.4	47.3	45.6	44.5	44.3	43.8	42.8	40.9	41.6	41.5	40.4	26.1	
	Passenger vehicle	10.2	9.8	9.8	9.2	8.9	9.0	9.1	9.0	8.8	8.9	8.9	9.0	9.2	9.2	8.1	
Natural gas	Bus	NO	47.6	45.9	44.9	43.3	42.0	42.5	41.9	41.3	39.9	38.3	37.2	36.7	36.1	26.8	
	Cargo truck	18.7	18.9	20.2	19.9	20.2	21.1	20.6	20.6	21.0	20.9	20.9	20.6	20.1	19.1	17.5	
	Special-purpose vehicle	11.1	11.2	12.0	11.8	12.0	12.3	12.5	12.7	12.7	12.6	11.8	11.7	11.6	11.6	10.8	

Note: Estimated by dividing the distance traveled on Table 3-41 by number of vehicle on Table 3-42.

1) Due to absence of mileage statistical data, the values until FY2009 are assumed to be the mean value of FY2010-2014.

Table 3-46 Fuel efficiency per vehicle type

Fuel	Vehicle type	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Gasoline	Light passenger vehicle	km/L	14.2	12.9	12.0	12.6	12.6	12.8	13.0	13.3	13.5	13.7	14.0	14.1	14.4	14.8	15.1
	Passenger vehicle (non-hybrid) <sup>1)</sup>	km/L	10.0	9.2	9.0	9.8	9.8	9.9	9.9	10.0	10.1	10.2	10.3	10.4	10.5	10.5	10.6
	Passenger vehicle (hybrid)	km/L	NO	NO	NO	IE	16.3	16.1	16.2	15.7	15.5	16.0	16.2	16.5	16.9	16.9	17.1
	Bus <sup>2)</sup>	km/L	4.1	3.9	4.1	4.3	5.8	6.0	6.2	6.5	6.7	6.8	7.1	7.3	7.6	7.7	7.7
	Light cargo truck	km/L	12.3	11.4	11.1	11.7	12.1	12.1	12.0	12.0	12.0	12.1	12.3	12.4	12.6	12.8	13.0
	Small cargo truck <sup>3)</sup>	km/L	8.2	7.7	8.2	8.5	9.3	9.3	9.2	9.1	9.0	9.0	9.2	9.3	9.4	9.7	9.9
	Regular cargo truck	km/L	4.4	4.2	4.4	4.6	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
	Special-purpose vehicle	km/L	5.1	4.8	5.2	6.4	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
	Passenger vehicle	km/L	9.7	7.8	7.0	6.9	9.0	9.0	9.0	9.2	9.3	9.6	10.0	10.5	10.9	12.3	
Diesel	Bus	km/L	3.6	3.4	3.4	3.6	3.6	3.6	3.5	3.5	3.5	3.6	3.5	3.6	3.6	3.6	3.4
	Small cargo truck	km/L	9.7	10.0	9.7	10.1	9.1	8.9	8.9	8.7	8.6	8.6	8.6	8.7	8.7	8.7	8.6
	Regular cargo truck	km/L	3.3	3.2	3.4	3.7	3.7	3.8	3.8	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9
	Special-purpose vehicle	km/L	3.0	3.0	3.2	3.8	4.0	4.0	4.0	4.1	4.0	4.0	4.0	4.0	4.0	4.0	4.0
	All types	km/L	6.0	5.6	5.3	5.4	5.4	5.4	5.3	5.3	5.4	5.4	5.5	5.5	5.6	5.6	5.8
LPG	All types	km/m <sup>3</sup>	4.1	4.1	4.1	4.1	4.1	4.2	4.1	4.2	4.2	4.2	4.2	4.1	4.1	4.0	
Natural gas	All types <sup>4)</sup>	km/m <sup>3</sup>	4.1	4.1	4.1	4.1	4.1	4.2	4.1	4.2	4.2	4.2	4.2	4.1	4.1	4.0	

Note: Mileage in *Statistical Yearbook of Motor Vehicle Fuel Consumption* and *Statistical Yearbook of Motor Vehicle Transport* are divided by fuel consumption in each statistics.

- 1) Hybrid passenger vehicle is included until FY2009.
- 2) Passenger car for business-noncargo-use and special-purpose car for private-noncargo-use are included since FY2010.
- 3) Regular cargo truck and special-purpose car for business cargo are included since FY2010.
- 4) Due to absence of fuel consumption statistical data, the values until FY2009 are assumed to be the same as the value of FY2010.

In regard to the relation between mileage and fuel consumption used for emission estimation, *Statistical Yearbook of Motor Vehicle Transport* and *Statistical Yearbook of Motor Vehicle Fuel Consumption* provide the annual total mileage, the fuel consumption (and the fuel efficiency derived from them). The annual total mileage from these statistics are used as a basis of the activity data to estimate CH<sub>4</sub> and N<sub>2</sub>O emissions. The CO<sub>2</sub> emissions are estimated by using *General Energy Statistics* (Japan's energy balance tables). *General Energy Statistics* uses the fuel consumption given in the above mentioned MLIT's statistics as primary statistics. Therefore, the same statistics are used as a basis in estimating both CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emissions.

### e) Category-specific Recalculations

New measurements of raw emission factors for vehicles were provided by JAMA, MOE, NIES, and Bureau of Environment of Tokyo Metropolitan Government. Therefore, the emission factors were revised for gasoline hybrid passenger vehicles since FY2003, gasoline passenger vehicles since FY2005, gasoline light cargo truck since FY2007, diesel passenger vehicles since FY2009, diesel regular cargo truck since FY2017, and gasoline light passenger vehicles since FY2018. In response to these revision, the CH<sub>4</sub> and N<sub>2</sub>O emissions for the period of FY2003-FY2019 were recalculated. See Chapter 10 for impact on trend.

### f) Category-specific Planned Improvements

The emission factors will be reviewed, as appropriate, in order to represent Japan's circumstances more suitably.

## 3.2.9.2.b. Motorcycles

### a) Category Description

This section provides the estimation methods for CH<sub>4</sub> and N<sub>2</sub>O emissions from motorcycles.

## b) Methodological Issues

### ● Estimation Method

The CH<sub>4</sub> and N<sub>2</sub>O emissions from motorcycles are established by using Tier 3 method in accordance with the decision tree of the *2006 IPCC Guidelines* (Vol. 2, page 3.14, Fig. 3.2.3). According to the Tier 3 method (Vol. 2, page 3.15, Equation 3.2.5), the equation indicates the aggregation of two types of emissions in different condition, one is the emissions in “hot” (running) condition when the engine is warm, and the other is “cold start” condition when the engine is cold at starting.

In Japan, the emission control regulation<sup>16</sup> for motorcycle has been established in 1999, and JAMA has collected the CH<sub>4</sub> and N<sub>2</sub>O emission data measured by test from “hot” and “cold start” condition engines of each type of emission controlled motorcycles. For these motorcycles, the emission factors are established from these measured data, and for emission uncontrolled motorcycles the default values in the *2006 IPCC Guidelines* are used. The CH<sub>4</sub> and N<sub>2</sub>O emissions are estimated and aggregated by using the equations below.

$$E = \sum_{i,j} (EF_{hot,i,j} \times AD_{hot,i,j} + EF_{cold,i,j} \times AD_{cold,i,j})$$

- $E$  : CH<sub>4</sub> and N<sub>2</sub>O emissions from motorcycles  
 $EF_{hot,i,j}$  : Emission factor for vehicle-km by type of motorcycle and by emission control status  
 $AD_{hot,i,j}$  : Total annual distance traveled by motorcycles by type and by emission control status  
 $EF_{cold,i,j}$  : Emission factor per startup by type and by emission control status  
 $AD_{cold,i,j}$  : Number of engine startups per year by each type of motorcycle and by emission control status  
 $i$  : Vehicle type  
 $j$  : Emission control status

### ● Emission Factors

#### ➤ “Hot” condition

The CH<sub>4</sub> and N<sub>2</sub>O emission factors established by JAMA are used for the emission controlled motorcycles, and for uncontrolled motorcycles the default values in the *2006 IPCC Guidelines* are used.

Table 3-47 CH<sub>4</sub> and N<sub>2</sub>O emission factors of motorcycle in “hot” condition [mg/km]

Vehicle type (displacement)	3 <sup>rd</sup> Regulation <sup>1)</sup>		1 <sup>st</sup> and 2 <sup>nd</sup> Regulation <sup>1)</sup>		Uncontrolled <sup>2)</sup>	
	CH <sub>4</sub>	N <sub>2</sub> O	CH <sub>4</sub>	N <sub>2</sub> O	CH <sub>4</sub>	N <sub>2</sub> O
Motor-driven cycles class 1 (50cc and under)	2.1	0.18	13.3	2.64	53	4
Motor-driven cycles class 2 (51cc-125cc)	3.4	1.39	16.7	0.23		
Mini-sized motorcycles (126cc-250cc)	4.6	0.95	12.5	0.85		
Small-sized motorcycles (Over 250cc)	2.4	0.47	22.2	1.09		

Note:

- 1) Data provided by JAMA
- 2) *2006 IPCC Guidelines*, Vol. 2, page 3.22, Table 3.2.3 Motorcycles/Uncontrolled/Running(hot)

#### ➤ “Cold start” condition

The CH<sub>4</sub> and N<sub>2</sub>O emission factors established by JAMA are used for the emission controlled motorcycles, and for uncontrolled motorcycles the default values in the *2006 IPCC Guidelines* are used.

<sup>16</sup> The regulated gases are CO, hydrocarbons (HC) and NO<sub>x</sub>.

Table 3-48 CH<sub>4</sub> and N<sub>2</sub>O emission factors for motorcycles in “cold start” condition [mg/start]

Vehicle type (displacement)	3 <sup>rd</sup> Regulation <sup>1)</sup>		1 <sup>st</sup> and 2 <sup>nd</sup> Regulation <sup>1)</sup>		Uncontrolled <sup>2)</sup>	
	CH <sub>4</sub>	N <sub>2</sub> O	CH <sub>4</sub>	N <sub>2</sub> O	CH <sub>4</sub>	N <sub>2</sub> O
Motor-driven cycles class 1 (50cc and under)	32.3	5.6	15.8	11.2	33	15
Motor-driven cycles class 2 (51cc-125cc)	41.7	18.9	18.3	4.2		
Mini-sized motorcycles (126cc-250cc)	31.9	17.2	30.2	13.7		
Small-sized motorcycles (Over 250cc)	78.0	21.3	26.1	6.9		

Note:

1) Data provided by JAMA

2) 2006 IPCC Guidelines, Vol. 2, page 3.22, Table 3.2.3 Motorcycles/Uncontrolled/cold start

### ● Activity Data

#### ➤ “Hot” condition

For the estimation of annual distance traveled by each vehicle type and by each emission control status, firstly and based on the number of owned vehicle by each vehicle type (*Monthly Report Statistics of Vehicles* (JAMA)), the number of sold vehicle by each sales year and by each vehicle type (JAMA and Japan Light Motor Vehicle and Motorcycle Association) is multiplied by the survival ratio by each past year (Japan Automobile Research Institute, 2008), and then the ratio of number of owned vehicle of each year by each past year is obtained, and the number of owned vehicle by each sales year and by each vehicle type is calculated. Secondary, this number is multiplied by annual travel distance by each vehicle type per one vehicle (calculated from *Survey of Motorcycle Market Trends* (JAMA)) and multiplied by use factor by each vehicle type and by each past year (Japan Automobile Research Institute, 2007), then the annual travel distance by each sales year and by each vehicle type is obtained. The emission control status is judged by the sales year.

#### ➤ “Cold start” condition

For the estimation of annual number of startup by each vehicle type and by emission control status, the number of owned vehicle by each vehicle type and by each emission control status, which is obtained through the calculation of “hot” condition activity data, is multiplied by annual number of startup by each vehicle type per one vehicle (calculated from *Survey of Motorcycle Market Trends*) and multiplied by use factor by each vehicle type and by each past year (Japan Automobile Research Institute, 2007), and then the annual number of startup by each sales year and by each vehicle type is obtained. The emission control status is judged by the sales year.

Table 3-49 Activity data of motorcycles

Activity data	Vehicle type (Displacement)	Emission control by regulation	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
Distance traveled	Motor-driven cycles class 1 (50cc and	3rd regulation	Million vehicle-km	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	522	856	955	1,096	
		1st & 2nd regulation		NO	NO	1,773	4,165	3,643	3,182	3,092	3,325	3,248	2,829	2,646	1,905	1,434	933	686	
		Uncontrolled		10,623	6,268	3,153	753	112	66	42	29	18	10	6	3	2	1	0	
	Motor-driven cycles class 2 (51cc-125cc)	3rd regulation		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	531	1,091	1,250	1,559
		1st & 2nd regulation		NO	NO	243	1,237	2,192	2,540	2,695	2,877	2,992	2,909	2,993	2,427	1,970	1,257	997	
		Uncontrolled		2,060	1,853	1,568	686	172	131	91	61	39	23	14	8	5	2	1	
	Mini-sized motorcycles (126cc-250cc)	3rd regulation		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	478	926	1,206	1,674
		1st & 2nd regulation		NO	NO	565	2,664	3,127	3,025	3,053	3,141	3,208	3,268	3,277	2,494	2,131	1,617	1,352	
		Uncontrolled		6,111	3,577	2,209	1,055	330	252	195	147	109	79	56	35	23	14	9	
	Small-sized motorcycles (over 250cc)	3rd regulation		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	474	920	1,235	1,634
		1st & 2nd regulation		NO	NO	317	1,662	2,751	2,781	2,952	2,883	3,037	3,471	3,568	2,896	2,552	2,017	1,761	
		Uncontrolled		3,568	3,083	2,505	1,292	559	448	367	271	212	179	136	93	69	44	31	
Number of startup	Motor-driven cycles class 1 (50cc and	3rd regulation	Million	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	110	180	222	254	
		1st & 2nd regulation		NO	NO	349	739	626	592	574	577	564	550	513	400	301	217	159	
		Uncontrolled		1,838	1,131	621	134	19	12	8	5	3	2	1	1	0	0	0	
	Motor-driven cycles class 2 (51cc-125cc)	3rd regulation		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	58	119	164	204
		1st & 2nd regulation		NO	NO	31	140	228	245	259	274	285	325	334	264	214	165	131	
		Uncontrolled		285	255	203	78	18	13	9	6	4	3	2	1	0	0	0	
	Mini-sized motorcycles (126cc-250cc)	3rd regulation		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	28	54	77	107
		1st & 2nd regulation		NO	NO	41	177	193	195	196	179	183	204	204	146	124	104	86	
		Uncontrolled		361	223	159	70	20	16	13	8	6	5	4	2	1	1	1	
	Small-sized motorcycles (over 250cc)	3rd regulation		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	10	20	38	50
		1st & 2nd regulation		NO	NO	19	78	111	111	117	95	87	111	114	62	55	62	54	
		Uncontrolled		187	177	154	60	23	18	14	9	6	6	4	2	1	1	1	

### c) Uncertainties and Time-series Consistency

#### ● Uncertainties

The uncertainty of the emissions from motorcycle is included and reported in “3.2.9.2.a Road transportation: vehicles other than motorcycles”. Therefore, please refer to the description in the uncertainties of the section.

#### ● Time-series Consistency

The same estimation factors are used throughout the time-series. As for the activity data, the number of owned vehicle, travel distance per one vehicle, and number of startup per one vehicle are estimated using the data provided by JAMA, Japan Light Motor Vehicle and Motorcycle Association, and MOE by a consistent method throughout the time-series from FY1990 to the nearest year.

### d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the 2006 IPCC Guidelines. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

### e) Category-specific Recalculations

The CH<sub>4</sub> and N<sub>2</sub>O emissions from motor-driven cycles for FY2019 were recalculated, because the number of owned vehicle for FY2019 were obtained. Actual values of emission factors were provided by JAMA, therefore, CH<sub>4</sub> and N<sub>2</sub>O emissions since FY2017 were recalculated. See Chapter 10 for impact on trend.

### f) Category-specific Planned Improvements

There are no major planned improvements in this category.

## 3.2.9.3. Railways (1.A.3.c.)

### a) Category Description

This section provides the estimation methods for CH<sub>4</sub> and N<sub>2</sub>O emissions from railways. Emissions

from railways come mainly from diesel-engine railway cars. In addition, there are small amounts of emissions from coal-fired steam locomotives.

### b) Methodological Issues

#### ● Estimation Method

The emissions are calculated by using Tier 1 method in accordance with the *2006 IPCC Guidelines* (Vol. 2, page 3.41, Fig. 3.4.2).

$$E = \sum_i (EF_i \times AD_i)$$

- $E$  : CH<sub>4</sub> and N<sub>2</sub>O emissions from railways  
 $EF_i$  : Emission factor of fuel consumption in railways by fuel type  
 $AD_i$  : Annual consumptions by fuel type  
 $i$  : Fuel type (diesel oil and coal)

#### ● Emission Factors

For emission factors for diesel-powered railway cars, the default values of “Diesel” shown in the *2006 IPCC Guidelines* are used after conversion to a per-liter value using the calorific value of diesel oil.

For the emission factors for steam locomotives, the default values of “sub-bituminous coal” shown in the *2006 IPCC Guidelines* are used after conversion to a per-weight value using the calorific value of imported steam coal.

Table 3-50 Default values for railway emission factors

Gas	Unit	Diesel engines	Steam locomotives
CH <sub>4</sub>	kg-CH <sub>4</sub> /TJ(NCV)	4.15	2
N <sub>2</sub> O	kg-N <sub>2</sub> O/TJ(NCV)	28.6	1.5

Reference: *2006 IPCC Guidelines*, Vol. 2, p. 3.43, Table 3.4.1

#### ● Activity Data

For the consumption of diesel oil by diesel engines in railways and coal consumption by steam locomotives, the diesel oil and coal consumption in the railway shown in the *General Energy Statistics* is used as activity data, respectively.

Table 3-51 Activity data used for estimation of emissions from railways

Fuel type	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Diesel oil	1000 kL	356	313	270	248	218	211	211	205	199	198	189	197	186	186	186
Coal	kt	1.3	1.2	1.7	1.4	1.7	1.7	1.6	1.5	1.5	1.5	1.6	1.5	1.4	1.5	0.6

### c) Uncertainties and Time-series Consistency

#### ● Uncertainties

Since the default values in the *2006 IPCC Guidelines* are adopted for the emission factors of railways, the uncertainties indicated in the *2006 IPCC Guidelines* (-60% to +151% for CH<sub>4</sub> and -50% to +200% for N<sub>2</sub>O) are adopted. Also, since the values in the *General Energy Statistics* are used for the activity data, the default values in the *2006 IPCC Guidelines* (-5% to +5%) are adopted for the uncertainty of activity data. As a result, the uncertainty of the emissions from railways is evaluated as -60% to +151% for CH<sub>4</sub> and -50% to +200% for N<sub>2</sub>O.

#### ● Time-series Consistency

The same emission factors are used throughout the time-series. The data given in the *General Energy Statistics* are used as activity data consistently throughout the time-series.

**d) Category-specific QA/QC and Verification**

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

**e) Category-specific Recalculations**

The emissions for FY2011-FY2015, FY2017 and FY2019 were recalculated due to a revision of calorific value and the energy consumption of the *General Energy Statistics*. See Chapter 10 for impact on trend.

**f) Category-specific Planned Improvements**

There are no major planned improvements in this category.

**3.2.9.4. Domestic Navigation (1.A.3.d.)****a) Category Description**

This section provides the estimation methods for CH<sub>4</sub> and N<sub>2</sub>O emissions from domestic navigation of ships for passenger and freight transport.

**b) Methodological Issues**● **Estimation Method**

The emissions were calculated by using Tier 1 method in accordance with the decision tree of the *2006 IPCC Guidelines* (Vol. 2, page 3.49, Fig. 3.5.1).

$$E = \sum_i (EF_i \times AD_i)$$

$E$  : CH<sub>4</sub> and N<sub>2</sub>O emissions associated with the navigation of domestic vessels

$EF_i$  : Emission factor of fuel consumption in domestic vessels

$AD_i$  : Consumption of each type fuel by domestic vessels

$i$  : Fuel type (diesel oil, fuel oil A, B and C)

● **Emission Factors**

The default values for Ocean-Going Ships (diesel engines) given in the *2006 IPCC Guidelines* (see the following table) are converted to emission factors per liter using the calorific value for each type of fuel (diesel oil, fuel oil A, B and C).

Table 3-52 Default emission factors for navigation

Gas	Emission factor
CH <sub>4</sub>	7 [kg-CH <sub>4</sub> /TJ(NCV)]
N <sub>2</sub> O	2 [kg-N <sub>2</sub> O/TJ(NCV)]

Reference: *2006 IPCC Guidelines* Vol. 2, page 3.50, Table 3.5.3

● **Activity Data**

The consumption of each fuel type in the domestic navigation taken from the *General Energy Statistics* is used for activity data.

Table 3-53 Activity data used for estimation of emissions from ships

Fuel type	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Diesel oil	1000 kL	133	208	204	195	154	149	141	142	157	148	147	155	149	150	150
Fuel oil A	1000 kL	1,602	1,625	1,728	1,324	1,007	969	1,006	994	984	980	1,013	1,010	993	1,020	1,036
Fuel oil B	1000 kL	526	215	152	63	18	16	16	14	12	9	7	7	5	3	0
Fuel oil C	1000 kL	2,446	3,002	3,055	2,873	2,482	2,460	2,517	2,487	2,482	2,386	2,392	2,347	2,361	2,300	2,178

- **Completeness**

According to the *2006 IPCC Guidelines* (Vol. 3, page 5.7), CH<sub>4</sub> and N<sub>2</sub>O emissions from use of lubricants are very small in comparison to CO<sub>2</sub>, and these can be neglected for the greenhouse gas calculation. Therefore, the estimation is not done.

**c) Uncertainties and Time-series Consistency**

- **Uncertainties**

Since the default values in the *2006 IPCC Guidelines* are adopted for the emission factors of domestic navigation, the uncertainties indicated in the *2006 IPCC Guidelines* (-50% to +50% for CH<sub>4</sub> and -40% to +140% for N<sub>2</sub>O) are adopted. Also, since the values in the *General Energy Statistics* are used for the activity data, the default values in the *2006 IPCC Guidelines* (-13% to +13%) are adopted for the uncertainty of activity data. As a result, the uncertainty of the emissions from domestic navigation is evaluated as -52% to +52% for CH<sub>4</sub> and -42% to +141% for N<sub>2</sub>O.

- **Time-series Consistency**

The same values for emission factors are throughout the time-series. The values given in the *General Energy Statistics* are used as activity data for domestic navigation consistently throughout the time-series from FY1990 to the nearest year.

**d) Category-specific QA/QC and Verification**

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

**e) Category-specific Recalculations**

The emissions since FY2011 were recalculated due to a revision of calorific value and the energy consumption of the *General Energy Statistics*. See Chapter 10 for impact on trend.

**f) Category-specific Planned Improvements**

There are no major planned improvements in this category.

### 3.2.9.5. Other Transportation (1.A.3.e.)

This subcategory is reported as “NO”, since fossil fuels are not combusted to transport materials by pipelines and no other activities to be reported are found.

### 3.2.10. CO<sub>2</sub> Emissions from Other Sectors and Other (1.A.4., 1.A.5: CO<sub>2</sub>)

**a) Category Description**

This section provides the estimation methods for CO<sub>2</sub> emissions from the commercial/institutional



(1.A.4.a), residential (1.A.4.b), agriculture/forestry/fishing (1.A.4.c) and other (1.A.5) sectors. The emissions from fuel combustion for the national defense purpose are included in commercial/institutional (1.A.4.a).

In FY2020, CO<sub>2</sub> emissions from this category accounted for 138,804 kt-CO<sub>2</sub>, and represented 12.1% of Japan's total GHG emissions (excluding LULUCF). The commercial/institutional (1.A.4.a) accounts for 47.6%, and is the largest subcategory within the "Other sectors" category in FY2020.

#### **b) Methodological Issues**

##### ● **Estimation Method**

The Tier 2 Sectoral Approach has been used in accordance with the decision tree of the *2006 IPCC Guidelines* to calculate emissions (Vol.2, Page 1.9, Fig. 1.2), as was the case for the energy industries (1.A.1). See section 3.2.4. b).

The energy consumption and emissions from waste incineration with energy recovery are reported in fuel combustion (1.A.) as "other fossil fuels" and "biomass" in accordance with the *2006 IPCC Guidelines*.

The estimation method, emission factors and activity data for emissions from waste incineration with energy recovery are the same as those used in the waste incineration (5.C.) in accordance with the *2006 IPCC Guidelines*. Please refer to Chapter 7 for further details on the estimation methods.

The CO<sub>2</sub> emissions from biomass are not included in the national totals but are reported in the CRFs as reference in accordance with the *2006 IPCC Guidelines*.

##### ● **Emission Factors**

The emission factors elaborated in the energy industries (1.A.1) were also used in this category. See section 3.2.4. b).

##### ● **Activity Data**

The data given in the *General Energy Statistics* were used for activity data, as was the case for the energy industries (1.A.1).

The activity data for each sub-category were calculated by totaling the final energy consumption in the commercial industry (#650000), residential (#700000), and agriculture, forestry and fishery (#611000) sectors, energy consumption related to non-utility power generation for use in one's own offices (auto power generation: #25xxxx), and energy consumption related to steam production for use in own offices (auto steam generation: #26xxxx) shown in the *General Energy Statistics*. Because the final energy consumption above includes the amount of non-energy use which was used for purposes other than combustion (non-energy and feedstock use: #951100, #951800 and #952000), these values were deducted from the energy consumption in each category.

The energy consumption of each fuel in the agriculture, forestry and fishery (#611000) sector in the *General Energy Statistics* is classified to mobile combustion and stationary combustion according to the ratio in the Table 3-56, which is the survey results by MOE in FY2014 and FY2015. Please refer to the Table 3-55 for which category the emissions from mobile or stationary combustion to be allocated in the CRF table.

The auto power generation and auto steam generation sectors are included in the energy transformation

& own use sector in *General Energy Statistics*. However, the 2006 IPCC Guidelines allocates CO<sub>2</sub> emissions from energy consumption for power or steam generation to the sectors generating that power or steam. As such, these CO<sub>2</sub> emissions are added to those from each office in the final energy consumption sector and are reported in 1.A.4.

Table 3-54 Energy consumptions in Other Sectors (1.A.4) (unit: PJ)

Fuel	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Liquid fuels	1,921	2,080	2,190	2,222	1,573	1,506	1,413	1,441	1,346	1,292	1,279	1,296	1,219	1,182	1,222
Solid fuels	3	2	1	1	19	15	12	15	12	12	29	21	81	71	70
Gaseous fuels	418	537	649	731	835	847	826	836	832	846	850	909	870	893	815
Other fossil fuels	196	219	257	278	243	242	257	248	246	239	274	278	260	268	262
Biomass	15	18	22	44	59	62	63	65	73	84	64	68	72	67	65
Total	2,553	2,856	3,118	3,277	2,729	2,672	2,571	2,606	2,509	2,473	2,495	2,573	2,501	2,480	2,433

Table 3-55 Correspondence between sectors of Japan's Energy Balance Table and those of the CRF (1.A.4 and 1.A.5)

CRF		General Energy Statistics	
1A4	Other sectors		
		Auto power generation (except for Production, transmission and distribution of electricity [#255330] (until 2015), Agriculture, fishery, mining and construction [#251000] and Manufacturing [#252000])	#255000
1A4a	Commercial/institutional	Auto steam generation (except for Agriculture, fishery, mining and construction [#261000] and Manufacturing [#262000])	#265000
		Final energy consumption; Commercial industry	#650000
		Non-energy and feedstock use; Commercial	#951800
1A4b	Residential	Final energy consumption; Residential	#700000
		Non-energy and feedstock use; Household	#952000
1A4c	Agriculture/forestry/fishing		
		Auto power generation; Agriculture, fishery, mining and construction (agriculture, forestry and fishery)	#251000
		Auto steam generation; Agriculture, fishery, mining and construction (agriculture, forestry and fishery)	#261000
		Final energy consumption; Agriculture, forestry and fishery [#610000]; stationary sources (estimates)	
		Non-energy and feedstock use; Agriculture, fishery, mining and construction (agriculture, forestry and fishery)	#951100
		Final energy consumption; Agriculture [#611100]; mobile sources (estimates)	
		Final energy consumption; Forestry [#611200]; mobile sources (estimates)	
		Final energy consumption; Fishery, except aquaculture [#611300]; mobile sources (estimates)	
		Final energy consumption; Aquaculture [#611400]; mobile sources (estimates)	
1A5	Other	NO	-

Note: #95xxxx items are subtracted as non-energy use activities.

Table 3-56 Ratio of mobile and stationary combustion by fuel in the agriculture/forestry/fishing (1.A.4.c)

Fuel	Agriculture		Forestry		Aquaculture			Fishery, except Aquaculture		
	Mobile combustion	Stationary combustion	Mobile combustion	Stationary combustion	Mobile combustion (ships)	Mobile combustion	Stationary combustion	Mobile combustion (ships)	Mobile combustion	Stationary combustion
Diesel oil	99%	1%	100%	0%	0%	100%	0%	0%	100%	0%
Fuel oil A	5%	95%	0%	100%	100%	0%	0%	100%	0%	0%
Kerosene	2%	98%	0%	100%	0%	0%	100%	0%	0%	100%
LPG and city gas	5%	95%	0%	100%	0%	0%	100%	0%	0%	100%

Reference: MOE (2015a)

### c) Uncertainties and Time-series Consistency

Same as 3.2.4 Energy Industries (1. A. 1). See section 3.2.4. c).

### d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the 2006 IPCC Guidelines.

The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

#### ***e) Category-specific Recalculations***

Due to the updates of the activity data and the emission factors based on the update of the *General Energy Statistics*, the emissions for the period of FY1990-FY1992 and FY1995-FY2019 were recalculated.

Updating the statistical data and improving the estimation methodology in the waste sector, CO<sub>2</sub> emissions from other fossil fuels for the period of FY1990-FY2019 were recalculated. See section 7.4.3 for details.

See Chapter 10 for impact on trend.

#### ***f) Category-specific Planned Improvements***

There are no major planned improvements in this category.

### **3.2.11. CH<sub>4</sub> and N<sub>2</sub>O Emissions from Other Sectors and Other (1.A.4., 1.A.5: CH<sub>4</sub> and N<sub>2</sub>O)**

#### ***a) Category Description***

This section provides the estimation methods for CH<sub>4</sub> and N<sub>2</sub>O emissions from the Commercial/institutional (1.A.4.a), Residential (1.A.4.b), Agriculture/forestry/fishing (1.A.4.c), and Other (1.A.5) sectors.

This category also provides the estimation methods for determining CH<sub>4</sub> and N<sub>2</sub>O emissions from mobile combustion such as off-road vehicles, fishing boats and other machinery. The emissions from fuel combustion for the national defense purpose are included in Commercial/institutional (1.A.4.a).

#### ***b) Methodological Issues***

##### **● Estimation Method**

##### **➤ Furnaces**

For Commercial/institutional (1.A.4.a) and the stationary combustion in Agriculture/forestry/fishing (1.A.4.c), same with Energy Industries (1.A.1), CH<sub>4</sub> and N<sub>2</sub>O emissions from fuel combustion in this category are calculated by using Tier 3 method in accordance with the decision tree of the *2006 IPCC Guidelines* (Vol.2, Page 1.9, Fig. 1.2). See section 3.2.5. b) (1.A.1).

##### **➤ Biomass boilers**

See section 3.2.5. b) (1.A.1).

##### **➤ Residential**

For Residential (1.A.4.b), CH<sub>4</sub> and N<sub>2</sub>O emissions from fuel combustion in this category are calculated by using Tier 1 method, since furnace-specific activity data is not available.

##### **➤ Off-road vehicles and other machinery**

The emissions from mobile combustion in Agriculture/forestry/fishing (1.A.4.c) are estimated by Tier 1 in accordance with the decision tree of the *2006 IPCC Guidelines* to calculate emissions (Vol.2, Page 3.34, Fig. 3.3.1).

## ● Emission Factors

### ➤ Furnaces

For Commercial/institutional (1.A.4.a) and the stationary combustion in Agriculture/forestry/fishing (1.A.4.c), the emission factors which were established in Energy Industries (1.A.1) were used. See Table 3-22 and Table 3-23 (1.A.1).

### ➤ Biomass boilers

See section 3.2.5. b) (1.A.1).

### ➤ Residential

For Residential (1.A.4.b), the emission factors which were provided in the *2006 IPCC Guidelines* (Vol. 2, pages 2.22-2.23, Table 2.5) were used.

Table 3-57 CH<sub>4</sub> and N<sub>2</sub>O emission factors for residential (1.A.4.b)

Furnace type	Fuel type	CH <sub>4</sub> Emission factor [kg-CH <sub>4</sub> /TJ]	N <sub>2</sub> O Emission factor [kg-N <sub>2</sub> O/TJ]
Household equipment	Liquid fuels	9.5	0.57
	Solid fuels	290	1.4
	Gaseous fuels	4.5	0.090
	Biomass fuels	290	3.8

Note: Conversion to the GCV basis by multiplying the IPCC default values by 0.95 (liquid, solid and biomass fuels) or 0.9 (gaseous fuels) (*2006 IPCC Guidelines*, Vol.2, page 1.16)

### ➤ Off-road vehicles and other machinery

The emission factors of diesel oil used for the mobile combustion in agriculture, fishing and aquaculture were estimated from the values of “1.A.4.c.ii-Agriculture/ Diesel” in the Table 3-1 of EEA (2016). The emission factors of fuel oil A and kerosene used for agriculture were not shown in the guidebook but were applied the same value of diesel oil since most of the fuel oil A and kerosene are also used for tractors. The emission factors of LPG and city gas were estimated from the value of “LPG” in the same Table, and the emission factors of diesel oil for forestry were estimated from the values of “1.A.4.c.ii-Forestry/ Diesel” in the same Table.

The emission factors of fuel oil A used for fishing and aquaculture were estimated from the values on Table 3.5.3 “Default water-borne navigation CH<sub>4</sub> and N<sub>2</sub>O emission factors” in the *2006 IPCC Guidelines* vol. 2, page 3.50.

Table 3-58 Emission factors of CH<sub>4</sub> and N<sub>2</sub>O for off-road vehicles and other machinery in Agriculture/forestry/fishing (1.A.4.c)

Fuel	Unit	CH <sub>4</sub> emission factor	N <sub>2</sub> O emission factor	Reference
Diesel oil, kerosene, fuel oil A used for other than ships	g/t	87	136	EEA (2016), Non-road mobile sources and machinery, Table 3-1
Diesel oil for forestry	g/t	49	138	
LPG, city gas	g/t	354	161	
Fuel oil A for ships	kg/TJ(NCV)	7	2	<i>2006 IPCC Guidelines</i> , Vol.2, Table 3.5.3

## ● Activity Data

### ➤ Furnaces

The fuel consumption, obtained by multiplying the fuel consumption of each sector and each fuel type in the *General Energy Statistics* by the ratio of stationary combustion in the Table 3-56 and the fuel consumption ratio by furnace type, is assumed to be the activity data for the stationary combustion

namely combustion in furnaces. Same with Energy Industries (1.A.1), the fuel consumption ratios by furnace were estimated from data by furnace on the *General Survey of the Emissions of Air Pollutants* and data on each fuel consumption statistics (*Yearbook of the Current Survey of Energy Consumption in the Selected Industries, Structural Survey of Energy Consumption, Electric Power Statistics, and Current Survey of Production Concerning Gas Industry*). See section 3.2.5. b) (1.A.1).

➤ *Biomass boilers*

See section 3.2.5. b) (1.A.2).

➤ *Residential*

The fuel consumption by fuel type in the *General Energy Statistics* was used for the activity data of residential (1.A.4.b).

➤ *Off-road vehicles and other machinery*

The fuel consumption, estimated by multiplying the fuel consumption of each fuel type in Agriculture, Forestry and Fishery in the *General Energy Statistics* by the ratios of fuel consumption of mobile combustion (Table 3-56), were used for the activity data of mobile combustion namely off-road vehicles and other machinery.

**c) *Uncertainties and Time-series Consistency***

➤ *Furnaces (including biomass boilers)*

See section 3.2.7. c).

➤ *Residential*

The uncertainties of the emission factors are set by the default values. The uncertainties of the activity data are set by the values established in section 3.2.4. c).

➤ *Off-road vehicles and other machinery*

See section 3.2.7. c).

**d) *Category-specific QA/QC and Verification***

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

**e) *Category-specific Recalculations***

Since the activity data for FY1990-2019 in the *General Energy Statistics* were revised, the CH<sub>4</sub> and N<sub>2</sub>O emissions in those years were recalculated.

Updating the statistical data in the waste sector, CH<sub>4</sub> and N<sub>2</sub>O emissions in FY2019 were recalculated. See section 7.4.3 for details.

See Chapter 10 for impact on trend.

**f) *Category-specific Planned Improvements***

See section 3.2.5. f).

### 3.2.12. Emissions from waste incineration with energy recovery

The three cases below in which waste is utilized as raw material or fuel meet the definition of emissions from waste incineration with energy recovery.

- Waste incineration with energy recovery
- Direct use of waste as alternative fuel
- Incineration of waste processed as fuel

The estimation method for emissions from these sources is applied for waste incineration (5.C) in accordance with the *2006 IPCC Guidelines*. The emissions are included in fuel combustion (1.A.) in accordance with the *2006 IPCC Guidelines*. Please refer to Chapter 7 for the details of the estimation methods.

The reporting category of the emissions for each type of waste is either “energy industries (category 1.A.1)”, “manufacturing industries and construction (1.A.2)” or “other sectors (1.A.4)” according to the use of waste as raw material or fuel. The fuel type is classified as “other fossil fuels” and “biomass”.

Greenhouse gas emissions during the direct use of waste as a raw material, such as plastics used as reducing agents in blast furnaces or as a chemical material in coking furnaces, or the use of intermediate products manufactured using the waste as a raw material, are also subject to the estimation of emissions.

Refuse-derived solid fuels (RDF: Refuse-Derived Fuel, RPF: Refuse Paper and Plastic Fuel) are also subject to the estimation of emissions as fuels produced from waste.

Table 3-59 Waste types whose emissions are estimated for “Waste Incineration and Energy Use (Reported on Energy Sector) (1.A.)”

Category	Waste type		Fuel type to be allocated to CRF	Treatment type	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	
1.A.4. (7.4.3.1) <sup>7)</sup>	Municipal solid waste	Plastics	Fossil-fuel derived plastics	Other fossil fuels	* Incinerator -continuous, -semi- continuous -batch type	○	○ <sup>2)</sup>	○ <sup>2)</sup>
			Biomass-based plastics	Biomass <sup>8)</sup>		NA <sup>1)</sup>		
		PET bottles	Fossil-fuel derived PET bottles	Other fossil fuels		○		
			Biomass-based PET bottles	Biomass <sup>8)</sup>		NA <sup>1)</sup>		
		Paper/ cardboard	Fossil-fuel derived fraction	Other fossil fuels <sup>9)</sup>		○		
			Biogenic fraction	Biomass		NA <sup>1)</sup>		
		Nappies	Fossil-fuel derived fraction	Other fossil fuels		○		
			Biogenic fraction	Biomass		NA <sup>1)</sup>		
		Textiles	Synthetic textiles	Other fossil fuels		○		
			Natural fiber	Biomass		NA <sup>1)</sup>		
	Other (biogenic)		Biomass	NA <sup>1)</sup>				
	Industrial solid waste	Waste oil	Fossil-fuel derived oil	Other fossil fuels	Incinerator	○	○	○
			Animal and vegetable oil	Biomass		NA <sup>1)</sup>	○	○
		Plastics	Fossil-fuel derived plastics	Other fossil fuels		○	○	○
			Biomass-based plastics	Biomass <sup>8)</sup>		NA <sup>1)</sup>	IE <sup>3)</sup>	IE <sup>3)</sup>
		Food waste [Animal and vegetable residues/animal carcasses]		Biomass		NA <sup>1)</sup>	○	○
		Paper/ cardboard	Fossil-fuel derived fraction	Other fossil fuels <sup>9)</sup>		○	IE <sup>4)</sup>	IE <sup>4)</sup>
			Biogenic fraction	Biomass		NA <sup>1)</sup>	○	○
		Wood		Biomass		NA <sup>1)</sup>	○	○
		Textile	Synthetic textile	-		IE <sup>5)</sup>	IE <sup>5)</sup>	IE <sup>5)</sup>
Natural fiber			Biomass	NA <sup>1)</sup>		○	○	
Sludge	Sewage sludge	-	NO	NO	NO			
	Other than sewage sludge	Biomass	NA <sup>1)</sup>	○	○			
Specially controlled industrial waste		-	IE <sup>5)</sup>	IE <sup>5)</sup>	IE <sup>5)</sup>			
1.A.1, 1.A.2 and 1.A.4 (7.4.3.2) <sup>7)</sup>	Municipal solid waste	Plastics	Fossil-fuel derived plastics	Other fossil fuels	Direct use as alternative fuel	○	○	○
			Biomass-based plastics	Biomass <sup>8)</sup>		NA <sup>1)</sup>	IE <sup>3)</sup>	IE <sup>3)</sup>
	PET bottles			-		NO	NO	NO
	Industrial solid waste	Waste oil	Fossil-fuel derived oil	Other fossil fuels		○	○	○
			Animal and vegetable oil	Biomass		NA <sup>1)</sup>	○	○
		Plastics	Fossil-fuel derived plastics	Other fossil fuels		○	○	○
			Biomass-based plastics	Biomass <sup>8)</sup>		NA <sup>1)</sup>	IE <sup>3)</sup>	IE <sup>3)</sup>
	Wood		Biomass	NA <sup>1)</sup>		○	○	
	Waste tire	Fossil-fuel derived fraction	Other fossil fuels	○		○	○	
		Biogenic fraction	Biomass <sup>8)</sup>	NA <sup>1)</sup>		IE <sup>6)</sup>	IE <sup>6)</sup>	
1.A.1 and 1.A.2 (7.4.3.3) <sup>7)</sup>	Refuse Derived Fuel (RDF)		Fossil-fuel derived fraction	Other fossil fuels	Incineration of waste processed as fuel	○	○	○
			Biogenic fraction	Biomass <sup>8)</sup>		NA <sup>1)</sup>	IE <sup>6)</sup>	IE <sup>6)</sup>
	Refuse Paper and Plastic Fuel (RPF)		Fossil-fuel derived fraction	Other fossil fuels		○	○	○
			Biogenic fraction	Biomass <sup>8)</sup>		NA <sup>1)</sup>	IE <sup>6)</sup>	IE <sup>6)</sup>

Note:

- CO<sub>2</sub> emissions from the incineration of biomass-derived waste are not included in the total emissions; instead it is estimated as a reference value and reported as “Biomass” fuel in the CRF tables.
- CH<sub>4</sub> and N<sub>2</sub>O emissions from incineration of municipal solid waste in bulk are estimated by each incineration type and reported as “Other fossil fuels” in the CRF tables.
- Included in fossil-fuel derived plastics in ISW
- Included in biogenic fraction of paper/cardboard
- Included in “Specially controlled industrial waste” incineration without energy recovery
- Included in the fossil-fuel derived fraction
- For details of categories to be reported in the CRF, see descriptions on each section.
- For the biomass fraction in solid waste, etc. such as plastics, waste tire, RPF and RDF, it is difficult to distinguish the activity data on calorie basis for energy sector from the fossil-fuel derived fraction since there are no appropriate way to decompose calorimetric data of mixed solid waste. Hence, the activity data is reported as “IE”, and is included in “other fossil fuels”.
- For the fossil-fuel derived fraction in “paper/cardboard”, it is difficult to distinguish the activity data on calorie basis for energy sector from the biogenic fraction. Hence, the activity data is reported as “IE”, and is included in “biomass”.

Table 3-60 Reporting categories on the energy sector whose emissions are estimated for waste incineration and energy use

Treatment type	Waste type	Application breakdown	Major application	Reporting category on the energy sector	CO <sub>2</sub> <sup>2)</sup>	CH <sub>4</sub>	N <sub>2</sub> O	
Waste incineration with energy recovery	MSW	(Unclassified)	Waste incineration with energy recovery	1.A.4.a. Commercial/institutional	○	○	○	
	ISW				○	○	○	
Direct use of waste as alternative fuel	MSW Plastics	Liquefaction	Fuel	1.A.2.g. Other	○	○	○	
		Blast furnace reducing agent	Reducing agent in blast furnace	1.A.2.a. Iron and steel	○	NO <sup>3)</sup>	NO <sup>3)</sup>	
		Coke oven chemical feedstock	Alternative fuel or raw material in coke oven	1.A.1.c. Manufacture of solid fuels	○	IE <sup>4)</sup>	NO <sup>5)</sup>	
		Gasification	Fuel	1.A.2.g. Other	○	NE <sup>6)</sup>	NE <sup>6)</sup>	
	Industrial waste	Waste oil	(Unclassified)	Fuel	1.A.2.g. Other	○	○	○
			Plastics	Blast furnace reducing agent	Blast furnace reducing agent	1.A.2.a. Iron and steel	○	NO <sup>3)</sup>
		Chemical industry		Boiler fuel	1.A.2.c. Chemicals	○	○	○
		Paper industry		Boiler fuel	1.A.2.d. Pulp, paper and print	○	○	○
		Cement burning		Cement burning	1.A.2.f. Non-metallic minerals	○	○	○
		Automobile manufacturer		Boiler fuel	1.A.2.g. Other	○	○	○
		Liquefaction		Fuel	1.A.2.g. Other	○	○	○
		Gasification		Fuel	1.A.2.g. Other	○	NE <sup>6)</sup>	NE <sup>6)</sup>
		Wood		(Unclassified)	Fuel	1.A.2.g. Other	NA	○
		Waste tire		Cement burning	Cement burning	1.A.2.f. Non-metallic minerals	○	○
	Boiler			Fuel	1.A.2.g. Other	○	○	○
	Iron manufacture			Alternative fuel or raw materials in iron manufacturing	1.A.2.a. Iron and steel	○	NO <sup>3)</sup>	NO <sup>3)</sup>
	Gasification			Fuel in iron manufacturing	1.A.2.a. Iron and steel	○	○	○
	Metal refining			Fuel in metal refining	1.A.2.b. Non-ferrous metals	○	○	○
	Tire manufacture			Fuel in tire manufacturing	1.A.2.c. Chemicals	○	○	○
	Paper manufacture			Fuel in paper manufacturing	1.A.2.d. Pulp, paper and print	○	○	○
Power generation	Power generation			1.A.4.a. Commercial/institutional	○	○	○	
Incineration of waste processed as fuel	Refuse-derived fuel (RDF)	(Unclassified)	Fuel use (including power generation)	1.A.2.g. Other <sup>1)</sup>	○	○	○	
	Refuse paper and plastic fuel (RPF)	Petroleum product manufacturer	boiler fuel	1.A.1.b. Petroleum refining	○	○	○	
		Chemical industry	boiler fuel	1.A.2.b. Chemicals	○	○	○	
		Paper industry	Fuel use in paper manufacturing	1.A.2.d. Pulp, paper and print	○	○	○	
		Cement manufacturer	Cement burning	1.A.2.f. Non-metallic minerals	○	○	○	

Note:

- 1) Emissions from power generation and heat supply excluding in-house use should be included in the category 1.A.1.a. However, they are reported in the category 1.A.2.g., because the actual circumstances are not understood at the moment.
- 2) CO<sub>2</sub> emissions from the incineration of biomass-derived fraction are not included in the total emissions; instead it is estimated as a reference value and reported as "Biomass" fuel in the CRF tables. For detail, see Table 3-59.
- 3) Blast furnace gas generated from steel industry is entirely recovered.
- 4) These emissions are included in "solid fuels" in the same category 1.A.1.c.
- 5) N<sub>2</sub>O is likely not produced since the atmosphere in coke oven is normally at least 1,000 degree Celsius, and reducing.
- 6) Considering that small fraction of these sources is combusted as alternative fuel but these are mostly used to obtain feedstock for ammonia productions, the emissions are not estimated.

Table 3-61 shows the greenhouse gas emissions from waste incineration and energy use (reported on energy sector) (1.A.).



Table 3-61 GHG emissions from waste incineration and energy use (reported on energy sector) (1.A.)

Gas	Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
CO <sub>2</sub> <sup>1)</sup>	I.A.1. Energy industries	a. Public electricity and heat production	kt-CO <sub>2</sub>	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	
		b. Petroleum refining	kt-CO <sub>2</sub>	NO	NO	0.6	6.4	5.8	4.6	5.5	4.5	5.0	6.1	4.5	5.0	0.3	0.1	0.6
		c. Manufacture of solid fuels and other energy industries	kt-CO <sub>2</sub>	NO	NO	15	246	247	237	240	NO	24	40	34	45	24	34	29
	I.A.2. Manufacturing industries and construction	a. Iron and steel	kt-CO <sub>2</sub>	NO	NO	312	639	549	488	538	474	580	562	590	626	531	570	419
		b. Non-ferrous metals	kt-CO <sub>2</sub>	119	63	51	17	2	2	NO	NO	NO	NO	NO	NO	NO	NO	NO
		c. Chemicals	kt-CO <sub>2</sub>	14	64	89	67	73	72	84	82	65	68	63	65	63	48	29
		d. Pulp, paper and print	kt-CO <sub>2</sub>	NO	56	114	998	1,804	1,825	1,850	1,930	1,986	2,044	2,089	2,150	2,181	2,073	2,055
		e. Food processing, beverages and tobacco	kt-CO <sub>2</sub>	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
		f. Non-metallic minerals	kt-CO <sub>2</sub>	197	492	879	1,088	1,324	1,355	1,357	1,453	1,636	1,590	1,711	1,780	1,965	2,050	2,047
		g. Other	kt-CO <sub>2</sub>	3,878	4,474	4,462	5,874	5,624	5,479	5,724	5,607	5,357	5,742	5,399	5,434	5,827	5,995	6,163
	I.A.4	a. Commercial/institutional	kt-CO <sub>2</sub>	6,505	7,146	9,043	8,406	6,801	6,990	7,737	7,549	7,172	7,254	8,169	8,540	7,902	8,607	8,252
		Total	kt-CO <sub>2</sub>	10,712	12,294	14,966	17,341	16,430	16,452	17,537	17,100	16,826	17,308	18,660	18,645	18,494	19,377	18,995
	CH <sub>4</sub> <sup>2)</sup>	I.A.1. Energy industries	a. Public electricity and heat production	kt-CH <sub>4</sub>	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
			b. Petroleum refining	kt-CH <sub>4</sub>	NO	NO	1.7E-06	1.8E-05	1.6E-05	1.3E-05	1.5E-05	1.3E-05	1.4E-05	1.7E-05	1.2E-05	1.4E-05	8.6E-07	3.2E-07
c. Manufacture of solid fuels and other energy industries			kt-CH <sub>4</sub>	NO	NO	IE	IE	IE	IE	IE	NO	IE	IE	IE	IE	IE	IE	IE
I.A.2. Manufacturing industries and construction		a. Iron and steel	kt-CH <sub>4</sub>	NO	NO	NO	7.7E-04	1.4E-03	1.3E-03	1.3E-03	1.2E-03	1.4E-03	1.4E-03	1.4E-03	1.6E-03	1.7E-03	1.6E-03	2.8E-04
		b. Non-ferrous metals	kt-CH <sub>4</sub>	3.2E-04	1.8E-04	1.4E-04	7.7E-05	7.7E-06	7.7E-06	NO	NO	NO	NO	NO	NO	NO	NO	NO
		c. Chemicals	kt-CH <sub>4</sub>	2.0E-05	1.0E-04	1.5E-04	1.7E-04	1.9E-04	1.9E-04	2.2E-04	2.2E-04	1.8E-04	1.9E-04	1.7E-04	1.7E-04	1.6E-04	1.2E-04	6.4E-05
		d. Pulp, paper and print	kt-CH <sub>4</sub>	NO	1.0E-04	2.2E-04	2.7E-03	4.8E-03	4.9E-03	5.0E-03	5.2E-03	5.4E-03	5.6E-03	5.7E-03	5.9E-03	6.0E-03	5.7E-03	5.7E-03
		e. Food processing, beverages and tobacco	kt-CH <sub>4</sub>	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
		f. Non-metallic minerals	kt-CH <sub>4</sub>	0.03	0.08	0.14	0.20	0.22	0.22	0.23	0.23	0.26	0.25	0.27	0.28	0.31	0.32	0.32
		g. Other	kt-CH <sub>4</sub>	1.8	1.8	2.2	2.9	4.2	4.4	4.5	4.8	5.3	5.0	4.9	5.2	5.1	5.5	5.8
I.A.4		a. Commercial/institutional	kt-CH <sub>4</sub>	0.54	0.54	0.60	0.15	0.14	0.17	0.17	0.15	0.15	0.14	0.15	0.15	0.14	0.14	0.14
		Total	kt-CH <sub>4</sub>	2.3	2.4	3.0	3.3	4.6	4.8	4.9	5.2	5.7	5.4	5.4	5.7	5.5	6.0	6.3
			kt-CO <sub>2</sub> eq.	59	60	74	81	114	120	122	129	142	135	134	142	138	149	157
N <sub>2</sub> O <sup>2)</sup>		I.A.1. Energy industries	a. Public electricity and heat production	kt-N <sub>2</sub> O	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
	b. Petroleum refining		kt-N <sub>2</sub> O	NO	NO	1.1E-05	1.2E-04	1.0E-04	8.3E-05	1.0E-04	8.1E-05	9.0E-05	1.1E-04	8.0E-05	9.1E-05	5.6E-06	2.1E-06	1.0E-05
	c. Manufacture of solid fuels and other energy industries		kt-N <sub>2</sub> O	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	I.A.2. Manufacturing industries and construction	a. Iron and steel	kt-N <sub>2</sub> O	NO	NO	NO	9.1E-04	1.6E-03	1.5E-03	1.5E-03	1.5E-03	1.7E-03	1.6E-03	1.7E-03	1.9E-03	2.0E-03	1.9E-03	3.4E-04
		b. Non-ferrous metals	kt-N <sub>2</sub> O	2.4E-04	1.3E-04	1.1E-04	5.6E-05	5.6E-06	5.6E-06	NO	NO	NO	NO	NO	NO	NO	NO	NO
		c. Chemicals	kt-N <sub>2</sub> O	8.5E-03	6.8E-03	8.5E-03	4.5E-03	3.3E-03	3.0E-03	3.2E-03	2.4E-03	1.7E-03	1.9E-03	1.5E-03	5.8E-03	6.5E-03	6.8E-03	8.2E-03
		d. Pulp, paper and print	kt-N <sub>2</sub> O	NO	6.6E-04	5.9E-03	2.2E-02	5.9E-02	5.7E-02	5.7E-02	5.6E-02	6.2E-02	6.1E-02	6.4E-02	6.7E-02	6.8E-02	6.5E-02	6.3E-02
		e. Food processing, beverages and tobacco	kt-N <sub>2</sub> O	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
		f. Non-metallic minerals	kt-N <sub>2</sub> O	2.7E-03	6.9E-03	1.2E-02	1.7E-02	1.9E-02	1.9E-02	1.9E-02	2.0E-02	2.3E-02	2.2E-02	2.4E-02	2.5E-02	2.7E-02	2.8E-02	2.8E-02
		g. Other	kt-N <sub>2</sub> O	5.8E-02	5.1E-02	5.3E-02	6.1E-02	6.8E-02	7.0E-02	7.1E-02	7.4E-02	7.9E-02	7.7E-02	7.5E-02	7.8E-02	7.8E-02	8.3E-02	8.7E-02
	I.A.4	a. Commercial/institutional	kt-N <sub>2</sub> O	1.2	1.3	1.6	1.1	0.9	0.9	1.0	1.0	1.0	0.9	1.0	1.0	1.0	1.0	1.0
		Total	kt-N <sub>2</sub> O	1.3	1.4	1.6	1.2	1.1	1.1	1.1	1.1	1.1	1.1	1.2	1.2	1.1	1.2	1.1
			kt-CO <sub>2</sub> eq.	379	416	488	372	328	326	342	334	335	319	358	363	340	347	339

Note:

- 1) Include fossil-fuel derived component only.  
CO<sub>2</sub> emissions from the incineration of biomass-derived waste (including biomass-based plastics and waste animal and vegetable oil) is not included in the total emissions in accordance with the 2006 IPCC Guidelines; instead it is estimated as a reference value and reported under "Biomass" in CRF table 1.A(a).
- 2) Include both fossil-fuel derived component and biogenic component.

### 3.3. Fugitive Emissions from Fuels (1.B.)

The Fugitive Emissions subsector consists of intentional and unintentional GHG emissions from unburned fossil fuels during their mining, production, processing, refining, transportation, storage, and distribution, and from geothermal power plants.

There are two main source categories in this sector: solid fuels (1.B.1): emissions from coal mining and handling, and oil and natural gas (1.B.2): emissions from the oil and natural gas industries. The main source of emissions from solid fuels is CH<sub>4</sub> contained in coal bed, whereas fugitive emissions, venting, flaring, volatilization, and accidents are the main emission sources in the oil and natural gas industries. The emissions from geothermal power generation are also reported in 1.B.2.d.

In FY2020, GHG emissions from fugitive emissions from fuels were 1,037 kt-CO<sub>2</sub> eq. and accounted for 0.1% of Japan's total GHG emissions (excluding LULUCF). The emissions have decreased by 80% compared to 1990.

Table 3-62 Emission trends of the fugitive emissions subsector (1.B)

Gas	CRF Category	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
CO <sub>2</sub>	1.B.1 Solid Fuels	a. Coal Mining	5.4	2.5	1.7	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.4	0.4	
		b. Solid Fuel Transformation	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
		c. Other (Uncontrolled Combustion and Burning Coal Dump)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	1.B.2 Oil and Natural Gas	a. Oil	0.03	0.03	0.03	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02
		b. Natural Gas	0.6	0.7	0.8	1.0	1.0	1.0	1.0	0.9	0.9	0.8	0.9	0.9	0.8	0.8	0.8	0.7
		c. Venting and Flaring	81.2	109.1	122.6	164.3	221.7	224.0	232.2	222.0	209.8	223.3	245.2	264.7	242.3	222.0	197.6	197.6
		d. Other (Geothermal Generation)	104.4	409.2	386.6	341.9	251.2	251.9	256.5	215.2	237.9	200.1	210.5	170.0	179.8	145.7	145.7	
	Total		kt-CO <sub>2</sub>	192	522	512	508	475	478	490	439	449	425	457	436	423	369	345
	CH <sub>4</sub>	1.B.1 Solid Fuels	a. Coal Mining	192.4	97.5	63.3	26.3	22.6	22.1	21.9	21.4	21.7	20.9	20.7	21.2	19.1	18.3	18.0
			b. Solid Fuel Transformation	3.4	3.3	2.7	1.8	1.4	1.3	1.2	1.2	1.1	1.0	1.0	0.9	0.9	0.9	0.8
c. Other (Uncontrolled Combustion and Burning Coal Dump)			NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	
1.B.2 Oil and Natural Gas		a. Oil	1.0	1.1	1.1	1.2	1.0	1.0	1.0	0.9	0.9	0.8	0.8	0.8	0.7	0.7	0.7	
		b. Natural Gas	7.0	7.8	8.8	10.7	11.1	10.9	10.5	9.8	9.2	9.3	10.0	9.9	9.4	8.7	7.8	
		c. Venting and Flaring	0.3	0.5	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	
		d. Other (Geothermal Generation)	0.2	0.8	0.7	0.7	0.5	0.5	0.5	0.4	0.5	0.4	0.4	0.3	0.4	0.3	0.3	
Total		kt-CH <sub>4</sub>	204.3	110.9	76.9	41.0	36.8	36.0	35.3	33.9	33.5	32.6	33.0	33.4	30.6	29.0	27.7	
		kt-CO <sub>2</sub> eq.	5,107	2,773	1,922	1,026	920	900	882	848	838	816	824	834	764	726	692	
N <sub>2</sub> O		1.B.1 Solid Fuels	a. Coal Mining	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
	b. Solid Fuel Transformation		0.007	0.007	0.005	0.004	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	
	c. Other (Uncontrolled Combustion and Burning Coal Dump)		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	
	1.B.2 Oil and Natural Gas	a. Oil	IE,NA	IE,NA	IE,NA	IE,NA	IE,NA	IE,NA	IE,NA	IE,NA	IE,NA	IE,NA	IE,NA	IE,NA	IE,NA	IE,NA	IE,NA	
		b. Natural Gas	0.0004	0.0005	0.0004	0.0004	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0002	0.0003	0.0003	
		c. Venting and Flaring	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	
		d. Other (Geothermal Generation)	0.0070	0.0071	0.0058	0.0040	0.0031	0.0028	0.0027	0.0027	0.0025	0.0023	0.0022	0.0021	0.0020	0.0020	0.0018	
	Total		kt-N <sub>2</sub> O	0.0070	0.0071	0.0058	0.0040	0.0031	0.0028	0.0027	0.0027	0.0025	0.0023	0.0022	0.0021	0.0020	0.0020	
			kt-CO <sub>2</sub> eq.	2.09	2.11	1.72	1.18	0.91	0.84	0.82	0.80	0.75	0.70	0.65	0.63	0.59	0.59	
	Total of all gases		kt-CO <sub>2</sub> eq.	5,301	3,296	2,436	1,535	1,396	1,378	1,373	1,287	1,288	1,241	1,282	1,271	1,188	1,095	1,037

(Reference) Biomass-origin CO<sub>2</sub> emissions

CO <sub>2</sub>	1.B.1 Solid Fuels	b. Solid Fuel Transformation	kt-CO <sub>2</sub>	130.7	129.2	105.9	70.5	53.5	49.0	47.5	46.5	43.6	40.6	37.3	36.3	34.1	33.5	31.0
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#### 3.3.1. Solid Fuels (1.B.1.)

##### 3.3.1.1. Coal Mining and Handling (1.B.1.a.)

###### 3.3.1.1.a. Underground Mines (1.B.1.a.i.)

###### a) Category Description

This category provides the estimation methods for CH<sub>4</sub> and CO<sub>2</sub> emissions from coal mining, post-mining process, and abandoned mines.

Coal contains CH<sub>4</sub> which was formed during the coalification process. Most will have been naturally

released from the ground surface before mine development, but mining releases the CH<sub>4</sub> remaining in coal beds into the atmosphere. Also, CH<sub>4</sub> may be released during post-mining activities, i.e. subsequent handling, processing and transportation of coal. In addition, some of the coal mines still emit CH<sub>4</sub> after they have been abandoned. Also, relatively low-density CO<sub>2</sub> is included in coal in comparison with CH<sub>4</sub>, and is emitted to the air through the similar process with the CH<sub>4</sub>.

The number of operational coal mines in Japan has decreased and coal production has decreased greatly as well. As a result, the amount of CH<sub>4</sub> emissions from coal mining has decreased year by year.

Furthermore, the coal mining practices have changed recently, resulting in the decreasing trend of CH<sub>4</sub> IEF. Specifically, coal is now mined in more shallow areas. Therefore, emitting less CH<sub>4</sub>. This is because deep areas are costly to mine compared to coal in shallow areas. Additionally, areas which have been previously mined, thus already releasing CH<sub>4</sub>, are re-mined for coal, using the latest technology. This contributes to low CH<sub>4</sub> emissions per amount of coal mined, even if compared with other countries.

The mining activities in Japan are elaborated in Matsumoto (2006) and Matsumoto *et al.* (2018).

## b) Methodological Issues

### ● Estimation Method

#### ➤ CH<sub>4</sub>

#### - Mining Activities

CH<sub>4</sub> emissions from mining activities are drawn from actual measurements obtained from individual coal mines using the Tier 3 method, in accordance with the decision tree of the *2006 IPCC Guidelines* (Vol. 2, page 4.11, Fig. 4.1.1).

#### - Post-Mining Activities

CH<sub>4</sub> emissions from post-mining activities are estimated using the Tier 1 method, which uses default emission factors in accordance with the decision tree of the *2006 IPCC Guidelines* (Vol. 2, page 4.11, Fig. 4.1.1). The emissions are estimated by multiplying the amount of coal mined from underground mines by the emission factor.

#### - Abandoned Underground Mines

In accordance with the decision tree in the *2006 IPCC Guidelines* (Vol 2, page 4.1.1, Fig4.1.1) and by using the Tier 2 method, the CH<sub>4</sub> emissions from abandoned underground mines are estimated by multiplying the number of abandoned mines, which are not submerged, by emission factors which are established with consideration of types of coal and period of being abandoned as shown in the following equation.

$$E = N \times F \times ER \times EF \times CF, \quad EF = (1 + a \times T)^b$$

*E* : Amount of GHG fugitive emissions from abandoned coal mine [kt/year]

*N* : Number of abandoned mines which was not submerged [sites]

*F* : The percentage of mines that release fugitive emissions

*ER* : GHG emissions from mines before mine closure [m<sup>3</sup>/year]

*EF* : Emissions reduction factor

*a, b* : Parameters determining emission decline curve

*T* : Time period of mine closure [year]

*CF* : Gas density [kt/m<sup>3</sup>] CH<sub>4</sub>: 0.67×10<sup>-6</sup>

➤  $CO_2$ - **Mining Activities**

$CO_2$  emissions are estimated by multiplying the production amount of coal by  $CO_2$  emission factor.

- **Post-Mining Activities**

$CO_2$  emissions are estimated by multiplying the production amount of coal by  $CO_2$  emission factor.

- **Abandoned Underground Mines**

The estimation method of  $CO_2$  emissions is similar to that of  $CH_4$  described above, and the  $CO_2$  emission factor is established based on  $CH_4$  emission factor.

● **Emission Factors**➤  $CH_4$ - **Mining Activities**

$CH_4$  emission factor for mining activities is established by converting the total emissions of  $CH_4$  gas (in volume unit) identified in a survey by J-COAL (Japan Coal Frontier Organization; former Japan Coal Energy Center) into weight basis using the density of  $CH_4$  ( $0.67 [kt/10^6m^3]$ ) at  $20^\circ C$  and 1 atmosphere, and then dividing it by the production amount of coal from underground mines. From FY1991 to 1994, since actual measurement data cannot be obtained, the emission factors for those years are interpolated using FY1990 and 1995 values.

Table 3-63 Emission factors for mining activities: underground mines

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Reference
Coal production of underground mines (A)	kt	9,471	8,118	4,016	1,635	1,225	1,132	1,100	1,103	1,124	980	1,102	1,275	660	459	565	Survey by J-COAL
$CH_4$ total emissions (B)	$10^6 m^3$	262	92	57	4.2	2.0	1.8	1.8	1.9	2.3	2.4	2.4	2.9	1.5	1.3	1.2	Survey by J-COAL
$CH_4$ total emissions (C)	kt- $CH_4$	176	62	38	2.8	1.3	1.2	1.2	1.2	1.5	1.6	1.6	1.9	1.0	0.9	0.8	=(B)*0.67
Emission factor	kg- $CH_4$ /t	19	8	9	1.7	1.1	1.0	1.1	1.1	1.4	1.6	1.4	1.5	1.5	1.9	1.4	=(C)/(A)*1000

- **Post-Mining Activities**

Due to the lack of data for emissions from post-mining activities in Japan, the emission factors are calculated as  $1.675 [kg-CH_4/t]$  by converting the average value ( $2.5 [m^3/t]$ ) of the default values given in the *2006 IPCC Guidelines* with the density of  $CH_4$  ( $0.67 [kt/10^6m^3]$ ) at  $20^\circ C$  and 1 atmosphere.

- **Abandoned Underground Mines**

To establish emission factor for abandoned underground mines, following values are used for the formula on the previous page;

The median of default values which is indicated in Table 4.1.5 in page 4.24 in the *2006 IPCC Guidelines* Vol.2 (1990-1925: 5%, 1926-1950: 26.5%, 1951-1975: 40%, 1976-2000: 54%, 2001-: 54.5%) are used for (F), the percentage of mines that release fugitive emissions.

The lower default value (1.3million cubic meter/year/site) indicated in Table 4.1.8 in page 4.27 in the *2006 IPCC Guidelines* Vol.2 is used for (ER), GHG emissions from mines before mine closure, by taking scale of mine into consideration.

The coefficients for sub-bituminous coal ( $a = 0.27$ ,  $b = -1.00$ ) indicated in Table 4.1.9 in page 4.27 in the *2006 IPCC Guidelines* Vol.2 are used for parameters to determine declining curve for emissions.

➤  $CO_2$ - **Mining Activities**

$CO_2$  emission factor for mining activities is established by multiplying  $CH_4$  emission factor (volume

basis) by proportion of volume fraction of CO<sub>2</sub> in coalbed gas to that of CH<sub>4</sub> (0.0088), which is obtained by using Hokkaido Development Agency (1965), and by CO<sub>2</sub> density (1.84kg/m<sup>3</sup>).

- **Post-Mining Activities**

In the same way as calculated for mining activities, the emissions factors for post-mining activities are established by multiplying CH<sub>4</sub> emission factor (volume basis) by 0.0088.

- **Abandoned Underground Mines**

In the same way as calculated for mining activities, the emissions factors for post-mining activities are established by multiplying CH<sub>4</sub> emission factor (volume basis) by 0.0088.

● **Activity Data**

- **Mining Activities, Post-Mining Activities**

The values used for activity data for underground mining and post-mining activities are derived by subtracting the surface mining production from the total raw coal production as given in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* and the data provided by J-COAL.

Table 3-64 Trends in coal production

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Total coal production	kt	10,676	8,814	4,625	2,146	1,782	1,784	1,819	1,824	1,903	1,774	1,855	1,991	1,307	1,014	1,042
Surface mines		1,205	695	610	511	557	652	719	721	778	795	753	716	647	555	477
Underground mines		9,471	8,118	4,016	1,635	1,225	1,132	1,100	1,103	1,124	980	1,102	1,275	660	459	565

- **Abandoned Underground Mines**

For activity data, the number of abandoned mines which were not submerged, estimated from the list of abandoned mine in J-COAL (2002).

Table 3-65 The number of abandoned mines which were not submerged

Fiscal year of abandonment	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970
Number of abandoned coal mine without submergence	39	34	28	48	12	32	91	103	61	46	33	42	21	42	29
Fiscal year of abandonment	1971	1972	1973	1974	1975	1976	1977	1978	1980	1987	1989	1992	1994	1995	Total
Number of abandoned coal mine without submergence	13	20	12	1	2	3	1	2	2	2	3	1	1	1	725

● **Recovery and flaring**

- **Mining Activities**

There is no flaring activity of CH<sub>4</sub> which has been emitted from the coal bed during mining in Japan, however there are activities of recovering CH<sub>4</sub> and using it as fuel. Therefore, the net amount of the emissions is estimated by subtracting the recovered value from the total CH<sub>4</sub> emissions. The values of recovery were provided by the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* (FY1990-FY1997) and the data provided by J-COAL (since FY1998).

Table 3-66 Trends in CH<sub>4</sub> recovery from mining activities

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Recovery	1000 m <sup>3</sup>	50,139	11,112	9,810	2,044	941	733	591	826	448	844	955	482	301	293	303

- **Post-Mining Activities**

The CH<sub>4</sub> recovery/flaring are reported as “NE,” because the existence of such activities has not been confirmed,

- **Abandoned Underground Mines**

Reported as “NO” since any activities for CH<sub>4</sub> recovery or flaring has not been implemented.

c) **Uncertainties and Time-series Consistency**

● **Uncertainties**

For the uncertainties of CH<sub>4</sub> emissions during mining activities, the actual measurement values provided by J-COAL are used for reporting. However, it is difficult to evaluate the uncertainties of these data; therefore, for evaluating the uncertainties, the figures (combined the uncertainty due to measurement error and the uncertainty of error due to the change of flow rate, by using error propagation equation) given in the *2006 IPCC Guidelines* are used, and the uncertainties are established at -5% to +5%. For the uncertainties of CO<sub>2</sub> emissions during mining activity, the uncertainty of CH<sub>4</sub> emissions and the uncertainty of proportion of volume fraction of CO<sub>2</sub> in coalbed gas to that of CH<sub>4</sub>, which is calculated using data provided by Hokkaido Development Agency are combined by error propagation equation, and the uncertainties are established at -19% to +19%.

For the uncertainties in CH<sub>4</sub> emission factors during post-mining activities, since the default values given in the *2006 IPCC Guidelines* are used for the estimation factors, the uncertainty values given in the *2006 IPCC Guidelines* (-33% to +300%) are used. For the uncertainties in CO<sub>2</sub> emission factors during post-mining activities, the uncertainty in CH<sub>4</sub> emission factors and the uncertainty in proportion of volume fraction of CO<sub>2</sub> in coalbed gas to that of CH<sub>4</sub>, which is calculated using data provided by Hokkaido Development Agency are combined by error propagation equation, and the uncertainties are evaluated at -38% to +301%. For the uncertainties in activity data of CH<sub>4</sub> and CO<sub>2</sub>, during post-mining activities, the actual measurement values provided by J-COAL are used for reporting. However, it is difficult to evaluate the uncertainties of these data; therefore, for evaluating the uncertainties, the figures given in the *2006 IPCC Guidelines* (-2% to +2%) are used, as a result, the uncertainties in emissions during post-mining activities are evaluated at -33% to +300% for CH<sub>4</sub> emissions and -38% to +301% for CO<sub>2</sub> emissions.

The uncertainties in CH<sub>4</sub> emissions from abandoned mines are established at -50% to +100% based on the description on the uncertainty in Tier 2 given in the *2006 IPCC Guidelines*. For the uncertainties in CO<sub>2</sub> emissions from abandoned mines, the uncertainties in CH<sub>4</sub> emissions and the uncertainties in proportion of volume fraction of CO<sub>2</sub> in coalbed gas to that of CH<sub>4</sub>, which is calculated using data provided by Hokkaido Development Agency, are combined by error propagation equation, and the uncertainties are evaluated at -53% to +102%.

● **Time-series Consistency**

The CH<sub>4</sub> total emissions data for mining activities in underground mines are consistently derived from J-COAL statistics for FY1990 and since FY1995. From FY1991 to FY1994, time-series consistency is ensured by interpolating the emission factors.

The total coal production and coal production in surface mines are provided by the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* prepared from FY1990 to FY2000. Thereafter, they are provided by J-COAL, because the categories of surface mining production and total coal production in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* are no longer provided. The data from the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* prepared until 2000 are provided by J-COAL. Therefore, the total coal production data from both of these sources are the same and are used in a consistent manner since FY1990.

The CH<sub>4</sub> recovery data for mining activities are consistent, as were the case for the total coal production and coal production in surface mines.

The numbers of abandoned coal mines, which are the activity data for the abandoned coal mines, are derived from the J-COAL (2002). The default values in the *2006 IPCC Guidelines* are used for the ratio of gas emitting coal mines, the amount of CH<sub>4</sub> emissions from the coal mine before the closure, and the parameters to determine the decreasing curve of the emissions. Also, the CO<sub>2</sub> emissions from the coal mine before closure are estimated from the CH<sub>4</sub> emissions by assuming the ratio of volume is constant, so that the time-series consistency is ensured.

#### **d) Category-specific QA/QC and Verification**

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

In order to ensure the safety of coal mine workers in Japan, monitoring the concentration of CH<sub>4</sub> and CO in coal mines is ordained by law. Under the law, mining companies must set rules on monitoring management. Mining companies monitor accurately under strict management and checks, and compile relevant reports. Furthermore, national authorities regularly check the monitoring measurements and safety reports.

#### **e) Category-specific Recalculations**

Although the production amount of salable coal was used as activity data until the previous submissions, the *2006 IPCC Guidelines* require to use the production amount of raw coal. Therefore, the production amount was revised for all years. As a result, the emissions from post-mining activities for all years and those from mining activities for FY1991-1994 were recalculated. See Chapter 10 for impact on trend.

#### **f) Category-specific Planned Improvements**

There are no major planned improvements in this category.

### **3.3.1.1.b. Surface Mines (1.B.1.a.ii.)**

#### **a) Category Description**

This category provides the estimation methods for fugitive emissions of CH<sub>4</sub> and CO<sub>2</sub> occurring during coal mining and post-mining activities in surface mines. The emissions of CH<sub>4</sub> recovered/flared during coal mining in surface mines are reported as “NE,” because the existence of such activities has not been confirmed.

#### **b) Methodological Issues**

##### **● Estimation Method**

##### **➤ CH<sub>4</sub>**

##### **- Mining Activities**

The CH<sub>4</sub> emissions from mining activities are calculated using the Tier 1 method and the default emission factor in accordance with the decision tree in the *2006 IPCC Guidelines* (Vol.2, page 4.18, Fig.4.1.2).

- **Post-Mining Activities**

The CH<sub>4</sub> emissions from post-mining activities are calculated using the Tier 1 method and the default emission factor in accordance with the decision tree in the *2006 IPCC Guidelines* (Vol.2, page 4.18, Fig.4.1.2).

Both are calculated by multiplying the amount of coal mined from surface mines by the relevant emission factor.

- CO<sub>2</sub>

- **Mining Activities**

CO<sub>2</sub> emissions are estimated by multiplying the production amount of coal by CO<sub>2</sub> emission factor.

- **Post-Mining Activities**

CO<sub>2</sub> emissions are estimated by multiplying the production amount of coal by CO<sub>2</sub> emission factor.

- **Emission Factors**

- CH<sub>4</sub>

- **Mining Activities**

The value of 0.804 kg-CH<sub>4</sub>/t is used as emission factor for mining activities. It was derived by converting the average (1.2 m<sup>3</sup>/t) of the default values given in the *2006 IPCC Guidelines*, using the concentration of CH<sub>4</sub> at one atmospheric pressure and 20°C (0.67 kt/10<sup>6</sup>m<sup>3</sup>).

- **Post-Mining Activities**

The value of 0.067 kg-CH<sub>4</sub>/t is used as emission factor for post-mining activities. It was derived by converting the average (0.1 m<sup>3</sup>/t) of the default values given in the *2006 IPCC Guidelines*, using the concentration of CH<sub>4</sub> at one atmospheric pressure and 20°C (0.67 kt/10<sup>6</sup>m<sup>3</sup>).

- CO<sub>2</sub>

- **Mining Activities**

CO<sub>2</sub> emission factor for mining activities is established by multiplying CH<sub>4</sub> emission factor (volume basis) by proportion of volume fraction of CO<sub>2</sub> in coalbed gas to that of CH<sub>4</sub> (0.0088), which is obtained by using Hokkaido Development Agency (1965), and by CO<sub>2</sub> density (1.84 kg/m<sup>3</sup>).

- **Post-Mining Activities**

In the same way as calculated for mining activities, the CO<sub>2</sub> emissions factors for post-mining activities are established by multiplying CH<sub>4</sub> emission factor (volume basis) by 0.0088.

- **Activity Data**

The figure for the surface production given in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* and the data provided by the J-COAL were used as activity data for mining and post-mining activities (see Table 3-64).

### c) **Uncertainties and Time-series Consistency**

- **Uncertainties**

For the uncertainty in CH<sub>4</sub> emission factor during mining activities, since the default value given in the *2006 IPCC Guidelines* is used for emission factor, the uncertainty values given in the *2006 IPCC Guidelines* (-50% to +200%) are used. For the uncertainty in CO<sub>2</sub> emission factor during mining



activities, the uncertainty in CH<sub>4</sub> emission factor and the uncertainty in proportion of volume fraction of CO<sub>2</sub> in coalbed gas to that of CH<sub>4</sub>, which is calculated using data provided by Hokkaido Development Agency, are combined by error propagation equation, and the uncertainty is calculated as -53% to +201%. For the activity data of CH<sub>4</sub> and CO<sub>2</sub> during mining activities, the actually measured data provided by J-COAL are reported, however it is difficult to evaluate the uncertainty of the data. Therefore, the uncertainty values of -2% to +2% in the *2006 IPCC Guidelines* are used. As a result, the uncertainties in emissions during mining were evaluated at -50% to +200% for CH<sub>4</sub> and -53% to +201% for CO<sub>2</sub>.

For the uncertainty in CH<sub>4</sub> emission factor during post-mining activities, since the default value given in the *2006 IPCC Guidelines* is used for emission factor, the values given in the *2006 IPCC Guidelines* (-33% to +300%) are used. For the uncertainty in CO<sub>2</sub> emission factor during post-mining activities, the uncertainty in CH<sub>4</sub> emission factor and the uncertainty in proportion of volume fraction of CO<sub>2</sub> in coalbed gas to that of CH<sub>4</sub>, which is calculated using data provided by Hokkaido Development Agency, are combined by error propagation equation, and the uncertainties are evaluated at -38% to +301%. For activity data for CH<sub>4</sub> and CO<sub>2</sub> during post-mining activities, the actual measurement data provided by J-COAL are reported. However, it is difficult to evaluate the uncertainties in these data, the figures (-2% to +2%) given by the *2006 IPCC Guidelines* are used. As a result, the uncertainties in emissions during post-mining activities are evaluated at -33% to +300% for CH<sub>4</sub> and -38% to +301% for CO<sub>2</sub>.

#### ● *Time-series Consistency*

The total coal production and coal production in surface mines were provided by the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* prepared from FY1990 to FY2000. Thereafter, they have been provided by J-COAL, because the categories of surface mining production and total coal production in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* are no longer provided. The data from the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* prepared by METI until 2000 are provided by J-COAL. Therefore, the total coal production data from both of these sources are the same and have been used in a consistent manner since FY1990.

#### *d) Category-specific QA/QC and Verification*

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

#### *e) Category-specific Recalculations*

The emissions for FY1997 were recalculated due to the revision of coal production in surface mines. See Chapter 10 for impact on trend.

#### *f) Category-specific Planned Improvements*

There are no major planned improvements in this category.

### 3.3.1.2. Solid Fuel Transformation (1.B.1.b.)

#### *a) Category Description*

This category provides the estimation methods for the GHG emissions in the process of manufacturing

charcoal in the oven; CH<sub>4</sub> emissions are released due to imperfect combustion of carbon contained wood material which is raw material of charcoal.

## b) Methodological Issues

### ● Estimation Method

The emissions from manufacturing charcoal are estimated by multiplying production amount of charcoal by emission factor.

### ● Emission Factors

The default values of the charcoal production given in the *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories* (hereinafter, *2019 Refinement*) (Vol.2, page 4.103, Table 4.3.3) is used since no default value for this category is provided in the *2006 IPCC Guidelines*. Although the *2019 Refinement* provides the default values for the production of biochar (charcoal for amendment in cropland), the default values of charcoal production are also applied for the emission estimation of biochar production, considering the national circumstances. The default values of biochar are for products by flame curtain biochar kilns, but charcoal kilns, mechanical kilns, and open-hearth furnaces are mainly used for biochar manufacturing in Japan. It is appropriate to apply the default values of charcoal for biochar manufacturing.

### ● Activity Data

The activity data are the production amount of charcoal (hard charcoal, soft charcoal, bamboo charcoal, fine charcoal and sawdust charcoal), which is obtained from *Basic Data for Special Forest Product* (Forestry Agency) and *Data for Charcoal* (Forestry Agency).

Table 3-67 The Production Amount of Charcoal

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Charcoal Production	kt	83.2	82.3	67.4	44.9	34.1	31.2	30.3	29.6	27.7	25.9	23.7	23.1	21.7	21.3	19.7

### ● Completeness

CO<sub>2</sub> are also emitted by charcoal production, but the emissions are not included in the national totals but are reported in the NIR as reference because they are bio-derived. The emissions from charcoal combustion are included in “1.A Fuel Combustion”, however the CO<sub>2</sub> emissions are not included in the national totals but are reported in the CRFs as reference in accordance with the *2006 IPCC Guidelines*.

The emissions from coke production are included in “1.A Fuel Combustion”. The *2019 Refinement* provides additional methodologies for coke production. The flaring of coke oven gas (COG) is one of the coke production sources presented in the *2019 Refinement*. According to the interview with the Japan Iron and Steel Federation, flaring is not conducted during the usual operation, but it is conducted rarely during the suspension and construction of consumption process. Nevertheless, most of the factories report COG, including the amount of flaring, to the *Current Survey of Energy Consumption*, which is primary statistics of the *General Energy Statistics* (Japan’s energy balance tables). For the sources of coke production other than flaring presented in the *2019 Refinement*, the emissions are taken into account through the activity data (fuel consumption of the *General Energy Statistics*) or the CH<sub>4</sub> emission factor of coking furnace lid.

In Japan, the production of briquettes is considered to meet the description of the activity of solid fuel transformation. The process of coal briquette production includes introducing water to coal, and squeeze-drying it. Therefore, the process is not thought to involve any chemical reactions, but the

emissions of CO<sub>2</sub>, CH<sub>4</sub> or N<sub>2</sub>O cannot be denied. However, the emissions are not estimated as no actual measurement has been taken and no default value is provided.

#### ***c) Uncertainties and Time-series Consistency***

##### **● *Uncertainties***

As for emission factors, the uncertainties for the default emission factors for charcoal production provided in the *2019 Refinement* are adopted. (-68% to +121% for CH<sub>4</sub> and -75% to +163% for N<sub>2</sub>O)

As for activity data, the uncertainties are substituted by the uncertainties for coal mining and handling (1.B.1.a) given in the *2006 IPCC Guidelines* (-2% to +2%), because the uncertainties for charcoal production are not available in the *Basic Data for Special Forest Product*.

As a result, uncertainties for emissions from charcoal production are evaluated as -68% to +121% for CH<sub>4</sub> and -75% to +163% for N<sub>2</sub>O.

##### **● *Time-series Consistency***

The reference of the charcoal production amount in FY1990, which is the *Data for Charcoal*, is different from the reference in and after FY1991, which is the *Basic Data for Special Forest Product*. However, both data are provided by the Forestry Agency and the data capturing ranges are set to be the same. The default values in the *2019 Refinement* are used for the emission factors throughout the time-series so that the consistency is ensured.

#### ***d) Category-specific QA/QC and Verification***

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

#### ***e) Category-specific Recalculations***

Since the activity data for FY2019 in *Basic Data for Special Forest Product* were revised, the CH<sub>4</sub> and N<sub>2</sub>O emissions in that year were recalculated. See Chapter 10 for impact on trend.

#### ***f) Category-specific Planned Improvements***

There are no major planned improvements in this category.

### **3.3.1.3. Others (Uncontrollable combustion and burning coal dumps) (1.B.1.c)**

This category provides the estimation methods for CO<sub>2</sub> emissions generated by unintentional coal combustion due to mine fire.

As for FY1999, coal combustion was occurred by the fire in Ikejima Coal Mine. However, since the amount of combusted coal is not available, it is reported as “NE”. As for other fiscal years, any fire resulted in coal combustion was not occurred; therefore, it is reported as “NO”.

### 3.3.2. Oil, Natural Gas and Other Emissions from Energy Production (1.B.2.)

#### 3.3.2.1. Oil (1.B.2.a.)

##### 3.3.2.1.a. Exploration (1.B.2.a.i.)

This category deals with fugitive emissions of CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O from the exploratory drilling of oil fields.

In Japan, GHG emissions by the exploratory drilling of oil and natural gas fields are basically only from flaring. Therefore, the flaring emissions associated with exploratory drilling are included in “1.B.2.c.Flaring.iii Flaring (Combined)”.

“1.B.2.a.i. Exploration of Oil” and “1.B.2.b.1 Exploration of Natural Gas” are reported as “IE”, because the fugitive emissions other than flaring are also conceptionally included in “1.B.2.c.Flaring.iii Flaring (Combined)” since the default emission factors in the *GPG (2000)*, which covers all fugitive emissions as well as venting and flaring emissions, are used in “1.B.2.c.Flaring.iii Flaring (combined)” as described later.

##### 3.3.2.1.b. Production (1.B.2.a.ii.)

###### a) Category Description

This category provides the estimation methods for fugitive emissions of CO<sub>2</sub> and CH<sub>4</sub> occur at production of crude oil and in lowering measuring instrument into well at servicing of operating oil fields.

The emissions associated with fugitive emissions during oil production are estimated for offshore and onshore oil field. The emissions from operating oil fields occur in servicing are reported in “1.B.2.b.ii Production of Natural Gas” and not included in this category, because the activity data of number of wells in production is not able to be divided into the numbers of oil producing wells and natural gas producing wells.

###### b) Methodological Issues

###### ● Estimation Method

The fugitive emissions from oil production are estimated using the Tier 1 method, in accordance with the decision tree in the *2006 IPCC Guidelines* (Vol. 2, page 4.39, Fig.4.2.2).

###### ● Emission Factors

###### - Production

For emission factors for fugitive emissions from oil production, the default values for fugitive emissions of conventional oil from offshore and offshore oil fields, which are indicated in the *2006 IPCC Guidelines*, are used. As for emission factors for onshore fields, the medians of default values are used.

Table 3-68 Emission factors for fugitive emissions from oil production

		Unit	CH <sub>4</sub>	CO <sub>2</sub>	N <sub>2</sub> O <sup>3)</sup>
Conventional Oil	Fugitive emissions from offshore fields	kt/10 <sup>3</sup> m <sup>3</sup>	5.9×10 <sup>-7</sup>	4.3×10 <sup>-8</sup>	NA
	Fugitive emissions from onshore fields	kt/10 <sup>3</sup> m <sup>3</sup>	1.8×10 <sup>-3</sup> 1)	1.3×10 <sup>-4</sup> 2)	NA

Reference : *2006 IPCC Guidelines* Vol. 2, page 4.50, Table 4.2.4

Note:

- 1) The default value is  $1.5 \times 10^{-6}$  -  $3.6 \times 10^{-3}$
- 2) The default value is  $1.1 \times 10^{-7}$  -  $2.6 \times 10^{-4}$
- 3) Excluded from calculations, as the default value is “NA”

#### - Servicing

As the fugitive emissions from the servicing of oil and natural gas wells are reported in “1.B.2.b.ii Production of natural gas”, refer to that section for the emission factors as well.

#### ● Activity Data

##### - Production

The amount of crude oil production by offshore and onshore oil field (excluding condensate<sup>17</sup>) is used for activity data.

The amount of condensate production in offshore gas field is estimated by multiplying the production amount of condensate by the percentage of production volume in offshore in total production volume of natural gas.

The estimated value above is deducted from total volume of domestic crude production in offshore oil field to obtain the production amount of crude oil from offshore oil field (excluding condensate).

The production amount of crude oil in onshore oil field (excluding condensate) is estimated by deducting crude oil production in offshore (excluding condensate) from total amount of crude oil production (excluding condensate).

Total production volume of natural gas, crude oil, and condensate is obtained from the data given in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products* and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics*. The production amount of natural gas and crude oil from offshore is obtained from *Natural Gas Data Yearbook* (Japan Natural Gas Association).

Table 3-69 Amount of oil production excluding condensate from offshore and onshore oil fields

Item		Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Oil production excluding condensate	offshore	1000 kL	175	391	167	76	78	76	72	70	82	76	67	70	59	104	104
	onshore	1000 kL	245	232	218	295	215	208	209	195	180	164	152	141	136	142	150

#### - Servicing

Because the fugitive emissions from the servicing of oil and natural gas wells are reported in “1.B.2.b.ii Production of natural gas”, please refer to that section also for the activity data.

#### ● Completeness

In this category, the amount of crude oil production excluding condensate is used as activity data. The GHG emissions associated with condensate production are included in 1.B.2.b.ii and 1.B.2.b.iii, because emission factors of these categories include emission from condensate production.

#### c) Uncertainties and Time-series Consistency

##### ● Uncertainties

The uncertainties for emission factors established in the *2006 IPCC Guidelines* (-100% to +100%) are used for emission factors for oil production, since the default values in the guidelines are used exclusively. For activity data, because the uncertainties of statistical data used as reference are not

<sup>17</sup> Light, liquid hydrocarbon that is produced from natural gas wells associated with natural gas production

available, the values established in the *2006 IPCC Guidelines* (-15% to +15% of the uncertainties associated with measurement of flow rate (excluding sales volumes)) are used. As a result, the uncertainties for fugitive emissions of CO<sub>2</sub> and CH<sub>4</sub> from oil production are evaluated as -101% to +101% for each.

- ***Time-series Consistency***

Consistent values are used for emission factors from FY1990 to the nearest year, using the above-described method. The activity data for oil production are calculated by using the annual data from the *Yearbook of Mineral Resources and Petroleum Products*, the *Natural Gas Data Yearbook* and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics* by the consistent estimation method throughout the time-series from FY1990 to the nearest year.

***d) Category-specific QA/QC and Verification***

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

***e) Category-specific Recalculations***

Since the activity data for FY2019 in the *Natural Gas Data Yearbook* were revised, the CO<sub>2</sub> and CH<sub>4</sub> emissions in that year were recalculated. See Chapter 10 for impact on trend.

***f) Category-specific Planned Improvements***

As for the fugitive emissions from the servicing of oil and natural gas wells, the correlative relationships between emissions and production volume of crude oil remains unclear when using estimation method in accordance with the *2006 IPCC Guidelines*, and it is likely that the result of the estimating does not reflect the actual status. Therefore, the estimation method in the *GPG (2000)* is adopted. In the future, the background information regarding the *2006 IPCC Guidelines* estimation method will be collected, and if new information is obtained, the adoption of the estimation in the *2006 IPCC Guidelines* will be studied.

### **3.3.2.1.c. Transport (1.B.2.a.iii.)**

***a) Category Description***

This category provides the estimation methods for fugitive emissions of CO<sub>2</sub> and CH<sub>4</sub> occurring during the transportation of crude oil and condensate through pipelines, tank trucks, and tank cars to refineries.

***b) Methodological Issues***

- ***Estimation Method***

The fugitive emissions from transport of crude oil and condensate are estimated using the Tier 1 method in accordance with the decision tree in the *2006 IPCC Guidelines* (Vol.2, page 4.40, Fig.4.2.3) by multiplying the amount of crude oil and condensate production by the emission factors.

In this category, fugitive emissions from ocean transportation of crude oil which are produced at domestic offshore oil fields and are shipped from ocean to land, and the fugitive emissions from land

transportation are estimated. Crude oil is transported on sea entirely by pipeline, and is not expected to generate any fugitive emissions from other transportation modes. Land transport includes a number of methods, including pipeline, tank trucks, and tank cars, but it is difficult to differentiate them statistically. For that reason, the emissions were estimated under the assumption that all of the produced oil is transported by tank trucks and rail cars.

### ● Emission Factors

The default values given in the *2006 IPCC Guidelines* were used as emission factors.

Table 3-70 Emission factors for transportation of crude oil and condensate

Item	Unit	CH <sub>4</sub>	CO <sub>2</sub>	N <sub>2</sub> O
Oil Transport/ Tanker Trucks and Rail Cars	kt/10 <sup>3</sup> m <sup>3</sup>	2.5×10 <sup>-5</sup>	2.3×10 <sup>-6</sup>	NA
Natural Gas Liquids Transport/ Condensate	kt/10 <sup>3</sup> m <sup>3</sup>	1.1×10 <sup>-4</sup>	7.2×10 <sup>-6</sup>	ND

Reference : *2006 IPCC Guidelines* Vol. 2, page 4.50 and 4.53, Table 4.2.4

Note: N<sub>2</sub>O is excluded from calculations, as the default value is “NA” or “ND”.

### ● Activity Data

The amount of oil and condensate production in Japan given in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products Statistics* and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics* are used as activity data for fugitive emissions from transport.

Table 3-71 Production of crude oil and condensate in Japan

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Oil production excluding condensate	1000 kL	420	623	386	370	293	284	281	265	262	240	219	210	195	247	254
Condensate production		234	243	375	541	560	541	478	403	365	339	331	336	301	278	259
Oil production (total)		655	866	761	911	853	824	759	668	626	578	549	546	496	524	513

### c) Uncertainties and Time-series Consistency

#### ● Uncertainties

For the uncertainty of emission factors for CO<sub>2</sub> and CH<sub>4</sub> fugitive emissions from transportation of crude oil and condensate, the values established in the *2006 IPCC Guidelines* (-100% to +100%) are applied since the default values given in the guidelines are used exclusively. As for the uncertainty for activity data, the values established in the *2006 IPCC Guidelines* (-15% to +15% of the uncertainties associated with measurement of flow rate (excluding sales volumes)) are used since the uncertainties of statistical data used as reference are not available. As a result, the uncertainties for the CO<sub>2</sub> and CH<sub>4</sub> emissions from oil and condensate transport are evaluated to be -101% to +101% for each.

#### ● Time-series Consistency

For the emission factors, consistent values are used from FY1990 to the nearest year with the above-mentioned method. The activity data are calculated based on the annual data from the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products Statistics* and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics* by a consistent method throughout the time-series from FY1990 to the nearest year.

### d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*.

The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

**e) Category-specific Recalculations**

There have been no recalculations of emissions from this category.

**f) Category-specific Planned Improvements**

There are no major planned improvements in this category.

**3.3.2.1.d. Refining / Storage (1.B.2.a.iv.)**

**a) Category Description**

This category provides the estimation methods for fugitive emissions of CH<sub>4</sub> occurring when crude oil is refined or stored at oil refineries.

The CO<sub>2</sub> emissions from this source are reported as “NE”. Refining/storage activities exist in Japan and an extremely small amount of CO<sub>2</sub> is considered to be released into the atmosphere from these activities if CO<sub>2</sub> is included in crude oil. Because there are neither actual measurements of the CO<sub>2</sub> content of crude oil nor any default values for emission factors, CO<sub>2</sub> emissions from this source are not estimated.

**b) Methodological Issues**

● **Estimation Method**

- **Oil Refining**

The fugitive emissions from oil refining are estimated using the Tier 1 method in accordance with the decision tree in the *2006 IPCC Guidelines* (Vol. 2, page 4.40, Fig. 4.2.3).

- **Oil Storage**

For the fugitive emissions from oil storage, a country-specific emission factors can be used. Therefore, the emissions are estimated using these factors.

● **Emission Factors**

- **Oil Refining**

With respect to the emission factors for fugitive emissions during the refining process, the amount of CH<sub>4</sub> emitted during the crude oil refining process is considered to be negligible because no fugitive emission of CH<sub>4</sub> is likely to occur in Japan during crude oil refining at normal operation. For that reason, the lower limit of the default values shown in the *2006 IPCC Guidelines* is adopted.

Table 3-72 Emission factor during crude oil refining

Emission factor [kg-CH <sub>4</sub> /10 <sup>3</sup> m <sup>3</sup> ]	
Oil refining	2.6×10 <sup>-6</sup>

Reference : *2006 IPCC Guidelines* Vol. 2, page 4.53, Table 4.2.4

Note: The default value is 2.6×10<sup>-6</sup> - 41.0×10<sup>-6</sup>

- **Oil Storage**

Oil is stored in either corn-roof tanks or floating-roof tanks. All oil storage in Japan adopts floating-roof tanks, which means that the fugitive CH<sub>4</sub> emissions are considered to be very small. If fugitive CH<sub>4</sub> emissions were to occur, they could only occur by vaporization of oil left on the exposed wall wet with



oil when the floating roof descends as the stored oil is removed; thus, the amount of fugitive CH<sub>4</sub> emissions would be small.

The Petroleum Association of Japan has conducted experiments relating to the evaporation of CH<sub>4</sub> from tank walls by making the model of floating-roof tank, and based on the result the CH<sub>4</sub> emissions are estimated.

The emission factor associated with the storage of crude oil is obtained by dividing the emissions estimated by the Petroleum Association (0.007 kt-CH<sub>4</sub>/year as of 1998) by the amount of the crude oil put into the oil refining industry (from *General Energy Statistics*).

Table 3-73 Assumptions for calculation of emission factor during oil storage

CH <sub>4</sub> emissions [kt-CH <sub>4</sub> /year]	Input of crude oil to oil refining industry [10 <sup>3</sup> kL]	Emission factor [kt-CH <sub>4</sub> /10 <sup>3</sup> kL]
7×10 <sup>-3</sup>	242,861	2.9×10 <sup>-8</sup>

#### ● Activity Data

The values used for activity data during refining and storing are the values (in volume) of refined NGL (Natural Gas Liquids) and crude oil in the petroleum refining industry taken from the *General Energy Statistics*.

Table 3-74 Amount of crude oil and NGL refined in Japan

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Oil and NGL refined	10 <sup>6</sup> m <sup>3</sup>	204	241	242	241	209	197	197	200	189	188	191	184	177	174	139

#### c) Uncertainties and Time-series Consistency

##### ● Uncertainties

For the uncertainties of emission factors for fugitive emissions of CH<sub>4</sub> from refining crude oil and NGL, the values shown in the *2006 IPCC Guidelines* (-100% to +100%) are applied since the default values in the guidelines are used exclusively. The uncertainties for activity data for the fugitive emissions from refining crude oil and NGL are evaluated to be -21% to +21% respectively by error propagation method using the uncertainties of the standard calorific value and statistics used for estimating consumption. However, since the uncertainties of statistical data used for estimating consumption (*Yearbook of Mineral Resources and Petroleum Products* and *Yearbook of the Current Survey of Energy Consumption*) are not available, the default values provided in the *2006 IPCC Guidelines* (the uncertainties associated with measurement of flow rate (excluding sales volumes)) are substituted. As a result, the uncertainties for CH<sub>4</sub> fugitive emissions associated with refining of crude oil and NGL are evaluated at -102% to +102% for each.

As for the uncertainties of emission factors for fugitive emissions of CH<sub>4</sub> during storage of crude oil and NGL, the country-specific values were used. However, it is difficult to evaluate uncertainties; therefore, the values evaluated in the *2006 IPCC Guidelines* (-100% to +100%) are applied. The uncertainties for activity data for the fugitive emissions during storage of crude oil and NGL are evaluated to be -21% to +21% respectively by error propagation method using the uncertainties of standard calorific value and statistics used for estimating consumption. However, since the uncertainties of statistical data used for estimating consumption (*Yearbook of Mineral Resources and Petroleum Products* and *Yearbook of the Current Survey of Energy Consumption*) are not available, the default values provided in the *2006 IPCC Guidelines* (the uncertainties associated with measurement of flow rate (excluding sales volumes)) are substituted. As a result, the uncertainties for CH<sub>4</sub> fugitive emissions

associated with storage of crude oil and NGL are evaluated at -102% to +102% for each.

- **Time-series Consistency**

Consistent values are used for emission factors from FY1990 to the nearest year by using above-mentioned method. The activity data for refining and storage are calculated using the data from the *General Energy Statistics*, by a consistent method throughout the time-series from FY1990 to the nearest year.

**d) Category-specific QA/QC and Verification**

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

**e) Category-specific Recalculations**

Since the activity data for FY2019 in the *General Energy Statistics* were revised, the CH<sub>4</sub> emissions in that year were recalculated. See Chapter 10 for impact on trend.

**f) Category-specific Planned Improvements**

There are no major planned improvements in this category.

### 3.3.2.1.e. Distribution of Oil Products (1.B.2.a.v.)

Petroleum products are distributed in Japan, and where CO<sub>2</sub> and CH<sub>4</sub> are dissolved, it is conceivable that either or both will be emitted as a result of the relevant activity. The level of CO<sub>2</sub> or CH<sub>4</sub> emitted by the activity is probably negligible in light of the composition of the petroleum products, but because there is no measurement of the CO<sub>2</sub> or CH<sub>4</sub> content in petroleum products, it is not currently possible to calculate emissions. The emissions are reported as “NE” due to the absence of default emission factors.

### 3.3.2.1.f. Other (abandoned oil wells) (1.B.2.a.vi.)

The emissions from abandoned oil wells are reported under this category, since the estimation method for greenhouse gas emissions from abandoned oil wells was not provided in the *2006 IPCC Guidelines* but was provided in the *2019 Refinement*.

In accordance with the Enforcement Ordinance of the Mine Safety Act, systems are in place to prevent gas leakage from abandoned mines, as examples of measures to be taken by holders of mining rights, the following are listed: “Method of sealing wells”, “Method of installing cement plugs”, “Filling with muddy water, etc.”, “Examination after measures and confirmation of sealing condition” and “Method of restoration around the mine entrance area” (Ministry of Economy, Trade and Industry, 2012). Also, in the event of gas outburst or outflow of hazardous gas, this Enforcement Ordinance imposes an obligation to report the status of the disaster to the Minister of Economy, Trade and Industry immediately after the occurrence of the disaster, and management systems have been established to enable immediate identification of any leakage in this activity.

In addition, according to the Japan Natural Gas Association, the abandoned petroleum mines<sup>18</sup> in Japan have been taking measures to prevent gas leakage in accordance with the Mine Safety Act, and there have been no leaks from the wells. Also, each operator reportedly conducts regular inspections (about once a year) even after waiving the mining rights.

Judging from the above-mentioned measures regime in the abandoned mines, there are no emissions from the abandoned oil wells in Japan. Therefore, it is reported as “NA” in this category, which means that “the activity does occur, but do not result in emissions or removals of a specific gas”.

### **3.3.2.2. Natural Gas (1.B.2.b.)**

The natural gas supply network and the inventory categorization of GHG fugitive emissions from each process of the network are shown in Figure 3-7.

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<sup>18</sup> In Enforcement Ordinance of the Mine Safety Act, “petroleum” includes combustible natural gas (excluding those collected in connection with the mining of coal or lignite in mines intended for the mining of coal or lignite).

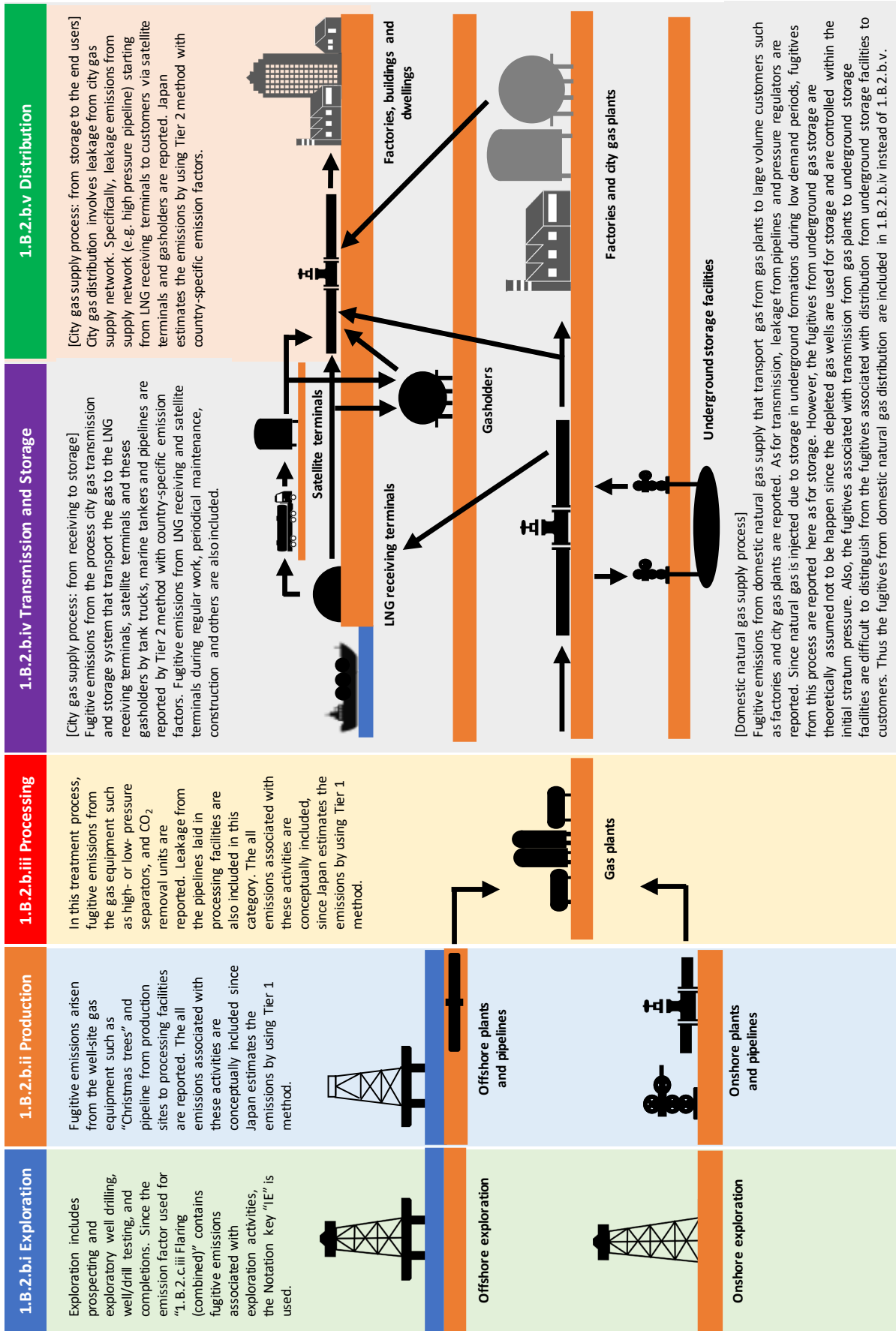


Figure 3-7 Supply network and inventory categorization of natural gas

### 3.3.2.2.a. Exploration (1.B.2.b.i.)

This category deals with fugitive emissions of CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O from the explorative drilling of natural gas fields. As well as “1.B.2.a.i Exploration of oil”, the emissions by the explorative drilling are basically only from flaring in Japan. Also, it is difficult to distinguish between oil fields and gas fields prior to exploration. Therefore, the emissions are included in “1.B.2.c.Flaring.iii Flaring (combined)”. In addition, similar to the “1.B.2.a.1 Exploration of oil”, all fugitive emissions as well as venting and flaring emissions are also conceptually included in “1.B.2.c.Flaring.iii Flaring (Combined)”. Therefore, the emissions from this category are reported here as “IE”.

### 3.3.2.2.b. Production (1.B.2.b.ii.)

#### a) Category Description

This category provides the estimation methods for fugitive CO<sub>2</sub> and CH<sub>4</sub> emissions from natural gas production and from the lowering work of measuring instruments during the servicing of natural gas wells. The fugitive emissions from natural gas production are estimated by offshore oil fields and onshore oil fields.

#### b) Methodological Issues

##### ● Estimation Method

The fugitive emissions from the production of natural gas are estimated using Tier 1 method, in accordance with the *2006 IPCC Guidelines* (Vol. 2, page 4.38, Fig. 4.2.1).

For the fugitive emissions related to well servicing, the estimation method of multiplying the amount of crude oil production by emission factors is provided in the *2006 IPCC Guidelines*, however, in Japan, correlation between the amount of crude oil production and the emissions related to well servicing is not clear. Therefore, the Tier1 method provided in the *GPG (2000)* (the estimation method of multiplying the number of production wells by the emission factors), which is considered to be more appropriate for the actual status in Japan, is used

##### ● Emission Factors

##### - Production

The default values given in the *2006 IPCC Guidelines* are used for the emission factors of fugitive emissions during the production of natural gas.

Table 3-75 Emission factors of fugitive emissions during production of natural gas

		Unit	CH <sub>4</sub>	CO <sub>2</sub>	N <sub>2</sub> O
Natural gas production	Fugitive emissions from offshore field	kt/10 <sup>6</sup> m <sup>3</sup>	3.8×10 <sup>-4</sup>	1.4×10 <sup>-5</sup>	NA
	Fugitive emissions from onshore field	kt/10 <sup>6</sup> m <sup>3</sup>	2.3×10 <sup>-3</sup>	8.2×10 <sup>-5</sup>	NA

Reference: *2006 IPCC Guidelines* Vol. 2, page 4.48, Table 4.2.4

Note: N<sub>2</sub>O is excluded from calculations, as the default value is “NA”.

##### - Servicing

The default values for fugitive emissions during the servicing of natural gas production wells given in the *GPG (2000)* were used.

Table 3-76 Emission factors during servicing of natural gas production wells

	Unit	CH <sub>4</sub>	CO <sub>2</sub>	N <sub>2</sub> O
Production well (servicing)	kt/number of wells	6.4×10 <sup>-5</sup>	4.8×10 <sup>-7</sup>	0

Reference : GPG (2000) Table 2.16

Note: N<sub>2</sub>O is excluded from calculations, as the default value is 0 (zero)

- **Activity Data**

- **Production**

The production volume of natural gas from offshore in the *Natural Gas Data Yearbook* is used for the production volume of natural gas from offshore gas field. The production volume of natural gas from onshore gas field is estimated by subtracting the production volume of natural gas from offshore gas field above from the total production volume of natural gas in Japan given in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products Statistics* and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics*.

- **Servicing**

Because it is impossible to statistically differentiate between oil fields and natural gas fields in the time-series, the total number of oil fields and natural gas fields are used for the estimation. As for activity data for fugitive emissions from well servicing, the number of natural gas and oil wells in production provided in *Natural Gas Data Yearbook* is used. As for the latest fiscal year, the values in the previous fiscal year are provisionally used.

Table 3-77 Natural gas production and the number of natural gas and oil wells in production

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Natural gas production	offshore	342	374	350	361	188	190	196	196	197	190	176	148	113	120	120
	onshore	1,724	1,863	2,149	2,779	3,155	3,144	2,981	2,744	2,549	2,525	2,621	2,777	2,544	2,347	2,170
	total	2,066	2,237	2,499	3,140	3,343	3,334	3,177	2,940	2,746	2,715	2,797	2,926	2,657	2,467	2,290
Number of gas and oil wells in production	well	1,230	1,205	1,137	1,115	1,046	1,047	1,038	1,059	1,046	1,034	1,019	1,001	1,042	1,045	1,045

### c) Uncertainties and Time-series Consistency

- **Uncertainties**

For the uncertainties of emission factors for fugitive emissions of CO<sub>2</sub> and CH<sub>4</sub> from production of natural gas, the values provided in the *2006 IPCC Guidelines* (-100% to +100%) are applied since the default values in the guidelines are used exclusively. As for the activity data, the values established in the *2006 IPCC Guidelines* (-15% to +15% of the uncertainties associated with measurement of flow rate (excluding sales volumes)) are used, since the uncertainties for statistical data used as reference are not available. As a result, the uncertainties of fugitive emissions of CO<sub>2</sub> and CH<sub>4</sub> from production of natural gas are evaluated to be -101% to +101% for each.

For the emission factors related to servicing of production well, the values established in the *GPG (2000)* (-25% to +25%) are applied since the default values in the guidelines are used exclusively. As for the activity data, the values established in the *2006 IPCC Guidelines* (-25% to +25% of the uncertainties associated with the factor of production facility number) are used, since the uncertainties for statistical data used as reference are not available. As a result, the uncertainties of fugitive emissions of CO<sub>2</sub> and CH<sub>4</sub> from servicing of production well are determined to be -35% to +35% for each.

- **Time-series Consistency**

Consistent values are used for emission factors from FY1990 to the nearest year by using the above-

mentioned method. The activity data are calculated by using the data on the production volume of natural gas from the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products Statistics* and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics* and on the number of oil/natural gas wells from the *Natural Gas Data Yearbook*. A consistent method is used throughout the time-series from FY1990 to the nearest year.

#### d) *Category-specific QA/QC and Verification*

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

#### e) *Category-specific Recalculations*

Since the activity data for FY2019 in the *Natural Gas Data Yearbook* were revised, the CO<sub>2</sub> and CH<sub>4</sub> emissions in that year were recalculated. See Chapter 10 for impact on trend.

#### f) *Category-specific Planned Improvements*

There are no major planned improvements in this category.

### 3.3.2.2.c. Processing (1.B.2.b.iii.)

#### a) *Category Description*

This category provides the estimation methods for fugitive CO<sub>2</sub> and CH<sub>4</sub> emissions from the processing of natural gas including adjustment of its constituent elements

#### b) *Methodological Issues*

##### ● *Estimation Method*

The fugitive emissions associated with processing natural gas are estimated using Tier 1 method in accordance with the decision tree in the *2006 IPCC Guidelines* (Vol.2, page 4.38, Fig.4.2.1).

##### ● *Emission Factors*

For the emission factors for the fugitive emissions during processing of natural gas, the median values between upper limit and lower limit indicated in the *2006 IPCC Guidelines* are used.

Table 3-78 Emission factors of fugitive emissions during natural gas processing

		Unit	CH <sub>4</sub>	CO <sub>2</sub>	N <sub>2</sub> O <sup>3)</sup>
Natural gas processing	Fugitive emissions from sweet gas plants	kt/10 <sup>6</sup> m <sup>3</sup>	7.55×10 <sup>-4</sup> <sup>1)</sup>	2.35×10 <sup>-4</sup> <sup>2)</sup>	NA

Reference: *2006 IPCC Guidelines* Vol. 2, page 4.48, Table 4.2.4

Note:

1) The default value of CH<sub>4</sub> is 4.8×10<sup>-4</sup> - 10.3×10<sup>-4</sup>

2) The default value of CO<sub>2</sub> is 1.5×10<sup>-4</sup> - 3.2×10<sup>-4</sup>

3) Excluded from calculations, as the default value is "NA".

##### ● *Activity Data*

The production volume of natural gas in Japan given in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products Statistics* and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products*,

*Ceramics and Building Materials Statistics* is used as activity data during processing. (Refer to Table 3-77).

### c) *Uncertainties and Time-series Consistency*

#### ● *Uncertainties*

For the uncertainties of emission factors for fugitive emissions of CO<sub>2</sub> and CH<sub>4</sub> during natural gas processing, the values provided in the *2006 IPCC Guidelines* (-100% to +100%) are applied since the default values in the guidelines are used exclusively. As for the activity data, the values established in the *2006 IPCC Guidelines* (-15% to +15% of the uncertainties associated with measurement of flow rate (excluding sales volumes)) are used, since the uncertainties of the statistical data used are not available. As a result, the uncertainties of fugitive emissions of CO<sub>2</sub> and CH<sub>4</sub> during natural gas processing are evaluated to be -101% to +101% for each.

#### ● *Time-series Consistency*

The default values are consistently used for emission factors from FY1990 to the nearest year. The activity data during natural gas processing are calculated by using the data from the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products Statistics* and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics*. A consistent method is used throughout the time-series from FY1990 to the nearest year.

### d) *Category-specific QA/QC and Verification*

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

### e) *Category-specific Recalculations*

There have been no recalculations of emissions from this category.

### f) *Category-specific Planned Improvements*

There are no major planned improvements in this category.

## 3.3.2.2.d. Transmission and Storage (1.B.2.b.iv.)

### a) *Category Description*

This category provides the estimation methods for CH<sub>4</sub> emissions from transmission of domestically produced natural gas, such as the release of gas when relocating and building pipelines, and the release of gas used to operate pressure regulators, and provides the estimation methods for CH<sub>4</sub> emissions from storage facilities of natural gas, such as the emissions occurring by normal operation, regular maintenance, and construction works in receiving domestic LNG (liquefied natural gas) facilities, city gas production facilities, and satellite facilities.

The CO<sub>2</sub> emissions in this source are reported as “NA”. Approximately 90% of city gas is based on LNG and is free of CO<sub>2</sub>. However, domestically produced natural gas from some of Japan’s natural gas strata contains CO<sub>2</sub>. Because nearly all of this CO<sub>2</sub> is removed at the natural gas production plants before the gas is sent to pipelines, thus almost no CO<sub>2</sub> in natural gas is emitted from natural gas pipelines, and



the natural gas provided by city gas suppliers most likely contains no CO<sub>2</sub>. The CO<sub>2</sub> emissions removed at natural gas production plants are included in venting (gas) (1.B.2.c.Venting.ii).

### b) Methodological Issues

#### ● Estimation Method

CH<sub>4</sub> emissions from transmission of natural gas are estimated by multiplying the sales volume of natural gas by the country-specific emission factors.

CH<sub>4</sub> emissions from storage facilities of natural gas are estimated by multiplying the amount of LNG and natural gas, which are utilized as raw material for city gas, by the country-specific emission factors.

#### ● Emission Factors

##### - Transmission

CH<sub>4</sub> emissions associated with the release of gas from the facilities of Japan Natural Gas Association member companies in relocating and building of pipelines have been surveyed in FY2004, FY2008 and onward; and CH<sub>4</sub> emissions associated with the release of gas used to operate pressure regulators have been surveyed in FY2004, FY2011 and onward by Japan Natural Gas Association. To establish country-specific emission factors for Japan, the results of the surveys are used.

The emission factors for emissions from relocating and building of pipelines, and for emissions from the release of gas used to operate pressure regulators are estimated respectively as shown in the following Table 3-79 and the total values are applied to the emission factors. For the sales volume of natural gas which is used for establishing emission factors, the data are sourced from the member companies of Japan Natural Gas Association and provided by the association.

Table 3-79 The method of estimating emission factors of natural gas transmission

Fiscal year	Relocation and building work of pipeline	Release of gas used to operate pressure regulators
1990 - 2003	The same value as FY2004 is consistently used.	
2004	Estimated by dividing the actual CH <sub>4</sub> emissions in FY2004 by the sales volume of natural gas in the same fiscal year.	
2005 - 2007	Estimated by interpolating the emission factor in FY2004 and that in FY2008 which is estimated by the same method as FY2004.	Estimated by interpolating the emission factor in FY2004 and that in FY2011 which is estimated by the same method as FY2004.
2008 - 2010	Estimated by dividing the actual CH <sub>4</sub> emissions in each fiscal year by the sales volume of natural gas in the same fiscal year.	
2011 -	Estimated by dividing the actual CH <sub>4</sub> emissions in each fiscal year by the sales volume of natural gas in the same fiscal year.	

As a result of the above estimation, the emission factors in each fiscal year are estimated as shown on the Table 3-80.

Table 3-80 The estimation result of emission factors of natural gas transmission [t-CH<sub>4</sub>/10<sup>6</sup>m<sup>3</sup>]

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Pipeline relocation & installation	t-CH <sub>4</sub> /10 <sup>6</sup> m <sup>3</sup>	0.220	0.220	0.220	0.190	0.071	0.037	0.073	0.062	0.070	0.115	0.217	0.077	0.129	0.119	0.029
Gas for operating pressure regulators	t-CH <sub>4</sub> /10 <sup>6</sup> m <sup>3</sup>	0.087	0.087	0.087	0.077	0.028	0.018	0.013	0.009	0.005	0.001	0.001	0.001	0.001	0.002	0.001
Total	t-CH <sub>4</sub> /10 <sup>6</sup> m <sup>3</sup>	0.306	0.306	0.306	0.267	0.099	0.056	0.087	0.071	0.075	0.116	0.218	0.078	0.131	0.121	0.030

##### - Storage

The emission factor is calculated by dividing the CH<sub>4</sub> emissions actually measured during regular maintenance or construction in the major LNG receiving terminals, city gas production facilities, and

satellite terminals in Japan, by the calorific value of the raw material input such as LNG and natural gas. The emission factor calculated using the FY1998 data is 905.41 [kg-CH<sub>4</sub>/PJ], while that calculated using the FY2007 data is 264.07 [kg-CH<sub>4</sub>/PJ]. The main reason of such change in emission factor is the reduction in CH<sub>4</sub> emissions, which is due to the progress in reduction measures such as the installation of new sampling and recovery lines used for gas analyses (changes to gas recovery lines from atmospheric dispersion) in LNG receiving terminals and city gas production facilities. Because the measures to reduce CH<sub>4</sub> emissions have been implemented gradually, the emission factors for the period from FY1999 to FY2006 are set by linear interpolation. At present, measures to reduce CH<sub>4</sub> emissions have been generally implemented, thereby affording little expectation of any major change in the emission factor for the time being. Therefore, the FY2007 emission factor value is kept for FY2008 and subsequent years.

### ● Activity Data

#### - Transmission

The sales volume of natural gas provided in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products* and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics* is used for activity data.

Table 3-81 Sales amount of natural gas

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Natural gas sales amount	10 <sup>6</sup> m <sup>3</sup>	2,067	2,339	2,617	3,329	4,020	4,208	3,928	3,790	3,792	3,709	3,806	4,000	3,980	3,903	3,768

#### - Storage

The amount of LNG and natural gas used as raw material for city gas, provided in the *General Energy Statistics*, is used for activity data

Table 3-82 LNG and natural gas used for the feedstock of city gas

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
LNG consumption with city gas production	PJ	464	676	864	1,230	1,531	1,574	1,592	1,555	1,567	1,567	1,641	1,665	1,635	1,584	1,532
Natural gas consumption with city gas production	PJ	40	48	61	86	115	118	112	107	106	103	101	96	85	75	71

### c) Uncertainties and Time-series Consistency

#### ● Uncertainties

A country-specific emission factor is used for CH<sub>4</sub> emissions from transmission of natural gas, however, since it is difficult to assess the uncertainties, the established values in the *2006 IPCC Guidelines* (-100% to +100%) are applied. As for activity data, because the uncertainties of statistical data used as reference are not available, the established values in the *2006 IPCC Guidelines* (-2% to +2% of the uncertainties associated with measurement of flow rate (sales volumes)) are applied. As a result, the uncertainties of fugitive emissions of CO<sub>2</sub> and CH<sub>4</sub> from natural gas transmission are assessed to be -100% to +100%.

For the emission factors for fugitive CH<sub>4</sub> emissions associated with storage of natural gas, a country-specific emission factor is used; however, since it is difficult to assess the uncertainties, the values established in the *2006 IPCC Guidelines* (-20% to +500%) are applied. As for the activity data, the values established in the *2006 IPCC Guidelines* (-15% to +15% of the uncertainties associated with measurement of flow rate (excluding sales volumes)) are used, since the uncertainties for statistical data

used as reference are not available. As a result, the uncertainties of CH<sub>4</sub> fugitive emissions from natural gas storage are assessed to be -25% to +500%.

● ***Time-series Consistency***

Regarding emission factors for transmission of natural gas in and after FY2004, the values are established by dividing the measured emissions by corresponding natural gas production amount for the fiscal years when emission measurement was implemented. For fiscal years when emission measurement was not implemented, emission factors are established by interpolating. For emissions before FY2003, the established values for FY2004 are used for all fiscal years. In addition, the natural gas sales volume used for activity data is provided in the *Yearbook of Production Supply and Demand of Petroleum, Coal and Coke*, in the *Yearbook of Mineral Resources and Petroleum Products Statistics* and in the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics*.

For emission factors for storage of natural gas, as described above and based on the emission factors established from the survey in FY1998 and FY2007, the emission factor for FY1998 is used for before FY1997, the emission factor for FY2007 is used for FY2008 and onward, and the emission factors for FY1999-2006 are established by interpolation using the FY1998 and FY2007 factors.

To ensure the consistency, the figures provided in the *General Energy Statistics* are adopted consistently for activity data of LNG and natural gas which are used as raw material of city gas.

***d) Category-specific QA/QC and Verification***

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

***e) Category-specific Recalculations***

Since the activity data for FY2019 in the *General Energy Statistics* were revised, the CH<sub>4</sub> emissions in that year were recalculated. See Chapter 10 for impact on trend.

***f) Category-specific Planned Improvements***

There are no major planned improvements in this category.

**3.3.2.2.e. Distribution (1.B.2.b.v.)**

***a) Category Description***

This category provides the estimation methods for CH<sub>4</sub> emitted from city gas supply networks.

In Japan, liquefied petroleum gas, coal, coke, naphtha, crude oil, and natural gas are refined and blended at gas plants into gas, which, after being conditioned to produce a certain calorific value, is supplied to urban areas through gas lines. Such gas fuel is called “city gas”, of which more than 90% is LNG-based. As for detail of city gas, please refer to the explanation of city gas emission factor in 3.2.1.b. Methodological issues (Figure 3-4, Table 3-16, etc.).

The emissions from CO<sub>2</sub> in this source are reported as “NA”. More than 90% of the city gas is based on LNG and is free of CO<sub>2</sub>. However, domestically produced natural gas from some of Japan’s natural gas

strata contains CO<sub>2</sub>. Because nearly all of this CO<sub>2</sub> is removed at the natural gas production plants before the gas is sent to pipelines, the natural gas provided by city gas suppliers most likely contains no CO<sub>2</sub>. The emissions of CO<sub>2</sub> removed at natural gas production plants are included in the venting (gas) (1.B.2.c.Venting.ii).

### b) Methodological Issues

#### ● Estimation Method

CH<sub>4</sub> emissions from high-pressure pipelines, from medium- and low-pressure pipelines and holders, and from service pipes are calculated by multiplying the sales volume of city gas by the country-specific emission factors.

#### ● Emission Factors

The emission sources in the supply of domestically produced city gas are (i) high-pressure pipelines, (ii) medium- and low-pressure pipelines and holders, and (iii) service pipes. The CH<sub>4</sub> emissions from the city gas pipelines of general gas companies calculated from the actual data by each emission source are shown in Table 3-83. The value of  $9.5 \times 10^{-6}$  kt-CH<sub>4</sub>/10<sup>6</sup>m<sup>3</sup>, which is obtained by dividing the CH<sub>4</sub> emissions (292 t-CH<sub>4</sub>) by the city gas amount sold by general gas companies in the same fiscal year of  $30,696 \times 10^6$ m<sup>3</sup> (Reference: *Current Survey of Production Concerning Gas Industry*), is used for the emission factor per sales amount.

Table 3-83 CH<sub>4</sub> emissions from city gas pipelines (FY2004 actual data)

Emission sources		CH <sub>4</sub> emissions[t/year]
High-pressure pipelines	New pipeline installation, and pipeline relocation	180
Medium- and low-pressure pipelines and holders	Construction, demolition, fugitive emissions, inspection of governor and others, holder construction, and overhauling	93
Service pipes	Installation of service pipes, post-installation purging, removal, change of meters, fugitive emissions, go around for opening valves and regular maintenance, and equipment repairs (mainly the emissions occur when the work is done at user sites (homes))	19

#### ● Activity Data

The city gas sales amount in calorific value in the *Current Survey of Production Concerning Gas Industry* is divided by the calorific value per volume in the *General Energy Statistics* to get the amount in volume, and the result is used for the activity data. The city gas sales amount is classified as industrial use, commercial use, residential use and other use. As the activity data include all of them, the emissions from city gas supplied to industrial plants are included in the estimation.

Table 3-84 The sales amount of city gas

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
The sales amount of city gas	PJ	643	877	1,064	1,419	1,644	1,691	1,688	1,667	1,681	1,671	1,738	1,776	1,740	1,692	1,654
Calorific value per volume	MJ/m <sup>3</sup>	41.9	41.9	41.1	44.8	44.8	44.8	44.8	40.8	40.8	40.7	40.7	40.8	40.0	40.0	39.9
The sales amount of city gas in volume	10 <sup>6</sup> m <sup>3</sup>	15,367	20,952	25,899	31,684	36,705	37,738	37,686	40,894	41,226	41,073	42,721	43,543	43,522	42,342	41,437

### c) Uncertainties and Time-series Consistency

#### ● Uncertainties

For emission factor in CH<sub>4</sub> fugitive emissions accompanied by city gas distribution, country-specific figure is used. However, it is difficult to evaluate the uncertainties in this figure; therefore, values (-20% to +500%) provided in the *2006 IPCC Guidelines* are adopted. As for activity data, since it is unable to evaluate the uncertainties in statistical data used as reference, the setting values (-2% to +2% of the

uncertainties associated with measurement of flow rate (sales volumes)) given in the *2006 IPCC Guidelines* are adopted. As a result, the uncertainties in CH<sub>4</sub> fugitive emissions accompanied by city gas distribution are evaluated at -20% to +500%.

- ***Time-series Consistency***

For the emission factor, the consistent value is used from FY1990 to the nearest year, by using the above-mentioned method. The activity data are calculated using the data from the *Current Survey of Production Concerning Gas Industry* with a consistent method throughout the time-series from FY1990 to the nearest year.

- d) ***Category-specific QA/QC and Verification***

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

- e) ***Category-specific Recalculations***

Since the city gas sales amount for FY2019 in the *Current Survey of Production Concerning Gas Industry* were revised, the CH<sub>4</sub> emissions in those years were recalculated. See Chapter 10 for impact on trend.

- f) ***Category-specific Planned Improvements***

There are no major planned improvements in this category.

### **3.3.2.2.f. Other (post-meter and abandoned gas wells) (1.B.2.b.vi.)**

The leakage of greenhouse gases from post-meter and abandoned gas wells is reported under this category.

The conceivable sources of CH<sub>4</sub> emissions from post-meter include gas pipe work in buildings, but because these emissions are included in those of “Natural Gas Distribution” (distribution through the city gas network) (1.B.2.b.v), CH<sub>4</sub> emissions from this source are reported as “IE.” Additionally, because CO<sub>2</sub> is basically not included among the city gas constituents, the CO<sub>2</sub> emissions from this source are reported as “NA.”

The *2019 Refinement* provides the estimation method for abandoned gas wells that was not provided in the *2006 IPCC Guidelines*. As mentioned in Section 3.3.2.1.f. (1.B.2.a.vi Other), for abandoned gas wells as well as for abandoned oil wells, systems to prevent gas leakage has been established in Japan based on the Mine Safety Act and the Enforcement Ordinance of the Mine Safety Act. Therefore, the emissions from abandoned gas wells are reported as “NA”.

### **3.3.2.3. Venting and Flaring (1.B.2.c.)**

This section includes fugitive emissions of CO<sub>2</sub> and CH<sub>4</sub> occurring from venting during oil field development, crude oil transportation, refining processes, and product transportation in the petroleum industry, as well as during gas field development, natural gas production, transmission, and processing in the natural gas industry.

It also includes CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emissions from flaring during the above processes.

### 3.3.2.3.a. Venting (Oil) (1.B.2.c.Venting.i.)

#### a) Category Description

This category provides the estimation methods for CO<sub>2</sub> and CH<sub>4</sub> emissions from venting in the petroleum industry.

#### b) Methodological Issues

##### ● Estimation Method

The emissions from venting in the petroleum industry were calculated using the Tier 1 method in accordance with the decision tree of the *2006 IPCC Guidelines* (Vol. 2, page 4.39, Fig. 4.2.2) by multiplying the amount of crude oil production by the default emission factors.

##### ● Emission Factors

The default values for conventional oil given in the *2006 IPCC Guidelines* were used for the emission factors of oil field venting.

Table 3-85 Emission factors of oil field venting

		Unit	CH <sub>4</sub>	CO <sub>2</sub>	N <sub>2</sub> O
Oil production/ Conventional oil	Venting	kt/1000 m <sup>3</sup>	7.2×10 <sup>-4</sup>	9.5×10 <sup>-5</sup>	NA

Reference : *2006 IPCC Guidelines* Vol. 2, page 4.50, Table 4.2.4

Note: N<sub>2</sub>O is excluded from calculations, as the default value is "NA"

##### ● Activity Data

The production volume of oil in Japan given in its *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke, Yearbook of Mineral Resources and Petroleum Products Statistics* and *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics* is used as activity data of the fugitive emissions from oil field venting. The production of condensate was excluded from the calculation (see Table 3-71).

#### c) Uncertainties and Time-series Consistency

##### ● Uncertainties

For the uncertainties in emission factors for CO<sub>2</sub> and CH<sub>4</sub> fugitive emissions from venting (oil), since the default values given in the *2006 IPCC Guidelines* are used for emission factors, the uncertainty values (-50% to +50%) provided in the *2006 IPCC Guidelines* are used. As for activity data, it is unable to evaluate the uncertainties in statistical data used as reference, the setting values (-15% to +15% of the uncertainties associated with measurement of flow rate (excluding sales volumes)) provided in the *2006 IPCC Guidelines* are used. As a result, the uncertainties in CO<sub>2</sub> and CH<sub>4</sub> fugitive emissions from venting (oil) are evaluated at -52% to +52% for each.

##### ● Time-series Consistency

For the emission factors, consistent values as described above are used from FY1990 to the nearest year. The activity data are calculated using the data from the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke, the Yearbook of Mineral Resources and Petroleum Products Statistics* and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics*, by a consistent method throughout the time-series from FY1990 to the nearest year.

**d) Category-specific QA/QC and Verification**

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

**e) Category-specific Recalculations**

There have been no recalculations of emissions from this category.

**f) Category-specific Planned Improvements**

There have been no major planned improvements in this category.

**3.3.2.3.b. Venting (Gas) (1.B.2.c.Venting.ii.)****a) Category Description**

This category source deals with CO<sub>2</sub> emissions accompanied by separation and diffusion of CO<sub>2</sub> which is contained in natural gas produced in natural gas production facilities when CO<sub>2</sub> contents does not meet the standard of non-combustion gas content provided by users.

As for other emission source in this category, intentional CO<sub>2</sub> and CH<sub>4</sub> emissions during transmission of natural gas are considered to be included in this category, because their emission factors are provided in the *2006 IPCC Guidelines*. However, the intentional CO<sub>2</sub> emissions from pipeline of natural gas are reported as “NA” in transmission of natural gas (1.B.2.b.iv.) in case of Japan. Therefore, the emissions are not reported. As for CH<sub>4</sub> emissions, the emissions are reported as “IE”, because they are included in emissions from transmission of natural gas (1.B.2.b.iv).

**b) Methodological Issues**● **Estimation Method**

For the emissions from this category in FY1990, FY1995 and onward, actual measurement data of CO<sub>2</sub> emission provided by Japan Petroleum Development Association is used for reporting.

For FY1991-1994, the natural gas amount produced from gas field, where separation of CO<sub>2</sub> from natural gas has been implemented (Minami Nagaoka and Katagai gas fields), is used for the activity data, and the emissions are estimated by multiplying the activity data by emissions factors. As for the emission factors, nominal emission factors are estimated by dividing the emissions in FY1990 and FY1995 provided by Japan Petroleum Development Association by activity data in the same fiscal years, and the emission factors for FY1991-1994 are estimated by interpolation using the values for FY1990 and FY1995.

● **Emission Factors**

For FY1990, FY1995 and onward, the values are estimated by dividing emissions data provided by Japan Petroleum Development Association by activity data. As for FY1991 – FY1994, the values are estimated by interpolation using the values for FY1990 and FY1995. (For emission estimating purpose, only emission factors for FY1991-1994 are used.)

Table 3-86 Emission factors of natural gas field venting

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Emission factor	kg-CO <sub>2</sub> /m <sup>3</sup>	0.133	0.117	0.126	0.114	0.120	0.119	0.122	0.122	0.124	0.128	0.129	0.127	0.129	0.128	0.113

#### ● Activity Data

The total production amount of Minami Nagaoka gas field and Katagai gas field indicated in *Natural Gas Data Yearbook* are used for activity data. (For emission estimating purpose, only activity data for FY1991-1994 are used.)

Table 3-87 Production amount of Natural gas from Minami-nagaoka and Katagai gas field

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Minami Nagaoka gas field	10 <sup>6</sup> m <sup>3</sup>	241	376	571	893	1,313	1,308	1,372	1,295	1,172	1,215	1,340	1,484	1,339	1,221	1,221
Katagai gas field	10 <sup>6</sup> m <sup>3</sup>	191	281	219	336	346	395	358	369	370	384	421	460	416	372	372
Total	10 <sup>6</sup> m <sup>3</sup>	432	657	789	1,229	1,660	1,704	1,731	1,664	1,542	1,598	1,761	1,944	1,755	1,593	1,593

#### c) Uncertainties and Time-series Consistency

##### ● Uncertainties

As for emissions from venting (natural gas), actual measurement emission data provided by Japan Petroleum Development Association is used for reporting for FY1990, FY1995 and onward. However, it is difficult to evaluate the uncertainty for the data. Therefore, the standard value of uncertainty associated with measurement of flow rate (-15% to +15%) provided in the *2006 IPCC Guidelines* is adopted.

##### ● Time-series Consistency

For the emissions from this source, the emission data provided by *Japan Petroleum Development Association* are consistently used for FY1990, FY1995 and onward. As for FY1991-1994, the emissions are estimated from the FY1990 and FY1995 emission data provided by *Japan Petroleum Development Association*.

#### d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

#### e) Category-specific Recalculations

Since the emissions for FY2013 provided by Japan Petroleum Development Association were revised, the CO<sub>2</sub> emissions in that year were recalculated. See Chapter 10 for impact on trend.

#### f) Category-specific Planned Improvements

There have been no major planned improvements in this category.

### 3.3.2.3.c. Venting (Combined) (1.B.2.c.Venting.iii.)

Statistical data are reported for two categories of petroleum and natural gas in Japan. As a result, fugitive emissions from venting in the combined petroleum and natural gas industries were reported as "IE" since they were accounted for in the emissions from venting in the petroleum industry (1.B.2.c.i) and the natural gas industry (1.B.2.c.ii).



### 3.3.2.3.d. Flaring (Oil) (1.B.2.c.Flaring.i.)

#### a) Category Description

This category provides the estimation methods for CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O from flaring in the petroleum industry.

#### b) Methodological Issues

##### ● Estimation Method

The CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O emissions from flaring in the petroleum industry were calculated using the Tier I method in accordance with the decision tree of the *2006 IPCC Guidelines*, by multiplying the amount of crude oil production in Japan by the default emissions factors.

##### ● Emission Factors

In the absence of actual measurement data or country-specific emission factors in Japan, the default values shown in the *2006 IPCC Guidelines* were used.

Table 3-88 Emission factors for flaring in the oil industry

	Unit	CH <sub>4</sub>	CO <sub>2</sub>	N <sub>2</sub> O
Flaring (conventional oil)	kt/10 <sup>3</sup> m <sup>3</sup>	2.5×10 <sup>-5</sup>	4.1×10 <sup>-2</sup>	6.4×10 <sup>-7</sup>

Reference : *2006 IPCC Guidelines* Vol. 2, p 4.50, Table 4.2.4

##### ● Activity Data

For the calculation of activity data for this emission source, the amounts of crude oil production shown in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Natural Resources and Petroleum Products* and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics* are used. The production of condensate is excluded from the calculation (see Table 3-71).

#### c) Uncertainties and Time-series Consistency

##### ● Uncertainties

For emission factors for CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O fugitive emissions from flaring (oil), since the default values given in the *2006 IPCC Guidelines* are used for the emission factors, the setting values (-50% to +50%) provided in the *2006 IPCC Guidelines* are used. As for activity data, it is unable to evaluate the uncertainties in statistical data used as reference, the setting values (-15% to +15% of the uncertainties associated with measurement of flow rate (excluding sales volumes)) provided in the *2006 IPCC Guidelines* are used. As a result, the uncertainties in CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O fugitive emissions from flaring (oil) are evaluated at -52% to +52% for each.

##### ● Time-series Consistency

For the emission factors, consistent values as described above are used from FY1990 to the nearest year. The activity data of the flaring in oil industry are calculated using the data from the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products Statistics* and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics*, by a consistent method throughout the time-series from FY1990 to the nearest year.

**d) Category-specific QA/QC and Verification**

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

**e) Category-specific Recalculations**

There have been no recalculations of emissions from this category.

**f) Category-specific Planned Improvements**

There have been no major planned improvements in this category.

**3.3.2.3.e. Flaring (Gas) (1.B.2.c.Flaring.ii.)****a) Category Description**

This category provides the estimation methods for CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O from flaring in the natural gas industry.

**b) Methodological Issues**

- **Estimation Method**

The CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O emissions associated with flaring in the natural gas industry were calculated using the Tier 1 method in accordance with the decision tree of the *2006 IPCC Guidelines* (Vol. 2, page 4.38, Fig. 4.2.1). The emissions were calculated by multiplying the amount of natural gas production by the emission factors. The total emissions associated with flaring both during gas production and processing were reported as the emissions from flaring in the natural gas industry.

- **Emission Factors**

The default values for fugitive emissions from flaring in the natural gas industry given in the *2006 IPCC Guidelines* are used.

Table 3-89 Emission factors for flaring in the natural gas industry

		Unit	CH <sub>4</sub>	CO <sub>2</sub>	N <sub>2</sub> O
Flaring in the natural gas industry	Gas production	kt/10 <sup>6</sup> m <sup>3</sup>	7.6×10 <sup>-7</sup>	1.2×10 <sup>-3</sup>	2.1×10 <sup>-8</sup>
	Gas processing/Sweet gas plants	kt/10 <sup>6</sup> m <sup>3</sup>	1.2×10 <sup>-6</sup>	1.8×10 <sup>-3</sup>	2.5×10 <sup>-8</sup>

Reference: *2006 IPCC Guidelines* Vol. 2, page 4.48, Table 4.2.4

- **Activity Data**

For the calculation of activity data for this emission source, the amounts of domestic production of natural gas shown in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Natural Resources and Petroleum Products* and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics* were used (see Table 3-77).

**c) Uncertainties and Time-series Consistency**

- **Uncertainties**

For the uncertainty of CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O emission factors for flaring (natural gas), the default values given in the *2006 IPCC Guidelines* are used for the emission factors exclusively. Therefore, the

uncertainty of -25% to +25% in the *2006 IPCC Guidelines* is applied. For the activity data, the uncertainty of the statistics used is not clear. Therefore, the value in the *2006 IPCC Guidelines* (-15% to +15% of the uncertainties associated with measurement of flow rate (excluding sales volumes)) is used. As a result, the uncertainty of CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O emissions from flaring (natural gas) are evaluated to be -29% to +29% for each.

- **Time-series Consistency**

For the emission factors, consistent values as described above are used from FY1990 to the nearest year. The activity data of flaring in natural gas industry are calculated using the data from the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products Statistics* and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics*, by a consistent method throughout the time-series from FY1990 to the nearest year.

**d) Category-specific QA/QC and Verification**

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

**e) Category-specific Recalculations**

There have been no recalculations of emissions from this category.

**f) Category-specific Planned Improvements**

There have been no major planned improvements in this category.

### 3.3.2.3.f. Flaring (Combined) (1.B.2.c.Flaring.iii.)

**a) Category Description**

In Japan, the statistical data are reported for two categories of oil and natural gas. Therefore, the fugitive emissions which can be distinguished of their category are reported in Flaring (Oil) (1.B.2.c.Flaring.i) or in Flaring (Natural gas) (1.B.2.c.Flaring.ii) respectively. In this category, CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O emissions accompanied by exploration and test before production of oil and natural gas, which are unable to be distinguished of their categories of oil industry or natural gas industry, are reported.

**b) Methodological Issues**

- **Estimation Method**

For the fugitive emissions accompanied by exploration and test before production of oil and natural gas, the emission factors, which are established using the crude oil production as activity data, are indicated as default values in the *2006 IPCC Guidelines*.

However, in case of Japan, the correlation between CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O emissions, which are accompanied by exploratory drilling and pre-production testing, and crude oil production, and the correlation between the GHG emissions, which are accompanied by the production during exploration and testing, and the production amount from commercial plants are not clear, thus there is a possibility of deviation between the estimated result and the actual condition, if the estimation method of using the crude oil production as activity data, which is indicated in the *2006 IPCC Guidelines*, is adopted.

Therefore, the Tier 1 method in *GPG (2000)*, which is considered to be closer to actual condition, is used in this category. The method used is to multiply the activity data of number of exploratory drilling well or testing well by the default emission factor.

### ● Emission Factors

The default values indicated in the *GPG (2000)* are adopted.

Table 3-90 Emission factors for exploratory drilling and testing wells

	Unit	CH <sub>4</sub>	CO <sub>2</sub>	N <sub>2</sub> O
Drilling	kt/number of wells	$4.3 \times 10^{-7}$	$2.8 \times 10^{-8}$	0
Testing	kt/number of wells	$2.7 \times 10^{-4}$	$5.7 \times 10^{-3}$	$6.8 \times 10^{-8}$

Reference: *GPG (2000)*, page 2.86, Table 2.16

### ● Activity Data

The values described in *Natural Gas Data Yearbook* are used for the number of exploratory drilled wells. As for the number of tested wells, it is difficult to grasp statistically, and the tested wells don't always become the succeeded wells. Therefore, the median of the number of wells drilled and the number of wells tested in the *Natural Gas Data Yearbook* is used as the number of wells tested. For the most recent year, the data of the previous year are provisionally used.

Table 3-91 Number of wells

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Number of wells drilled	well	8	7	7	10	2	1	4	5	1	2	2	0	0	1	1
Number of wells succeeded		1	3	4	5	0	1	2	3	1	1	0	0	0	0	0
Number of wells tested		5	5	6	8	1	1	3	4	1	2	1	0	0	1	1

## c) Uncertainties and Time-series Consistency

### ● Uncertainties

For the uncertainty of CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O emission factors for flaring (combined), the default values given in the *GPG (2000)* are used for the emission factors exclusively. Therefore, the uncertainty of -25% to +25% in *GPG (2000)* is applied. For the activity data, the uncertainty of the statistics used is not clear. Therefore, the value in the *2006 IPCC Guidelines* (-25% to +25%: uncertainty accompanied with the factor for number of production facilities) is used. As a result, the uncertainty of CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O emissions from flaring (combined) are evaluated to be -35% to +35% for each.

### ● Time-series Consistency

For the emission factors, consistent values as described above are used from FY1990 to the nearest year. The activity data are calculated using the data from the *Natural Gas Data Yearbook* by a consistent method throughout the time-series from FY1990 to the nearest year.

## d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

## e) Category-specific Recalculations

Since the activity data for FY2019 in the *Natural Gas Data Yearbook* was revised, the CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emissions in that year were recalculated. See Chapter 10 for impact on trend.

### ***f) Category-specific Planned Improvements***

There have been no major planned improvements in this category.

### **3.3.2.4. Other (Fugitive Emissions Associated with the Geothermal Power Generation) (1.B.2.d.)**

#### ***a) Category Description***

This category deals with the CO<sub>2</sub> and CH<sub>4</sub> emissions in the geothermal power plants, where the CO<sub>2</sub> and CH<sub>4</sub> from the steam production well are emitted from cooling tower into the atmosphere.

#### ***b) Methodological Issues***

##### **● *Estimation Method***

The emissions from this category are estimated by multiplying the amount of steam production (weight base) in each geothermal power plant by mass concentration rate of CO<sub>2</sub> and CH<sub>4</sub>, since any descriptions for estimation methods for this category are not provided in the *2006 IPCC Guidelines*. However, as for CO<sub>2</sub> and CH<sub>4</sub> in the steam produced in production well, even though there is a possibility that the steam dissolves in water during transmitting in condenser, it is difficult to estimate the dissolved amount. Therefore, the emissions are estimated assuming that the total amount of CO<sub>2</sub> and CH<sub>4</sub> in the produced steam is emitted into the air.

##### **● *Emission Factors***

Mass concentration rate of CO<sub>2</sub> in steam is estimated by using volume concentration of non-condensable gas in steam and volume concentration of CO<sub>2</sub> in non-condensable gas in each geothermal power plant (Japan Geothermal Energy Association, 2000).

Mass concentration rate of CH<sub>4</sub> is estimated by using volume concentration of non-condensable gas in steam in each geothermal power plant (Japan Geothermal Energy Association, 2000) and concentration of CH<sub>4</sub> in non-condensable gas (Geothermal Energy Association, 2012).

##### **● *Activity Data***

The amount of steam production in each geothermal power plant is estimated by multiplying an amount of steam production per hour in each plant provided in *Trend of Geothermal Power in Japan* (JGEA) and *Current Status and Trend of Geothermal Power* (Thermal and Nuclear Power Engineering Society), by operating time of production well which is assumed as the same as the power generating time of each power plant in *Current Status and Trend of Geothermal Power*.

Each emission factor for CO<sub>2</sub> and CH<sub>4</sub> for geothermal power plants in Japan and the trend of the produced amount of steam are indicated in the Table 3-92.

Table 3-92 Emission factor and produced amount of steam of geothermal power plants

Power plant name	Emission factor		Production amount of steam															
	CO <sub>2</sub>	CH <sub>4</sub>	[kt]															
	[t-CO <sub>2</sub> /kt]	[t-CH <sub>4</sub> /kt]	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
Matsukawa	12.2	0.025	1,884	1,493	1,708	1,115	813	777	745	872	857	666	412	610	737	604	604	
Otake	3.1	0.006	1,173	995	995	774	789	677	770	937	885	867	935	1,013	876	721	721	
Onuma	0.6	0.002	694	682	535	651	600	590	518	537	521	489	521	510	522	507	507	
Onikobe	2.6	0.008	1,018	1,015	1,035	982	1,185	456	348	357	381	334	402	NO	NO	NO	NO	
Hatchobaru 1	6.5	0.013	2,883	2,366	2,598	2,602	2,287	2,468	2,353	2,347	1,887	1,963	2,097	1,729	1,549	2,129	2,129	
Hatchobaru 2	5.8	0.011	2,514	2,686	2,532	2,452	2,291	1,943	2,219	2,342	2,264	2,209	1,848	2,107	1,663	1,693	1,693	
Kakkonda 1	0.3	0.001	3,498	3,126	1,966	2,021	1,535	1,537	1,276	1,374	1,400	1,362	1,455	1,371	946	1,228	1,228	
Kakkonda 2	0.4	0.001	NO	209	1,823	2,004	1,440	1,521	1,255	1,269	1,225	1,142	1,058	1,286	1,230	1,212	1,212	
Suginoi	8.5	0.019	220	284	203	144	129	139	170	147	136	140	137	110	111	122	122	
Mori	28.1	0.053	1,367	1,990	1,981	1,501	1,068	888	1,182	1,001	1,105	934	1,015	1,121	972	869	869	
Kirishima International Hotel	1.1	0.003	48	97	70	NO	30	81	58	68	38	NO	NO	NO	NO	NO	NO	
Uenotai	6.5	0.014	NO	1,882	2,070	1,601	482	1,480	1,846	1,784	1,717	1,512	1,521	1,449	1,561	1,203	1,203	
Yamakawa	5.8	0.012	NO	1,451	1,336	639	1,026	1,151	1,026	989	702	744	1,031	1,047	1,099	879	879	
Sumikawa	1.4	0.004	NO	3,234	2,846	2,908	2,611	2,145	1,853	2,038	2,903	2,903	2,676	2,334	2,375	2,100	2,100	
Yanaizunishiyama	68.8	0.130	NO	3,912	3,425	3,197	2,229	2,266	2,203	1,626	1,998	1,537	1,691	1,064	1,324	904	904	
Ogiri	0.4	0.001	NO	219	2,373	2,306	2,286	2,079	1,983	1,969	2,073	1,928	1,910	1,457	1,932	1,943	1,943	
Takigami	1.9	0.004	NO	NO	2,111	2,075	2,239	2,358	2,251	2,374	2,087	2,422	2,299	2,239	2,059	2,249	2,249	
Hachiojima	18.1	0.041	NO	NO	187	156	152	171	142	149	151	147	153	165	38	NO	NO	
Kuju	8.5	0.019	NO	NO	10	136	124	56	26	120	58	108	108	108	108	108	108	
Waita	8.5	0.019	NO	NO	NO	NO	NO	NO	NO	NO	NO	148	174	181	197	207	207	

### c) Uncertainties and Time-series Consistency

#### ● Uncertainties

As for the emission factors, because the emissions were estimated from the concentration of non-condensable gas in the steam and the concentration of GHG in the non-condensable gas, the uncertainty was estimated at -7% to +7% based on the uncertainty of measurement of gas concentration given in the *2006 IPCC Guidelines*. As for the activity data, because the uncertainty of the referred statistics was not available, the values given in the *2006 IPCC Guidelines* (-15% to +15% of the uncertainties associated with measurement of flow rate (excluding sales volumes)) were used. As a result, the uncertainty of CO<sub>2</sub> and CH<sub>4</sub> emissions from the steam generated in production well in geothermal production was evaluated as -17% to +17%.

#### ● Time-series Consistency

For the emission factors, consistent values are used from FY1990 to the nearest year, by using the above-mentioned method. The activity data are calculated by a consistent method throughout the time-series from FY1990 to the nearest year, based on the *Current Status and Trend of Geothermal Power*.

### d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

### e) Category-specific Recalculations

Since the generating time for FY2004 was revised and the activity data for FY2019 in the *Current Status and Trend of Geothermal Power* was revised, the CO<sub>2</sub> and CH<sub>4</sub> emissions in FY2004, 2018, 2019 were recalculated. See Chapter 10 for impact on trend.

### f) Category-specific Planned Improvements

There have been no major planned improvements in this category.

### 3.4. CO<sub>2</sub> transport and storage (1.C.)

CO<sub>2</sub> transport and storage sector provides the CO<sub>2</sub> emissions associated with the carbon dioxide capture and storage (CCS). CCS is the technology or methodology that captures the CO<sub>2</sub> which would be emitted to the atmosphere and stores it underground or under seabed.

This sector consists of three categories; Transport of CO<sub>2</sub> (1.C.1): emissions in the stage of CO<sub>2</sub> transport, Injection and storage (1.C.2): emissions in the stage of CO<sub>2</sub> injection and storage, and Other (1.C.3). There are five projects of CO<sub>2</sub> injected underground in the past in Japan. CO<sub>2</sub> Emissions in the stage of transport and injection can occur during the period of injection, and CO<sub>2</sub> emissions in the stage of storage can have occurred continuously since CO<sub>2</sub> is injected. Table 3-93 shows the emissions from CO<sub>2</sub> transport and storage (1.C).

Table 3-93 Past projects of CO<sub>2</sub> underground injection in Japan

Injection site	Period of injection	Purpose
Kubiki	March 1991 – June 1993	Enhanced oil recovery
Sarukawa	September 1997 – September 1999	Enhanced oil recovery
Nagaoka	July 2003 – January 2005	Demonstration of geological storage of CO <sub>2</sub>
Yubari	November 2004 – October 2007	Enhanced coal bed methane recovery
Tomakomai	April 2016 – November 2019	Demonstration of geological storage of CO <sub>2</sub>

Table 3-94 CO<sub>2</sub> emissions from CO<sub>2</sub> transport and storage (1.C)

IPCC Category	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
1.C.1 Transport of CO <sub>2</sub>	a. Pipelines	NE	NO	NO	NE	NO	NO	NO	NO	NO	NA	NA	NA	NA	NO
	b. Ships	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	c. Other	NE	NO	NO	NE	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1.C.2 Injection and storage	a. Injection	NE	NO	NO	NE	NO	NO	NO	NO	NO	NA	NA	NA	NA	NO
	b. Storage	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
1.C.3 Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

#### 3.4.1. Transport of CO<sub>2</sub> (1.C.1)

##### 3.4.1.1. Pipelines (1.C.1.a.)

This category provides the fugitive emissions of CO<sub>2</sub> in the stage of CO<sub>2</sub> transport by pipeline.

According to the interview to the entities of the projects shown in Table 3-93, the fugitive emissions in the stage of CO<sub>2</sub> transport by pipeline do not occur basically or the amount is quite small even if the fugitive emissions occur. Especially in the case of Tomakomai injection site, the pipeline is structurally designed to allow no gas leaks, and the assurance of airtightness is confirmed by execution of airtightness test. In addition, the approximate results of emissions estimated using the default emission factor of the *2006 IPCC Guidelines* (vol. 2, page 5.10, Table 5.2) are less than 3 kt-CO<sub>2</sub>, which is a criterion to include the emissions in the national totals established by the Committee for the Greenhouse Gases Emissions Estimation Methods in FY2012. Therefore, the emissions from this category are reported as insignificant NE in the year CO<sub>2</sub> injection was conducted (but reported as NA in the year CO<sub>2</sub> injection was conducted only in Tomakomai site where the airtightness is assured) and reported as NO in the other years. The treatment of insignificant NE is described in Annex 5.

##### 3.4.1.2. Ships (1.C.1.b.)

This category provides the fugitive emissions of CO<sub>2</sub> in the stage of CO<sub>2</sub> transport by ships. The

emissions are reported as NO, because ships were not used in the past projects in Japan.

### 3.4.1.3. Other (1.C.1.c.)

This category provides the fugitive emissions of CO<sub>2</sub> in the stage of liquefied CO<sub>2</sub> transport by a lorry from a plant to an injection site or from a storage tank of liquefied CO<sub>2</sub>. It is hard to consider the annual fugitive emissions become larger than 3 kt-CO<sub>2</sub> for following reasons: First, according to the interview to the entities of the projects shown in Table 3-93 (excluding the Tomakomai project), the fugitive emissions shown above do not occur basically or the amount is quite small even if the fugitive emissions occur. Second, the maximum amount of annual injection is about 6 kt-CO<sub>2</sub>. Therefore, the emissions from this category are reported as insignificant NE in the years CO<sub>2</sub> injection were conducted in the projects other than Tomakomai. The treatment of insignificant NE is described in Annex 5. The emissions from this category are reported as NO in the years CO<sub>2</sub> injection were conducted only in Tomakomai site because there were no related activities. The emissions are reported as NO in the years CO<sub>2</sub> injection was not conducted in any of the projects.

## 3.4.2. Injection and Storage (1.C.2)

### 3.4.2.1. Injection (1.C.2.a.)

This category provides the fugitive emissions of CO<sub>2</sub> in the stage of a compressor or an injection well at an injection site.

According to the interview to the entities of the projects shown in Table 3-93, the fugitive emissions in the stage of injection do not occur basically or the amount is quite small even if the fugitive emissions occur. In addition, the approximate results of emissions estimated using the emission factors shown in Koornneef *et al.* (2008) are less than 3 kt-CO<sub>2</sub>, which is a criterion to include the emissions in the national total established by the Committee for the Greenhouse Gases Emissions Estimation Methods in FY2012. Therefore, the emissions from this category are reported as insignificant NE in the year CO<sub>2</sub> injection was conducted (but reported as NA in the year CO<sub>2</sub> injection was conducted only in Tomakomai site where the airtightness is assured) and reported as NO in the other years. The treatment of insignificant NE is described in Annex 5.

### 3.4.2.2. Storage (1.C.2.b.)

This category provides the fugitive emissions from a storage site.

According to the interview to the entities of the projects shown in Table 3-93, the fugitive emissions from a storage site do not occur basically or the amount is quite small even if the fugitive emissions occur. In addition, the approximate results of emissions estimated using the ratio of stored CO<sub>2</sub> in a storage reservoir to the injected CO<sub>2</sub> shown in the IPCC (2005) are less than 3 kt-CO<sub>2</sub>, which is a criterion to include the emissions in the national total established by the Committee for the Greenhouse Gases Emissions Estimation Methods in FY2012. Therefore, the emissions from this category are reported as insignificant NE through all reporting years. The treatment of insignificant NE is described in Annex 5.



### 3.4.3. Other (1.C.3)

This category provides any other emissions from CCS not reported in Transport of CO<sub>2</sub> (1.C.1) and Injection and storage (1.C.2). The emissions are reported as NO, because there are no emissions to be reported in this subcategory.

### 3.4.4. Information item

This section provides the amount of CO<sub>2</sub> captured for geological storage. Although there is 'Total amount captured for storage' in 'Information item' of CRF table 1.C, it should be noted that amount of CO<sub>2</sub> captured is subtracted from CO<sub>2</sub> emissions not from CO<sub>2</sub> transport and storage (1.C.) but from categories CO<sub>2</sub> captured.

The amount of CO<sub>2</sub> captured is considered to be nearly equal to that of CO<sub>2</sub> injected in the past projects of geological injection of CO<sub>2</sub> conducted in Japan. Thus, the amount of CO<sub>2</sub> injected that was provided by the entities of the projects is reported as the amount of CO<sub>2</sub> captured in the fiscal years when the injections were conducted. The captured amount is reported in 1.A.1.b Petroleum refining or 2.B.1 Ammonia production in accordance with the source of CO<sub>2</sub> used in each project.

Table 3-95 Amount of CO<sub>2</sub> captured for geological storage

Injection site	Unit	1990	1991	1992	1993	1997	1998	1999	2003	2004	2005	2006	2007	2016	2017	2018	2019	2020	Reported under
Kubiki	kt	0.23	3.93	4.46	1.17	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	2.B.1 Ammonia production
Sarukawa	kt	NO	NO	NO	NO	2.37	4.87	2.71	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	2.B.1 Ammonia production
Nagaoka	kt	NO	NO	NO	NO	NO	NO	NO	3.98	6.43	NO	NO	NO	NO	NO	NO	NO	NO	2.B.1 Ammonia production
Yubari	kt	NO	NO	NO	NO	NO	NO	NO	NO	0.04	0.12	0.36	0.37	NO	NO	NO	NO	NO	1.A.1.b Petroleum refining
Tomakomai	kt	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	29.22	126.80	79.58	64.51	NO	1.A.1.b Petroleum refining

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## Chapter 4. Industrial Processes and Product Use (CRF sector 2)

### 4.1. Overview of Sector

Chemical and physical transformation in industrial processes releases GHGs into the atmosphere. This chapter describes the methodologies of estimating industrial process and product use emissions shown in Table 4-1. The estimation methods, emission factors, activity data, etc of each source are considered and approved by the breakout groups on Energy and Industrial Processes, and F-gases, of the Committee for Greenhouse Gas Emissions Estimation Methods, consisting of experts from various fields. (See Chapter 1)

Emissions have been estimated for all years, with zero emissions for some years and sources. To the extent that space and confidentiality concerns allow, relative indices are shown in the tables under each sub-category. Emissions by each sub-category and by gas are shown in the first table of each category.

Table 4-1 Categories in the industrial processes and product use sector

Source categories			CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	HFCs	PFCs	SF <sub>6</sub>	NF <sub>3</sub>	
2.A Mineral Industry	2.A.1	Cement Production	○							
	2.A.2	Lime Production	○							
	2.A.3	Glass Production	○							
	2.A.4	Other Process Uses of Carbonates	Ceramics	○						
			Other Uses of Soda Ash	○						
Non-metallurgical Magnesia Production			IE							
Other			○							
2.B Chemical Industry	2.B.1	Ammonia Production	○	NE	NA					
	2.B.2	Nitric Acid Production			○					
	2.B.3	Adipic Acid Production	NA		○					
	2.B.4	Caprolactam, Glyoxal and Glyoxylic Acid Production	Caprolactam			○				
			Glyoxal			○				
			Glyoxylic Acid			○				
	2.B.5	Carbide Production	Silicon Carbide	○	○					
			Calcium Carbide	○	NA					
	2.B.6	Titanium Dioxide Production	○							
	2.B.7	Soda Ash Production	IE							
	2.B.8	Petrochemical and Carbon Black Production	Methanol	NO	NO					
			Ethylene	○	○					
			Ethylene Dichloride and Vinyl Chloride Monomer	○	○					
			Ethylene Oxide	○	○					
			Acrylonitrile	○	NA					
			Carbon Black	○	○					
			Styrene		○					
Phthalic Anhydride			○							
Maleic Anhydride			○							
Hydrogen			○							
2.B.9	Fluorochemical Production	By-product Emissions: Production of HCFC-22				○				
		Fugitive emissions				○	○	○	○	
2.C Metal Industry	2.C.1	Iron and Steel Production	Steel	IE	NA					
			Use of Electric Arc Furnaces in Steel Production	○	○					
			Pig Iron	○	NA					
			Limestone and dolomite use in Iron and Steel Production	○						
			Direct Reduced Iron	NO	NO					
			Sinter	IE	IE					
			Pellet	IE	IE					
	2.C.2	Ferroalloys Production	IE	○						
	2.C.3	Aluminium Production	By-product Emissions	○				○		
			F-gases Used in Foundries						NO	
2.C.4	Magnesium Production				○		○			
2.C.5	Lead Production	IE								
2.C.6	Zinc Production	IE								
2.C.7	Rare Earths Production	NE				NE				
2.D Non-energy Products from Fuels and Solvent Use	2.D.1	Lubricant Use	○							
	2.D.2	Paraffin Wax Use	○							
	2.D.3	Other	Urea-based Catalysts	○						
			NMVOC Incineration	○						
Road Paving with Asphalt Asphalt Roofing										
2.E Electronics Industry	2.E.1	Integrated Circuit or Semiconductor				○	○	○	○	
	2.E.2	TFT Flat Panel Display				○	○	○	○	
	2.E.3	Photovoltaics					IE			
	2.E.4	Heat Transfer Fluid					IE			

Table 4-1 Categories in the industrial processes and product use sector (continued)

Source categories				CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	HFCs	PFCs	SF <sub>6</sub>	NF <sub>3</sub>				
2.F Product Uses as Substitutes for ODS	2.F.1	Refrigeration and Air-Conditioning	Domestic Refrigeration	manufacturing				○	NO	NO	NO			
				stocks				○	NO	NO	NO			
				disposal				○	NO	NO	NO			
			Commercial Refrigeration	Commercial Refrigeration	manufacturing					○	NO	NO	NO	
					stocks					○	NO	NO	NO	
					disposal					○	NO	NO	NO	
				Automatic Vending Machines	manufacturing						○	NO	NO	NO
					stocks						IE	NO	NO	NO
					disposal						IE	NO	NO	NO
			Transport Refrigeration	manufacturing						○	NO	NO	NO	
				stocks						○	NO	NO	NO	
				disposal						○	NO	NO	NO	
			Industrial Refrigeration	manufacturing						IE	NO	NO	NO	
				stocks						IE	NO	NO	NO	
				disposal						IE	NO	NO	NO	
	Stationary Air-Conditioning (Household)	manufacturing						○	NO	NO	NO			
		stocks						○	NO	NO	NO			
		disposal						○	NO	NO	NO			
	Mobile Air-Conditioning (Car Air Conditioners)	manufacturing						○	NO	NO	NO			
		stocks						○	NO	NO	NO			
		disposal						○	NO	NO	NO			
	2.F.2	Foam Blowing Agents	Closed Cells	Urethane Foam	manufacturing					○	NO	NO	NO	
					stocks					○	NO	NO	NO	
					disposal					IE	NO	NO	NO	
				Extruded Polystyrene Foam	manufacturing						○	NO	NO	NO
					stocks						○	NO	NO	NO
					disposal						IE	NO	NO	NO
			Open Cells	High Expanded Polyethylene Foam	manufacturing					○	NO	NO	NO	
					stocks					NO	NO	NO	NO	
					disposal					NO	NO	NO	NO	
	2.F.3	Fire Protection	manufacturing					NO	NO	NO	NO			
			stocks					○	NO	NO	NO			
			disposal					NO	NO	NO	NO			
	2.F.4	Aerosols	Metered Dose Inhalers	manufacturing					○	NO	NO	NO		
				stocks					○	NO	NO	NO		
				disposal					IE	NO	NO	NO		
Aerosols			manufacturing						○	NO	NO	NO		
			stocks						○	NO	NO	NO		
			disposal						IE	NO	NO	NO		
2.F.5	Solvents	manufacturing					NO	NO	NO	NO				
		stocks					○	○	NO	NO				
		disposal					IE	IE	NO	NO				
2.F.6	Other Applications													
2.G Other Product Manufacture and Use	2.G.1	Electrical Equipment	manufacturing							○				
			stocks							○				
			disposal								IE			
	2.G.2	SF <sub>6</sub> and PFCs from Other Product Use	Military Applications	manufacturing						NE	NE			
				stocks						NE	○			
				disposal						NE	NE			
			Accelerators	manufacturing							NE	NE		
				stocks							NO	○		
				disposal							NE	NE		
			Soundproof Windows	manufacturing							NE	NE		
				stocks							NE	NE		
				disposal							NE	NE		
			Adiabatic Properties: Shoes and Tyres	manufacturing							NE	NE		
				stocks							NO	NO		
				disposal							NE	NE		
			Other Railway Silicon Rectifiers	manufacturing							NA	NA		
				stocks							NA	NA		
				disposal							○	NA		
	2.G.3	N <sub>2</sub> O from Product Uses	Medical Applications					○						
			Use During Semiconductor/Liquid Crystal Manufacturing					○						
	2.H Other	2.H.2	Food and Beverages Industry					○						
2.H.3		Emissions from Imported Carbonated Gas					○							

In FY2020, total GHG emissions from this sector amounted to approximately 101,390 kt-CO<sub>2</sub> eq., accounting for 8.8% of national total emissions (excluding LULUCF) in Japan. The emissions of CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O from this sector have decreased by 42.0% compared to FY1990. The emissions of HFCs, PFCs, SF<sub>6</sub>, and NF<sub>3</sub> from this sector have increased by 62.7% compared to 1990.

The main driving factors for the decrease in emissions for this sector since FY1990 are the decrease in emissions of HFC-23 produced as a by-product of HCFC-22 production due to regulation under the Act on the Protection of the Ozone Layer Through the Control of Specified Substances and Other Measures (chemical industry), the decrease in CO<sub>2</sub> emissions from cement production (mineral industry) as the clinker production declined, the decrease in N<sub>2</sub>O emissions from adipic acid production (chemical industry) as the N<sub>2</sub>O abatement equipment came on stream. However, HFC emissions from the product uses as ODS substitutes have largely increased.

The methodological tiers used in the IPPU sector are as shown in the below Table 4-2.

Table 4-2 Methodological tiers used in the IPPU sector

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO <sub>2</sub>		CH <sub>4</sub>		N <sub>2</sub> O			
	Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor		
2.A. Mineral industry	CS,T2	CS						
2.B. Chemical industry	CS,T1,T2,T3	CS,D	CS,T1	CS	CS,T1,T2,T3	CS,PS		
2.C. Metal industry	CS,T1	CS,D	CS	CS				
2.D. Non-energy products from fuels and solvent use	D,T1,T2	CS,D	NA	NA	NA	NA		
2.E. Electronics industry								
2.F. Product uses as substitutes for ODS								
2.G. Other product manufacture and use					CS	OTH		
2.H. Other	CS		NA	NA	NA	NA		
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	HFCs		PFCs		SF <sub>6</sub>		NF <sub>3</sub>	
	Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor
2.A. Mineral industry								
2.B. Chemical industry	T2,T3	CS,OTH	T3	OTH	T3	OTH	T3	OTH
2.C. Metal industry	CS	CS	T2	D,CS	T2	OTH		
2.D. Non-energy products from fuels and solvent use								
2.E. Electronics industry	T2	D,CS	T2	D,CS	T2	D,CS	T2	D,CS
2.F. Product uses as substitutes for ODS	CS	D,CS	CS	CS				
2.G. Other product manufacture and use			CS	CS	CS,T1,T2	CS,D		
2.H. Other								

Note: D: IPCC default, T1-T3: IPCC Tier 1-3, CS: country specific, PS: plant specific, OTH: other

## 4.2. Mineral Industry (2.A.)

This category covers CO<sub>2</sub> emissions from the calcination of mineral raw material such as CaCO<sub>3</sub>, MgCO<sub>3</sub>, Na<sub>2</sub>CO<sub>3</sub>, etc. This section includes GHG emissions from Cement production (2.A.1.), Lime production (2.A.2.), Glass production (2.A.3.), and Other process uses of carbonates (2.A.4.).

In FY2020, emissions from this category were 31,217 kt-CO<sub>2</sub> and represented 2.7% of total GHG emissions (excluding LULUCF). The emissions decreased by 36.6% compared to FY1990.

Table 4-3 CO<sub>2</sub> Emissions from 2.A. Mineral Industry

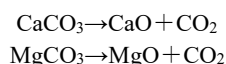
Gas		Units	1990	1995	1999	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020		
CO <sub>2</sub>	2.A.1	Cement production	kt-CO <sub>2</sub>	38,701	42,142	35,010	35,086	32,280	24,321	24,983	25,625	26,805	26,557	25,936	25,969	26,429	26,183	25,328	24,490	
	2.A.2	Lime production	kt-CO <sub>2</sub>	6,674	5,795	5,703	5,900	6,646	6,285	5,896	5,679	5,767	5,812	5,477	5,504	5,583	5,615	5,481	5,470	
	2.A.3	Glass production	kt-CO <sub>2</sub>	313	283	236	233	252	164	168	179	193	194	193	189	196	199	191	191	
	2.A.4	Other process uses of carbonates	Ceramics	kt-CO <sub>2</sub>	930	1,066	951	981	737	891	855	903	930	932	855	766	738	680	605	356
			Other uses of soda ash	kt-CO <sub>2</sub>	119	118	100	102	78	63	61	52	48	51	49	47	42	45	40	18
	Other	kt-CO <sub>2</sub>	2,493	1,742	1,580	1,617	1,238	1,028	1,126	1,191	1,260	1,184	1,148	1,058	983	923	836	692		
	Total	kt-CO <sub>2</sub>	49,230	51,146	43,580	43,919	41,230	32,752	33,089	33,629	35,004	34,731	33,659	33,534	33,971	33,645	32,481	31,217		

### 4.2.1. Cement Production (2.A.1.)

#### a) Category Description

CO<sub>2</sub> is emitted by the calcination of limestone, the main component of which is calcium carbonate, during the production of clinker<sup>1)</sup>, an intermediate product of cement and the main component of which is calcium oxide. Although to a lesser extent than calcium carbonate, limestone also contains magnesium carbonate, which by calcination emits CO<sub>2</sub>.

CO<sub>2</sub> emission mechanism of the cement production process



- 1) Cement clinker, a black nodule like a volcanic rock with a diameter of 1 cm or so is formed, by introducing a mixture of raw materials such as clay, silica stone, or iron materials, in addition to the main material limestone, into a large rotating kiln after pre-heating, and calcining them under high temperatures, and then rapidly cooling by air. This is ground up, and with the addition of gypsum, is transformed into cement. (from Japan Cement Association's website, partially edited)

#### b) Methodological Issues

##### ● Estimation Method

Following the Tier 2 method in the 2006 IPCC Guidelines, the CO<sub>2</sub> emissions from this source was estimated by multiplying the amount of clinker produced by a country-specific emission factor.

$$E = EF_{cl} \times M_{cl} \times CF_{ckd}$$

$E$	: CO <sub>2</sub> emissions from cement production [t-CO <sub>2</sub> ]
$EF_{cl}$	: Emission factor [t-CO <sub>2</sub> /t-clinker]
$M_{cl}$	: Clinker production [t]
$CF_{ckd}$	: Cement kiln dust correction coefficient

##### ● Emission Factors

Since Japan's cement industry takes in large amounts of waste and byproducts from other industries and recycles them as substitute raw materials for cement production, clinker contains CaO and MgO from sources other than carbonates. This CaO and MgO do not go through the limestone calcination stage and therefore does not emit CO<sub>2</sub> during the clinker production process. For that reason, emission factors were determined by estimating the CaO and MgO content of clinker from carbonates, by subtracting CaO and MgO originating from waste and other sources from the total CaO and MgO content of clinker. Japan applies 1.00 for the cement kiln dust (CKD) correction coefficient, because normally almost all CKD is recovered and used again in the production process, as confirmed by the Cement Association.

The emission factors for CO<sub>2</sub> emitted from cement production were established as follows.

$$EF = EF_{CaO} + EF_{MgO}$$

$EF_{CaO}$	: CaCO <sub>3</sub> -origin CO <sub>2</sub> emission factor (established by the following equation)
$EF_{MgO}$	: MgCO <sub>3</sub> -origin CO <sub>2</sub> emission factor (established by the following equation)



$$EF_{CaO} = (CaO_{cl} - CaO_{Cl-Waste}) \times 0.785$$

$$CaO_{Cl-Waste} = W_{dry} \times CaO_{waste} / M$$

$CaO_{cl}$	: CaO content of clinker
$CaO_{Cl-waste}$	: CaO content of clinker (waste-origin)
0.785	: Molecular weight ratio of CO <sub>2</sub> to CaO
$W_{dry}$	: Weight of inputs of waste and other materials (dry)
$CaO_{Waste}$	: CaO content of waste and other materials
$M$	: Production amount of clinker

$$EF_{MgO} = (MgO_{cl} - MgO_{Cl-Waste}) \times 1.092$$

$$MgO_{Cl-Waste} = W_{dry} \times MgO_{waste} / M$$

$MgO_{cl}$	: MgO content of clinker
$MgO_{Cl-Waste}$	: MgO content of clinker (waste-origin)
1.092	: Molecular weight ratio of CO <sub>2</sub> to MgO
$W_{dry}$	: Weight of inputs of waste and other materials (dry)
$MgO_{Waste}$	: MgO content of waste and other materials
$M$	: Production amount of clinker

➤ **Dry weight of waste and other materials input in raw material processing**

The following 13 types of waste and other materials were chosen for this calculation: coal ash (incineration residue), sewage sludge incineration ash, municipal solid waste incineration ash, glass refuse/ceramics refuse, concrete refuse, blast furnace slag (water granulated), blast furnace slag (slow-cooled), steelmaking slag, nonferrous slag, casting sand, particulates/dust, coal ash (fluidized bed furnace ash), and coal ash (from dust collectors) (these waste account for over 90% of the CaO and 80% of the MgO from waste and other materials). Waste amounts (emission-based) and the water content of each waste and other material were determined from studies by the Japan Cement Association (only for 2000 and thereafter).

➤ **Content of CaO and MgO from waste and other materials in clinker**

The dry weights of each type of waste and other materials are multiplied by the respective CaO and MgO content for each type as found by the Japan Cement Association, thereby yielding the respective total CaO and MgO amounts in clinker derived from waste and other materials. This is divided by clinker production amount to find the CaO and MgO content from waste and other materials in clinker.

➤ **CaO and MgO content of clinker, excluding the CaO and MgO from waste and other materials**

CaO and MgO content in waste and other materials is subtracted from the respective average CaO and MgO content of clinker as determined by the Japan Cement Association, which yields the respective proportion of CaO and MgO in clinker that is used to set emission factors.

Table 4-4 Composition of waste-origin material

Group	Types of waste	Water content	CaO content	MgO content
Incineration residue	Coal ash	7.2 - 16.3%	5.0 - 5.8%	1.0 - 1.1%
	Sewage sludge incineration ash <sup>1)</sup>	10.9 - 17.8%	7.4 - 12.5%	3.5 - 3.8%
	Municipal solid waste incineration ash <sup>1)</sup>	15.6 - 24.6%	10.0 - 26.5%	2.6 - 2.8%
Glass refuse, Concrete refuse, and Ceramics refuse	Glass refuse, Ceramics refuse <sup>1)</sup>	12.1 - 32.7%	17.5 - 31.1%	1.0 - 2.5%
	Concrete refuse <sup>1)</sup>	0 - 37.2%	6.4 - 43.9%	1.0 - 1.1%
Slag	Blast furnace slag (water granulated)	5.0 - 16.9%	40.0 - 42.4%	4.7 - 5.8%
	Blast furnace slag (slow-cooled)	5.5 - 11.7%	40.8 - 41.5%	6.1 - 6.5%
	Steelmaking slag	7.7 - 14.3%	34.8 - 40.5%	2.0 - 3.0%
	Nonferrous slag	3.8 - 8.4%	6.4 - 10.0%	1.1 - 1.5%
	Casting sand <sup>1)</sup>	9.6 - 14.0%	6.5%	1.3 - 1.6%
Particulates (dust collector dust)	Particulates/dust	8.9 - 14.3%	9.0 - 13.4%	1.2 - 1.5%
	Coal ash (fluidized bed furnace ash) <sup>1)</sup>	0.1 - 3.2%	14.5 - 20.7%	0.7 - 0.9%
	Coal ash	1.0 - 3.9%	4.1 - 5.0%	1.0 - 1.1%

Note: 1) Newly added from FY2009.

Table 4-5 CO<sub>2</sub> emission factors for cement production

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Average CaO content in clinker	%	65.9	65.9	66.0	65.9	65.8	65.8	65.8	65.8	65.8	65.8	65.8	65.8	65.8	65.8	65.8
Waste origin CaO content in clinker	%	2.6	2.6	2.9	2.0	1.7	2.0	1.8	1.7	1.6	1.6	1.6	1.7	1.8	1.8	1.6
CaO content in clinker excluding waste origin CaO	%	63.3	63.3	63.0	63.9	64.1	63.7	64.0	64.1	64.1	64.2	64.1	64.1	64.0	64.0	64.2
CO <sub>2</sub> /CaO		0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785
Emission factor	t-CO <sub>2</sub> /t	0.497	0.497	0.495	0.501	0.503	0.500	0.502	0.503	0.503	0.504	0.503	0.503	0.502	0.502	0.504
Average MgO content in clinker	%	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
Waste origin MgO content in clinker	%	0.3	0.3	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
MgO content in clinker excluding waste origin MgO	%	1.0	1.0	0.9	1.0	1.0	1.0	1.0	1.1	1.1	1.1	1.1	1.1	1.0	1.0	1.1
CO <sub>2</sub> /MgO		1.092	1.092	1.092	1.092	1.092	1.092	1.092	1.092	1.092	1.092	1.092	1.092	1.092	1.092	1.092
Emission factor	t-CO <sub>2</sub> /t	0.010	0.010	0.010	0.011	0.011	0.011	0.011	0.012	0.012	0.012	0.012	0.012	0.011	0.011	0.012
Combined emission factor	t-CO <sub>2</sub> /t	0.508	0.508	0.505	0.512	0.514	0.511	0.514	0.514	0.515	0.516	0.515	0.515	0.514	0.514	0.515

### ● Activity Data

Cement Association provides the data on the amount of clinker produced. Because there is no statistics on clinker production from FY1990 to FY1999, an estimation is made for past (FY1990 - FY1999) clinker production using the average values of the FY2000 - FY2003 ratios of clinker production (Cement Association data) to limestone consumption (*Yearbook of Ceramics and Building Materials Statistics* (Ministry of Economy, Trade and Industry)).

Table 4-6 Clinker production

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Consumption of limestone (actual)	kt (dry)	89,366	97,311	81,376	-	-	-	-	-	-	-	-	-	-	-	-
Clinker production (actual)	kt	-	-	69,528	63,003	47,279	48,884	49,883	52,105	51,573	50,307	50,436	51,351	50,979	49,293	47,522
Ratio of actual clinker production to actual consumption of limestone		0.853	0.853													
Estimated clinker production after correction	kt	76,253	83,032													

### c) Uncertainties and Time-series Consistency

#### ● Uncertainty

For the uncertainty of the CO<sub>2</sub> emission factor and activity data for cement production, the default value given in the 2006 IPCC Guidelines was applied. As a result, the uncertainty of emissions was estimated to be 4%.

- **Time-series Consistency**

CO<sub>2</sub> emissions from cement production from FY1990 to FY1999 is estimated using estimated activity data and emission factors based on values provided by the Japan Cement Association. For years from FY2000 and onward, the methodology described in the sections above is consistently applied using the data provided by Japan Cement Association.

**d) Category-specific QA/QC and Verification**

General inventory QC procedures have been conducted in accordance with the 2006 IPCC Guidelines. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

**e) Category-specific Recalculations**

There have been no source-specific recalculations.

**f) Category-specific Planned Improvements**

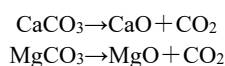
No improvements are planned.

#### 4.2.2. Lime Production (2.A.2.)

**a) Category Description**

CO<sub>2</sub> is emitted during the calcination of CaCO<sub>3</sub>, MgCO<sub>3</sub> in limestone used as raw material to produce quicklime.

CO<sub>2</sub> generation mechanism of quicklime production process



**b) Methodological Issues**

- **Estimation Method**

CO<sub>2</sub> emissions are calculated by multiplying limestone consumption by the country-specific emission factor.

$$E = EF \times M$$

<i>E</i>	: CO <sub>2</sub> emissions generated by use of raw materials in quicklime production [t-CO <sub>2</sub> ]
<i>EF</i>	: Emission factor [t-CO <sub>2</sub> /t-raw material]
<i>M</i>	: Amount of limestone consumed [t-raw material]

- **Emission Factors**

An emission factor per unit raw material (limestone) (0.428 t-CO<sub>2</sub>/t-raw material)<sup>1</sup> provided by the Japan Lime Association was used.

The Emission factor per unit raw material was calculated by finding the CO<sub>2</sub> emissions per unit raw material estimated from the amounts of carbon and other substances in raw material

<sup>1</sup> The emission factor per lime produced can be derived as follows: 0.428 [t-CO<sub>2</sub>/t-material] / (1-0.428) [t-lime/t-material] = 0.748 [t-CO<sub>2</sub>/t-lime]

constituents and quicklime products, and then finding the weighted average using production amounts of each district. The emission factor for lime production is the same for all years because annual change is thought to be small. This emission factor is country-specific, as described above.

● **Activity Data**

Limestone consumption data for quicklime and slaked lime use, categorized under 'Ceramic and quarry products- other ceramics and quarry products' in the *Adjusted Price Transaction Table* is used. It is converted to dry weight using the water content from limestone used for cement.

The *Adjusted Price Transaction Table* (Research Institute of Economy, Trade and Industry, hereafter, RIETI):

The *Adjusted Price Transaction Table* is a table created from the monetary input table in the Input-Output Table and the consumption data provided in industrial statistics and is an application of similar estimation methods as in the *General Energy Statistics* (the Energy Balance Table).

In the existing transaction table attached to the Input-Output Table, although expressing the domestic supply and demand of products without any omission/duplication, there exists the possibility of over/under evaluation of transaction depending on the sector if the actual price differs, since transaction in each sector is based on the input from the average price across all industries. In contrast, the *Adjusted Price Transaction Table* attempts to eliminate differences between sectors, by taking into consideration the uneven transaction prices based on the differences in product quality/form in each sector, and through using statistical values in industrial statistics, etc to the extent which possible.

By using consumption data in the *Adjusted Price Transaction Table* as activity data, it is considered possible to capture activity data for all industries without omission/duplication, and to achieve a correct categorization of emission/non-emission related use, based on its detailed breakdown of sectors.

In the inventory, limestone/dolomite consumption data by sector in the *Adjusted Price Transaction Table* will be used as activity data for each limestone related source, excluding that for Cement production (2.A.1.).

As for the dolomite consumed in dolomitic lime production, it is accounted for under Other process uses of carbonates (2.A.4.), and therefore will not be included under Lime production (2.A.2.). The re-absorption of CO<sub>2</sub> by the production of light calcium carbonate is already deducted in the *Adjusted Price Transaction Table*.

As regards lime production in sugar mills, according to an interview conducted with three domestic producers documented in the *Report on the Development of the Foundation for the Mandatory GHG Accounting and Reporting System (2010)* by the Ministry of the Environment (MOE), as regards cane sugar, slaked lime is acquired from outside to make the lime milk at all domestic producers, and as for beet sugar, in cases when limestone is calcined, the CO<sub>2</sub> emitted is reabsorbed into the lime cake. On the basis of this information, CO<sub>2</sub> emissions from sugar manufacturing are not estimated.

As regards aluminium production in Japan, it was confirmed that lime has never been produced from FY1990 onward according to information from the Japan Aluminum Association. (Aluminium production ended in 2014.) Therefore, the CO<sub>2</sub> emissions are not estimated.

Table 4-7 Limestone consumption

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Limestone consumption (dry)	kt	15,595	13,540	13,785	15,527	14,684	13,775	13,269	13,474	13,579	12,797	12,860	13,045	13,119	12,807	12,780

### c) *Uncertainties and Time-series Consistency*

#### ● *Uncertainty*

For the uncertainty of the emission factor, the default value of 2% in the *2006 IPCC Guidelines* was used. For the uncertainty of activity data, the default value of 3% in the *2006 IPCC Guidelines* was used. As a result, the uncertainty for emissions was estimated as 4%.

#### ● *Time-series consistency*

Limestone consumption data provided in the *Adjusted Price Transaction Table* is used as lime production activity data for all years from FY1990. The emission factors are constant for all years from FY1990. Therefore, CO<sub>2</sub> emission from lime production has been estimated in a consistent manner throughout the time-series.

### d) *Category-specific QA/QC and Verification*

See section 4.2.1. d).

### e) *Category-specific Recalculations*

There have been no source-specific recalculations.

### f) *Category-specific Planned Improvements*

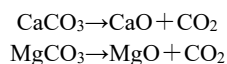
No improvements are planned.

## 4.2.3. Glass Production (2.A.3.)

### a) *Category Description*

Limestone contains CaCO<sub>3</sub> and minute amounts of MgCO<sub>3</sub>, and dolomite contains CaCO<sub>3</sub> and MgCO<sub>3</sub>. The heating of limestone and dolomite releases CO<sub>2</sub> derived from CaCO<sub>3</sub> and MgCO<sub>3</sub>. Similarly, CO<sub>2</sub> is emitted from soda ash, barium carbonate, potassium carbonate, strontium carbonate, and lithium carbonate. There is still no detailed information available regarding the use of bone ash in glass production in Japan.

CO<sub>2</sub> generating mechanism of limestone and dolomite use



### b) *Methodological Issues*

#### ● *Estimation Method*

The amounts of limestone, dolomite, soda ash, barium carbonate, potassium carbonate, strontium carbonate, and lithium carbonate used in glass production are multiplied by the emission factors to calculate emissions.

## ● Emission Factors

### ➤ Limestone

The emission factor is calculated by adding the value obtained when multiplying the molecular weight ratio of CO<sub>2</sub> and CaCO<sub>3</sub> by the CaCO<sub>3</sub> content, calculated from the percentage of CaO that can be extracted from limestone (55.4%, the median value of the “54.8% to 56.0%” given in *The Story of Lime* [Japan Lime Association]), and the value obtained when multiplying the molecular weight ratio of CO<sub>2</sub> and MgCO<sub>3</sub> by the MgCO<sub>3</sub> content, calculated from the percentage of MgO that can be extracted from limestone (0.5%, the median value of the “0.0% to 1.0%” given in *The Story of Lime*). The emission factor is country-specific, as shown below. A review of this EF was conducted in 2009, and it was confirmed that it remains valid.

- Proportion of CaO extractable from limestone : 55.4 % (Median of 54.8% to 56.0%<sup>b)</sup>)
- Proportion of MgO extractable from limestone : 0.5 %<sup>b)</sup> (Median of 0.0% to 1.0%<sup>b)</sup>)
- Molecular weight of CaCO<sub>3</sub> (primary constituent of limestone) : 100.0869<sup>a)</sup>
- Molecular weight of MgCO<sub>3</sub> : 84.3139<sup>a)</sup>
- Molecular weight of CaO : 56.0774<sup>a)</sup>
- Molecular weight of MgO : 40.3044<sup>a)</sup>
- Molecular weight of CO<sub>2</sub> : 44.0095<sup>a)</sup>
- CaCO<sub>3</sub> content = proportion of CaO extractable from limestone ×  
molecular weight of CaCO<sub>3</sub> / molecular weight of CaO
- MgCO<sub>3</sub> content = proportion of MgO extractable from limestone ×  
molecular weight of MgCO<sub>3</sub> / molecular weight of MgO
- Emission factor = (molecular weight of CO<sub>2</sub> / molecular weight of CaCO<sub>3</sub> × CaCO<sub>3</sub> content)  
+ (molecular weight of CO<sub>2</sub> / molecular weight of MgCO<sub>3</sub> × MgCO<sub>3</sub> content)  
= 440 [kg-CO<sub>2</sub>/t]

Reference:

- a) *Atomic Weights of the Elements 1999* [<http://www.ciaaw.org/pubs/TSAW-1999.pdf>] (IUPAC)
- b) *The Story of Lime* (Japan Lime Association)

### ➤ Dolomite

The emission factor is calculated by adding the value obtained when multiplying the molecular weight ratio of CO<sub>2</sub> and CaCO<sub>3</sub> by the CaCO<sub>3</sub> content, calculated from the percentage of CaO that can be extracted from dolomite (34.5%, the median value of the 33.1% to 35.85% range given in *The Story of Lime*), and the value obtained when multiplying the molecular weight ratio of CO<sub>2</sub> and MgCO<sub>3</sub> by the MgCO<sub>3</sub> content, calculated from the percentage of MgO that can be extracted from dolomite (18.3%, the median value of the 17.2% to 19.5% range given in *The Story of Lime*). The emission factor is country-specific, as shown below. A review of this EF was conducted in 2009, and it was confirmed that it remains valid.

- Proportion of CaO extractable from dolomite : 34.5% (Median value of the 33.1% to 35.85%<sup>a)</sup>)
- Proportion of MgO extractable from dolomite : 18.3% (Median value of the 17.2% to 19.5%<sup>a)</sup>)
- Molecular weight of CaCO<sub>3</sub> (major constituent of dolomite) : 100.0869
- Molecular weight of MgCO<sub>3</sub> (major constituent of dolomite) : 84.3142
- Molecular weight of CaO : 56.0774
- Molecular weight of MgO : 40.3044
- Molecular weight of CO<sub>2</sub> : 44.0098
- CaCO<sub>3</sub> content = proportion of CaO extractable from dolomite ×  
molecular weight of CaCO<sub>3</sub> / molecular weight of CaO

$$\begin{aligned} \bullet \text{ MgCO}_3 \text{ content} &= \text{proportion of MgO extractable from dolomite} \times \\ &\quad \text{molecular weight of MgCO}_3 / \text{molecular weight of MgO} \\ \circ \text{ Emission factor} &= \text{molecular weight of CO}_2 / \text{molecular weight of CaCO}_3 \times \text{CaCO}_3 \text{ content} \\ &\quad + \text{molecular weight of CO}_2 / \text{molecular weight of MgCO}_3 \times \text{MgCO}_3 \text{ content} \\ &= 471 \text{ [kg-CO}_2\text{/t]} \end{aligned}$$

Reference:

- a) *The Story of Lime* (Japan Lime Association)

### ➤ Soda ash

See section 2.A.4.b Other uses of soda ash.

### ➤ Other materials

For barium carbonate ( $\text{BaCO}_3$ ), 0.22t- $\text{CO}_2$ /t, based on molecular weight ratio of  $\text{CO}_2$  to  $\text{BaCO}_3$ , is used. For potassium carbonate ( $\text{K}_2\text{CO}_3$ ), 0.32t- $\text{CO}_2$ /t, based on molecular weight ratio of  $\text{CO}_2$  to  $\text{K}_2\text{CO}_3$ , is used. For strontium carbonate ( $\text{SrCO}_3$ ), 0.30t- $\text{CO}_2$ /t, based on molecular weight ratio of  $\text{CO}_2$  to  $\text{SrCO}_3$ , is used. For lithium carbonate ( $\text{Li}_2\text{CO}_3$ ), 0.60t- $\text{CO}_2$ /t, based on molecular weight ratio of  $\text{CO}_2$  to  $\text{Li}_2\text{CO}_3$ , is used.

## ● Activity Data

### ➤ Limestone, Dolomite, and Soda ash

Of the limestone, dolomite, and soda ash consumption data in the *Adjusted Price Transaction Table*, all limestone, dolomite, soda ash consumption categorized under 'emissive use' that are under the Glass products related sectors will be accounted for under this subcategory. Activity data is in dry weight, converted using the water content from limestone used for cement.

The corresponding sectors in the *Adjusted Price Transaction Table* are as follows:

Table 4-8 Main uses and corresponding sectors in the *Adjusted Price Transaction Table*

Use	Corresponding sectors (Limestone)	Corresponding sectors (Dolomite)	Corresponding sectors (Soda ash)
Glass products	251 Ceramic and quarry products - glass/glass products	251 Ceramic and quarry products - glass/glass products	251 Ceramic and quarry products - glass/glass products

Note: The numbers before the sector names are categorization numbers in the *Adjusted Price Transaction Table*.

Table 4-9 Amounts of limestone, dolomite, and soda ash consumption

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Limestone consumption (dry)	kt	66	42	26	31	17	16	20	23	23	23	22	24	25	23	23
Dolomite consumption (dry)	kt	264	250	203	230	151	154	164	176	176	174	169	176	177	170	169
Soda ash consumption (dry)	kt	358	320	257	288	197	201	217	235	236	237	232	240	245	237	237

### ➤ Other materials

For barium carbonate, shipment amounts for cathode-ray tube optical glass given in the *Mineral Resources Material Flow* (Japan Oil, Gas and Metals National Corporation) converted to pure substance mass (69%) are used for years FY2000 to FY2010. For other years, extrapolation using production amounts of glass bulbs for lights and electron tubes (including tubes and rods) given in the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials* (METI) are applied.

For potassium carbonate, domestic demand obtained by subtracting export quantities from import quantities given in the *Trade Statistics of Japan* (the Ministry of Finance) converted to pure substance mass (57%) are used for years FY1991 and onward.

For strontium carbonate, demand amounts of tube glass (including flat panel glass and other glass) converted to pure substance mass (59%) are used for years FY2000 to FY2006, FY2008, and FY2010. For FY2007 and FY2009, interpolation was applied. For years FY1990 to FY1999, extrapolation using production amounts of glass bulbs for lights and electron tubes (including tubes and rods) given in the *Yearbook of Ceramics and Building Materials Statistics* (METI) was applied, and for years from FY2011 and onward extrapolation using demand amounts of SrCO<sub>3</sub> given in the *Mineral Resources Material Flow* are applied.

For lithium carbonate, demand amounts of ceramic additives (19%) given in the *Mineral Resources Material Flow* are used for years FY2002 and onward. For years FY1998 to FY2001, extrapolation using demand amounts for glass additives given in the *Mineral Resources Material Flow* are applied. For years FY1990 to FY1997, production amounts of plate glass given in the *Yearbook of Ceramics and Building Materials Statistics* (METI) for years FY1990 to FY1997 are applied.

### c) *Uncertainties and Time-series Consistency*

#### ● *Uncertainty*

For the uncertainty of the emission factor, the default value of 5% in the *2006 IPCC Guidelines* was used. For the uncertainty of activity data, the default value of 3% in the *2006 IPCC Guidelines* was used. As a result, the uncertainty for emissions was estimated as 6%.

#### ● *Time-series consistency*

For activity data, the same source-data are used as much as possible throughout the time series. The emission factors are constant for all years from FY1990. Therefore, CO<sub>2</sub> emission has been estimated in a consistent manner throughout the time-series.

### d) *Category-specific QA/QC and Verification*

See section 4.2.1. d).

### e) *Category-specific Recalculations*

Recalculations occurred due to the revision of soda ash import amounts, etc (FY2019) in the *Adjusted Price Transaction Table* and demand amounts of lithium carbonate (FY2019) in the *Mineral Resources Material Flow*. See Chapter 10 for impact on trend.

### f) *Category-specific Planned Improvements*

No improvements are planned.

## 4.2.4. Other Process Uses of Carbonates (2.A.4.)

### 4.2.4.1. Ceramics (2.A.4.a)

#### a) *Category Description*

Limestone contains CaCO<sub>3</sub> and minute amounts of MgCO<sub>3</sub>, and dolomite contains CaCO<sub>3</sub> and MgCO<sub>3</sub>. The heating of limestone and dolomite releases CO<sub>2</sub> derived from CaCO<sub>3</sub> and MgCO<sub>3</sub>.



### b) Methodological Issues

#### ● Estimation Method

The amounts of limestone and dolomite used in ceramics production are multiplied by the emission factors to calculate emissions.

#### ● Emission Factors

##### ➤ Limestone

See section 4.2.3. b).

##### ➤ Dolomite

See section 4.2.3. b).

#### ● Activity Data

Of the limestone and dolomite consumption data in the *Adjusted Price Transaction Table*, all limestone and dolomite consumption categorized under 'emissive use' that are under the Ceramics products related sectors will be accounted for under this subcategory. Activity data is in dry weight, converted using the water content from limestone used for cement.

The corresponding sectors in the *Adjusted Price Transaction Table* are as follows:

Table 4-10 Corresponding sectors in the *Adjusted Price Transaction Table*

Uses	Corresponding sectors in the <i>Adjusted Price Transaction Table</i> (Limestone)		Corresponding sectors in the <i>Adjusted Price Transaction Table</i> (Dolomite)	
Ceramics products			063	Mining industry – non-metallic minerals
	2531-01	Ceramic and quarry products- ceramics	2531-01	Ceramic and quarry products- ceramics
	2591-01	Ceramic and quarry products - clay refractories	2591-01	Ceramic and quarry products - clay refractories
			2599-01	Ceramic and quarry products carbon graphite products
			2599-09	Ceramic and quarry products - other ceramic and quarry products
			2811-01 to 2899-09	Metal Products - metal products for construction use Metal Products - other metal products
		6741-09	Private services - other amusement	

Note: The numbers before the sector names are categorization numbers in the *Adjusted Price Transaction Table*.

Table 4-11 Amounts of limestone and dolomite consumption

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Limestone consumption																
For Ceramic Products (dry)	kt	442	1,110	1,138	467	400	423	426	629	761	799	670	617	622	510	266
Dolomite consumption																
For Ceramic Products (dry)	kt	1,561	1,227	1,020	1,128	1,519	1,421	1,519	1,387	1,269	1,069	1,000	991	863	808	508

### c) Uncertainties and Time-series Consistency

#### ● Uncertainty

Same as 4.2.3 Glass Production. See section 4.2.3.c).

#### ● Time-series consistency

Limestone and dolomite consumption data provided in the *Adjusted Price Transaction Table* is used as limestone and dolomite use activity data for all years from FY1990. The emission factors are constant

for all years from FY1990. Therefore, CO<sub>2</sub> emission from limestone and dolomite use has been estimated in a consistent manner throughout the time-series.

#### **d) Category-specific QA/QC and Verification**

See section 4.2.1. d).

#### **e) Category-specific Recalculations**

Recalculations occurred due to updates made to limestone (FY2018 and FY2019) and dolomite consumption (FY2019) data in the *Adjusted Price Transaction Table*. See Chapter 10 for impact on trend.

#### **f) Category-specific Planned Improvements**

No improvements are planned.

### **4.2.4.2. Other uses of soda ash (2.A.4.b)**

#### **a) Category Description**

CO<sub>2</sub> is released during the use of soda ash (Na<sub>2</sub>CO<sub>3</sub>).

#### **b) Methodological Issues**

##### ● **Estimation Method**

CO<sub>2</sub> emissions from soda ash use are calculated by multiplying soda ash consumption by the country-specific emission factor.

##### ● **Emission Factors**

Soda ash consumption data categorized under 'for emission purpose' in the *Adjusted Price Transaction Table* does not differentiate between domestic products and imported products, and therefore the emission factor is established by taking a weighted average of the below emission factors for domestic soda ash and imports, by total domestic shipment and total import amounts.

For domestic soda ash, the emission factor is set as follows using data on the purity of soda ash. (The inter-annual fluctuation in the purity of soda ash is small, and therefore the emission factor will be set constant over the time-series.)

$$\begin{aligned} EF &= P \times MW_{CO_2} / MW_{Na_2CO_3} \\ &= 0.995 \times 44.01 / 105.99 \\ &= 0.413[\text{t-CO}_2/\text{t}] \end{aligned}$$

*EF* : Emission factor for domestic soda ash

*P* : Purity of soda ash (arithmetic mean between the 2 domestic companies)

*MW<sub>CO<sub>2</sub></sub>* : Molecular weight of CO<sub>2</sub>

*MW<sub>Na<sub>2</sub>CO<sub>3</sub></sub>* : Molecular weight of Na<sub>2</sub>CO<sub>3</sub>

For soda ash imported, and other disodium carbonate imported, there is not enough information to set representative emission factors. Therefore, the default value (0.415 [t-CO<sub>2</sub>/t-Na<sub>2</sub>CO<sub>3</sub>]) specified in the 2006 IPCC Guidelines (vol. 3 p. 2.7) is used.

- **Activity Data**

Soda ash consumption data categorized under 'for emission purpose' in the *Adjusted Price Transaction Table* is used. (excluding consumption for glass production)

**c) Uncertainties and Time-series Consistency**

- **Uncertainty**

For the uncertainty of the emission factor, the default value of 5% in the *2006 IPCC Guidelines* was used. For the uncertainty of activity data, the default value of 3% in the *2006 IPCC Guidelines* was used. As a result, the uncertainty for emissions was estimated as 6%.

- **Time-series consistency**

Soda ash consumption data provided in the *Adjusted Price Transaction Table* is used as soda ash use activity data for all years from FY1990. The emission factor is constant for all years from FY1990. Therefore, CO<sub>2</sub> emission from soda ash use has been estimated in a consistent manner throughout the time-series.

**d) Category-specific QA/QC and Verification**

See section 4.2.1. d).

**e) Category-specific Recalculations**

Recalculations occurred for FY2019 due to updates made to soda ash consumption data and soda ash import amounts, etc, in the *Adjusted Price Transaction Table*. See Chapter 10 for impact on trend.

**f) Category-specific Planned Improvements**

No improvements are planned.

#### 4.2.4.3. Non-metallurgical Magnesium Production (2.A.4.c)

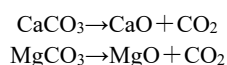
Emissions are included under 2.A.4.d. Other, and are therefore reported as IE.

#### 4.2.4.4. Other (2.A.4.d)

**a) Category Description**

Limestone contains CaCO<sub>3</sub> and minute amounts of MgCO<sub>3</sub>, and dolomite contains CaCO<sub>3</sub> and MgCO<sub>3</sub>. The heating of limestone and dolomite releases CO<sub>2</sub> derived from CaCO<sub>3</sub> and MgCO<sub>3</sub>.

CO<sub>2</sub> generating mechanism of limestone and dolomite use



**b) Methodological Issues**

- **Estimation Method**

The amounts of limestone and dolomite used in desulfurization of exhaust gas and production of chemical products are multiplied by the emission factors to calculate emissions.

- **Emission Factors**

- **Limestone**

See section 4.2.3. b).

- **Dolomite**

See section 4.2.3. b).

- **Activity Data**

Of the limestone and dolomite consumption data in the *Adjusted Price Transaction Table*, all limestone and dolomite consumption categorized under 'emissive use,' that are under the desulfurization of exhaust gas and production of chemical products related sectors will be accounted for under this subcategory. Activity data is in dry weight, converted using the water content from limestone used for cement.

The corresponding sectors in the *Adjusted Price Transaction Table* are as follows:

Table 4-12 Uses and corresponding sectors in the *Adjusted Price Transaction Table*

Uses	Corresponding sectors in the <i>Adjusted Price Transaction Table</i> (Limestone)		Corresponding sectors in the <i>Adjusted Price Transaction Table</i> (Dolomite)	
Desulfurization of exhaust gas	063	Mining industry – non-metallic minerals		
Chemical products	2011-01	Chemical Products - chemical fertilizers	2011-01	Chemical Products - chemical fertilizers
	2029-09	Chemical Products - other inorganic chemical industry products	2029-09	Chemical Products - other inorganic chemical industry products
			2081-011	Chemical Products - processed oil and fat products
	2049-09	Chemical Products - other organic chemical industry products	2049-09	Chemical Products - other organic chemical industry products
			2071-01	Chemical Products - medicaments
		2089-09	Chemical Products - catalytic and other chemical end products	

Note: The numbers before the sector names are categorization numbers in the *Adjusted Price Transaction Table*.

Table 4-13 Amounts of limestone and dolomite consumption

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Limestone consumption																
For Flue Gas Desulfurization (dry)	kt	1,841	2,139	1,813	2,075	1,795	2,008	2,149	2,067	1,741	1,627	1,605	1,501	1,369	1,303	1,263
For Chemical Products (dry)	kt	3,668	1,717	1,772	683	491	507	510	753	910	949	771	705	704	574	297
Dolomite consumption																
For Chemical Products (dry)	kt	147	96	84	54	47	41	44	41	38	32	27	27	23	21	13

### c) Uncertainties and Time-series Consistency

- **Uncertainty**

See section 4.2.3. c).

- **Time-series consistency**

Limestone and dolomite consumption data provided in the *Adjusted Price Transaction Table* is used as limestone and dolomite use activity data for all years from FY1990. The emission factors are constant for all years from FY1990. Therefore, CO<sub>2</sub> emission from limestone and dolomite use has been estimated in a consistent manner throughout the time-series.

**d) Category-specific QA/QC and Verification**

See section 4.2.1. d).

**e) Category-specific Recalculations**

Recalculations occurred due to updates made to limestone (FY2018 and FY2019) and dolomite (FY2019) consumption data in the *Adjusted Price Transaction Table*. See Chapter 10 for impact on trend.

**f) Category-specific Planned Improvements**

No improvements are planned.

**4.3. Chemical Industry (2.B.)**

This category covers CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O, HFCs, PFCs, SF<sub>6</sub>, and NF<sub>3</sub> emissions from the processes of chemical productions.

This section includes GHG emissions from the following sources: Ammonia production (2.B.1.), Nitric acid production (2.B.2.), Adipic acid production (2.B.3.), Caprolactam, glyoxal and glyoxylic acid production (2.B.4), Carbide production (2.B.5.), Titanium dioxide production (2.B.6.), Petrochemical and carbon black production (2.B.8.), and Fluorochemical production (2.B.9.).

In FY2020, emissions from this category were 4,715 kt-CO<sub>2</sub> eq. and represented 0.4% of Japan's total GHG emissions (excluding LULUCF). The total emissions of CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O from this category had decreased by 73.9% compared to FY1990. The total of HFCs, PFCs, SF<sub>6</sub>, and NF<sub>3</sub> had decreased by 98.2% compared to 1990.

Table 4-14 Emissions from 2.B. Chemical Industry

Gas		Units	1990	1995	1999	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020		
CO <sub>2</sub>	2.B.1	Ammonia production	kt-CO <sub>2</sub>	3,418	3,457	3,306	3,184	2,167	2,123	2,008	1,855	1,932	1,890	1,947	1,658	1,726	1,458	1,704	1,410	
	2.B.5	Carbide production	Silicon carbide	kt-CO <sub>2</sub>	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	
			Calcium carbide	kt-CO <sub>2</sub>	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
	2.B.6	Titanium dioxide production	kt-CO <sub>2</sub>	102	39	52	53	59	62	65	51	60	62	53	58	58	59	57	49	
	2.B.8	Petrochemical and carbon black production	Methanol	kt-CO <sub>2</sub>	56	51	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
			Ethylene	kt-CO <sub>2</sub>	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
			Ethylene dichloride and vinyl chloride monomer	kt-CO <sub>2</sub>	150	171	207	193	200	184	146	130	148	150	169	170	175	172	176	174
			Ethylene oxide	kt-CO <sub>2</sub>	171	191	238	231	240	202	202	204	220	214	221	212	227	214	211	190
			Acrylonitrile	kt-CO <sub>2</sub>	440	476	540	536	509	524	486	404	364	342	315	319	323	341	334	306
			Carbon black	kt-CO <sub>2</sub>	1,633	1,563	1,604	1,590	1,659	1,505	1,380	1,261	1,294	1,253	1,161	1,168	1,230	1,259	1,178	980
			Phthalic anhydride	kt-CO <sub>2</sub>	117	124	123	118	81	60	55	60	59	58	60	58	61	58	60	51
			Maleic anhydride	kt-CO <sub>2</sub>	123	138	165	163	114	102	91	78	89	88	90	91	94	92	85	79
	Hydrogen	kt-CO <sub>2</sub>	6	21	31	39	34	34	32	31	28	24	27	29	29	29	21	20		
Total		kt-CO <sub>2</sub>	7,041	7,014	6,938	6,810	5,795	5,427	5,103	4,652	4,787	4,683	4,591	4,300	4,485	4,220	4,348	3,671		
CH <sub>4</sub>	2.B.5	Carbide production	Silicon carbide	kt-CH <sub>4</sub>	C	C	C	C	C	C	C	C	C	C	C	C	C	C		
	2.B.8	Petrochemical and carbon black production	Methanol	kt-CH <sub>4</sub>	0.19	0.17	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	
			Ethylene	kt-CH <sub>4</sub>	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	
			Ethylene dichloride and vinyl chloride monomer	kt-CH <sub>4</sub>	0.01	0.02	0.02	0.02	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
			Ethylene oxide	kt-CH <sub>4</sub>	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
			Carbon black	kt-CH <sub>4</sub>	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
			Styrene	kt-CH <sub>4</sub>	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
Total		kt-CH <sub>4</sub>	1.50	1.48	1.31	1.37	1.35	1.45	1.43	1.13	1.13	1.01	1.27	1.07	1.01	0.91	1.00	0.95		
Total		kt-CO <sub>2</sub> eq.	37	37	33	34	34	36	36	28	28	25	32	27	25	23	25	24		
N <sub>2</sub> O	2.B.2	Nitric acid production	kt-N <sub>2</sub> O	2.47	2.46	2.47	2.57	2.52	1.81	1.49	1.53	1.54	1.55	1.40	1.28	1.16	1.07	1.02	0.68	
	2.B.3	Adipic acid production	kt-N <sub>2</sub> O	24.20	24.03	3.98	12.56	1.68	1.66	1.05	0.51	0.77	0.48	0.38	0.49	0.30	0.20	0.31	1.14	
	2.B.4	Caprolactam, glyoxal and glyoxylic acid production	Caprolactam	kt-N <sub>2</sub> O	4.66	4.93	5.40	5.20	3.36	2.56	2.48	2.30	1.92	1.26	0.90	0.50	0.55	0.43	0.51	0.40
			Glyoxal	kt-N <sub>2</sub> O	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
	Total		kt-N <sub>2</sub> O	32.28	32.43	12.86	21.30	8.58	6.08	5.06	4.34	4.22	3.28	2.68	2.27	2.01	1.70	1.85	2.22	
Total		kt-CO <sub>2</sub> eq.	9,620	9,665	3,833	6,348	2,558	1,813	1,507	1,293	1,259	979	798	676	599	506	551	663		
Total of CO <sub>2</sub> , CH <sub>4</sub> , and N <sub>2</sub> O			kt-CO <sub>2</sub> eq.	16,698	16,716	10,803	13,193	8,387	7,276	6,646	5,973	6,074	5,687	5,420	5,003	5,109	4,749	4,923	4,358	
Gas		Units	1990	1995	1999	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020		
HFCs	2.B.9	Fluorochemical production	By-product emissions: Production of HCFC-22	kt-CO <sub>2</sub> eq.	15,929	21,460	17,834	15,688	586	53	16	18	16	24	30	24	38	12	13	141
			Fugitive emissions	kt-CO <sub>2</sub> eq.	2	559	189	296	449	128	151	120	131	101	83	149	95	88	119	76
Total			kt-CO <sub>2</sub> eq.	15,930	22,019	18,023	15,984	1,035	181	168	138	147	124	113	172	133	100	132	216	
PFCs	2.B.9	Fluorochemical production	Fugitive emissions	kt-CO <sub>2</sub> eq.	331	914	1,570	1,661	1,041	248	206	148	111	107	115	97	81	87	64	74
SF <sub>6</sub>			Fugitive emissions	t	152.23	197.00	64.00	36.00	40.80	8.30	5.80	5.40	4.07	2.70	2.30	2.20	1.78	2.00	1.76	2.28
			Fugitive emissions	kt-CO <sub>2</sub> eq.	3,471	4,492	1,459	821	930	189	132	123	93	62	52	50	41	46	40	52
NF <sub>3</sub>			Fugitive emissions	t	0.16	1.00	3.00	7.00	72.10	76.90	93.10	76.40	86.40	56.09	23.50	25.10	13.61	3.37	1.12	0.88
Total			kt-CO <sub>2</sub> eq.	3	17	52	120	1,240	1,323	1,601	1,314	1,486	965	404	432	234	58	19	15	
Total of F-gases			kt-CO <sub>2</sub> eq.	19,735	27,442	21,103	18,587	4,246	1,942	2,108	1,723	1,837	1,258	684	751	489	291	256	357	

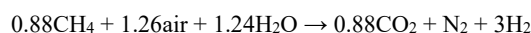
### 4.3.1. Ammonia Production (2.B.1.)

#### a) Category Description

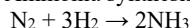
##### 1) CO<sub>2</sub>

In ammonia production, CO<sub>2</sub> is emitted when hydrocarbon feedstock is broken down to make H<sub>2</sub>.

#### CO<sub>2</sub> generating mechanism of ammonia production



Ammonia synthesis



## 2) CH<sub>4</sub>

Emission of CH<sub>4</sub> from the ammonia production has been confirmed by actual measurements. As there are not enough examples to enable the establishment of an emission factor, it is currently not possible to calculate emissions. The *2006 IPCC Guidelines* also do not give a default emission factor. Therefore, CH<sub>4</sub> was reported as “NE”.

## 3) N<sub>2</sub>O

Emission of N<sub>2</sub>O from ammonia production is theoretically impossible, and given that even in actual measurements the emission factor for N<sub>2</sub>O is below the limits of measurement, N<sub>2</sub>O was reported as “NA”.

### b) Methodological Issues

#### ● Estimation Method

CO<sub>2</sub> emissions are calculated by multiplying the amount of fuels consumed as ammonia feedstock by country-specific emission factors. Since carbonated gas, mainly provided from Ammonia production plants, was injected and geologically stored in years 1990 to 1993, 1997 to 1999, 2003, and 2004, this amount is deducted from emissions. (See section 3.4.4 (1.C.) for details)

#### ● Emission Factors

The same emission factors that are used to calculate CO<sub>2</sub> emissions from the Fuel combustion category (Chapter 3, 1.A.) are used for each feedstock listed in Table 4-15. It should be noted that the implied emission factor changes every year, since the composition of the feedstocks consumed for ammonia production varies annually.

Table 4-15 Emission factors and calorific values of feedstocks used when producing ammonia

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Naphtha	GCV	MJ/l	33.63	33.63	33.57	33.55	33.53	33.53	33.31	33.31	33.31	33.31	33.31	33.31	33.31	33.31
	CEF	tC/TJ	18.17	18.17	18.17	18.17	18.17	18.17	18.63	18.63	18.63	18.63	18.63	18.63	18.63	18.63
LPG	GCV	MJ/kg	50.53	50.63	50.70	50.75	50.77	50.76	50.78	50.07	50.09	50.10	50.10	50.11	50.10	50.10
	CEF	tC/TJ	16.54	16.51	16.49	16.48	16.47	16.47	16.38	16.37	16.36	16.36	16.35	16.36	16.36	16.34
Off gas	GCV	MJ/m <sup>3</sup>	39.35	39.35	44.90	44.90	44.90	44.90	46.12	46.12	46.12	46.12	46.12	46.12	46.12	46.12
	CEF	tC/TJ	14.15	14.15	14.15	14.15	14.15	14.15	14.44	14.44	14.44	14.44	14.44	14.44	14.44	14.44
Natural gas	GCV	MJ/m <sup>3</sup>	42.09	42.39	42.55	42.87	44.67	44.74	44.75	39.62	39.62	39.62	39.62	39.62	38.38	38.38
	CEF	tC/TJ	13.90	13.90	13.90	13.90	13.90	13.90	13.97	13.97	13.97	13.97	13.97	13.91	13.91	13.91
Coal	GCV	MJ/kg	25.95	25.95	26.60	25.70	25.70	25.70	25.97	25.97	25.97	25.97	25.97	26.08	26.08	26.08
	CEF	tC/TJ	24.71	24.71	24.71	24.71	24.71	24.71	24.42	24.42	24.42	24.42	24.42	24.29	24.29	24.29
Oil coke	GCV	MJ/kg	35.58	35.58	35.60	29.90	29.90	29.90	29.90	33.29	33.29	33.29	33.29	33.29	33.29	33.29
	CEF	tC/TJ	25.35	25.35	25.35	25.35	25.35	25.35	25.35	24.50	24.50	24.50	24.50	24.50	24.50	24.50
LNG	GCV	MJ/kg	54.54	54.53	54.52	54.51	54.49	54.48	54.47	54.46	54.46	54.46	54.46	54.46	54.70	54.71
	CEF	tC/TJ	13.94	13.95	13.94	13.94	13.95	13.95	13.96	13.96	13.96	13.96	13.96	13.87	13.87	13.86
COG	GCV	MJ/m <sup>3</sup>	21.51	21.57	21.27	21.42	21.32	21.12	20.75	18.87	18.87	18.87	18.87	18.87	18.38	18.38
	CEF	tC/TJ	10.99	10.99	10.99	10.99	10.99	10.99	10.99	10.93	10.93	10.93	10.93	10.88	10.88	10.88

Reference: *General Energy Statistics* (Agency for Natural Resources and Energy, hereafter ANRE)

#### ● Activity Data

The fixed units (including weight and volume) for the fuel types in Table 4-16 below, which are from

the Ministry of Economy, Trade and Industry's *Yearbook of the Current Survey of Energy Consumption*, were converted using the calorific values in the Agency for Natural Resources and Energy's *General Energy Statistics*, and results were used as activity data. Consumption data on some fuel types are confidential.

Table 4-16 Amount of feedstocks used for ammonia production

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Naphtha	kl	189,714	477,539	406,958	92,453	70,067	67,646	67,869	71,494	66,079	73,612	18,421	NO	NO	NO	NO
LPG	t	226,593	45,932	5,991	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Off gas	10 <sup>3</sup> m <sup>3</sup>	C	230,972	240,200	147,502	143,634	126,809	NO	NO	NO	NO	NO	NO	NO	NO	NO
Natural gas	10 <sup>3</sup> m <sup>3</sup>	C	100,468	86,873	77,299	41,640	41,169	45,808	47,956	51,858	17,498	637	979	1,011	906	941
Coal	t	C	209,839	726	1,239	629	879	390	919	787	362	891	483	928	450	845
Oil coke	t	C	273,125	420,862	353,983	394,116	365,340	405,557	401,721	426,743	468,684	416,722	462,107	371,819	454,952	347,107
LNG	t	C	46,501	23,395	165,606	157,918	161,588	169,109	168,155	127,824	122,453	131,446	122,081	122,818	122,555	132,158
COG	10 <sup>3</sup> m <sup>3</sup>	C	35,860	55,333	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

Note: C: Confidential

- **Point to Note**

Fuel consumption in this category has been deducted from energy sector activity data (see Chapter 3).

**c) Uncertainties and Time-series Consistency**

- **Uncertainty**

The uncertainty of each fuel was estimated. For the uncertainty of emission factors, the upper limit and lower limit values of the 95% confidence interval for the carbon emission factors were applied. For the uncertainty of the activity data, the same values were applied as in Fuel combustion category. As a result, the uncertainty of emissions are the following: naphtha -3 to +1%; LPG -3 to +1%; hydrocarbon gas -4 to +3%; natural gas -1 to +1%; coal (steam coal, imported coal) -4 to +3%; oil coke -3 to +1%; LNG -1 to +1%; and COG -4 to +3%.

- **Time-series Consistency**

For activity data, the same sources are used throughout the time series, from the *Current Survey of Energy Consumption*. The emission factor is constantly based on the *General Energy Statistics* (ANRE) throughout the time series. Therefore, CO<sub>2</sub> emission from ammonia production has been estimated in a consistent manner throughout the time-series.

**d) Category-specific QA/QC and Verification**

See section 4.2.1. d).

**e) Category-specific Recalculations**

There have been no source-specific recalculations.

**f) Category-specific Planned Improvements**

No improvements are planned.

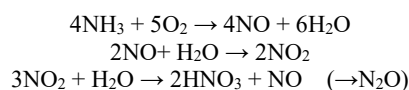


### 4.3.2. Nitric Acid Production (2.B.2.)

#### a) Category Description

N<sub>2</sub>O is emitted when nitric acid (HNO<sub>3</sub>) is produced from ammonia.

N<sub>2</sub>O generating mechanism in nitric acid production



In Japan, the main processes used in nitric acid production are the New Fauser Process (medium pressure) and Chemico Process (high pressure), both based on the Ostwald chemical process. With regard to N<sub>2</sub>O decomposition, there are catalytic decomposition units in operation.

#### b) Methodological Issues

##### ● Estimation Method

N<sub>2</sub>O emissions were estimated by multiplying the nitric acid production amount by an emission factor, based on the Tier 2 method given in the *2006 IPCC Guidelines*. Emission data for individual factories are confidential, and therefore the nitric acid production amount and the emission factor were set for all of Japan. The amount of N<sub>2</sub>O destroyed is currently unavailable but is reflected in the emission factor.

$$E = EF \times NAP$$

*E* : N<sub>2</sub>O emissions from nitric acid production [kg-N<sub>2</sub>O]

*EF* : Emission factor [kg-N<sub>2</sub>O/t]

*NAP* : Nitric acid production amount [t]

##### ● Emission Factors

Data for individual factories are confidential, and therefore the emission factor was set by using each factory's nitric acid production amount to find the weighted average of Japan's 10 nitric acid producing factories' emission factors (measurement data). These emission factors take N<sub>2</sub>O recovery and destruction into account.

Table 4-17 N<sub>2</sub>O emission factors for nitric acid production

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
EFs for nitric acid production	kg-N <sub>2</sub> O/t	3.50	3.51	3.92	4.18	3.58	3.49	3.38	3.55	3.54	3.60	3.59	3.27	3.26	3.28	3.00

##### ● Activity Data

Production amounts of nitric acid are directly provided by the Ministry of Economy, Trade and Industry.

Table 4-18 Amount of nitric acid production

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Nitric acid production	kt	706	701	656	602	506	426	453	434	437	388	356	355	328	311	227

#### c) Uncertainties and Time-series Consistency

##### ● Uncertainty

The standard deviation was calculated for the emission factors and production amounts of each plant, and the uncertainty of the emission factor was assessed to be 73%. For the uncertainty of activity data, the default value of 2% given by the *2006 IPCC Guidelines* was used. As a result, the uncertainty of emissions was estimated as 73%.

- **Time-series Consistency**

Emissions throughout the time series are consistently estimated using the activity data and emission factors provided by the Ministry of Economy, Trade and Industry.

- d) **Category-specific QA/QC and Verification**

See section 4.2.1. d).

- e) **Category-specific Recalculations**

There have been no source-specific recalculations.

- f) **Category-specific Planned Improvements**

No improvements are planned.

### 4.3.3. Adipic Acid Production (2.B.3.)

- a) **Category Description**

N<sub>2</sub>O is emitted in the adipic acid (C<sub>6</sub>H<sub>10</sub>O<sub>4</sub>) production process through the reaction of cyclohexanone, cyclohexanol, and nitric acid.

- b) **Methodological Issues**

- **Estimation Method**

Emissions were estimated using the N<sub>2</sub>O generation rates, N<sub>2</sub>O decomposition amount, and adipic acid production amount of the relevant operating sites.

- **Emission Factors**

Country-specific emission factors were established using the following parameters. Relevant emission factor/parameter data are confidential.

- **Nitrous oxide generation rate**

Actual measurement data provided from the sole producer of adipic acid as an end product in Japan.

- **Nitrous oxide decomposition rate**

The figure used is the result of measurement of the rate of decomposition of nitrous oxide in the operating site.

- **Decomposition unit operation rate**

A full-scale survey on the number of operation hours is conducted annually for N<sub>2</sub>O decomposition units and adipic acid production plants. The operating rate is based on this survey.

- **Activity Data**

The activity data for nitrous oxide emissions associated with the manufacturing of adipic acid is the amount of adipic acid produced provided to the Ministry of Economy, Trade and Industry by the manufacturer. Relevant data used in estimation is confidential.

- **Point to Note**

From 1990 to 1997, N<sub>2</sub>O emissions from adipic acid production increased gradually. However, N<sub>2</sub>O decomposition units were installed in adipic acid production plants in March 1999, and emissions since then have decreased dramatically. There was a temporary growth in the emissions in 2000 due to the

low operating rate of N<sub>2</sub>O decomposition units caused by mechanical failure of the decomposition units.

**c) Uncertainties and Time-series Consistency**

● **Uncertainty**

The uncertainty of the emission factor for adipic acid was estimated by combining the uncertainty of the N<sub>2</sub>O generation rate, N<sub>2</sub>O decomposition rate, and the operating rate of the decomposition unit. As a result, the uncertainty of the emission factor was estimated as 9%. A 2% uncertainty given by the 2006 IPCC Guidelines was applied for activity data. As a result, the uncertainty for adipic acid was estimated as 9%.

● **Time-series Consistency**

Activity data and emission factors consistently provided by the producer of adipic acid are used to estimate emissions throughout the time series.

**d) Category-specific QA/QC and Verification**

See section 4.2.1. d).

**e) Category-specific Recalculations**

There have been no source-specific recalculations.

**f) Category-specific Planned Improvements**

No improvements are planned.

#### 4.3.4. Caprolactam, Glyoxal and Glyoxylic Acid Production (2.B.4.)

##### 4.3.4.1. Caprolactam Production (2.B.4.a)

**a) Category Description**

Caprolactam is a monomer for nylon-6 which transforms into Nylon 6 by ring-opening polymerization. Nylon 6 is used as fibers for carpets, etc, or resin material. N<sub>2</sub>O is emitted from ammonia oxidation during the manufacturing process.

**b) Methodological Issues**

● **Estimation Method**

Emissions are calculated by multiplying the amount of caprolactam produced by a weighted average emission factor, based on plant-specific emission factors established in accordance with Tier 1 - 3 methods in the 2006 IPCC Guidelines.

● **Emission Factors**

A country-specific emission factor per production amount was established by dividing total emissions by total production amounts. This was based on data provided from Japan Chemical Industry Association, including production amounts, emission factors, and emissions for all three plants producing caprolactam in Japan. Each plant's emission factor fluctuates by year.

● **Activity Data**

Caprolactam production amounts from the *Yearbook of Current Production Statistics - Chemical*

Industry compiled by the Ministry of Economy were used as activity data.

Table 4-19 Caprolactam production amount

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Caprolactam production	kt	516	546	575	455	411	392	366	342	266	241	220	223	210	190	196

### c) *Uncertainties and Time-series Consistency*

#### ● *Uncertainty*

As for the uncertainty of the emission factor, the standard deviation was calculated from the emission factors and production amounts of each plant and was assessed to be 99%. For the uncertainty of activity data, the default value of 2% in the 2006 IPCC Guidelines was used. As a result, the uncertainty for emissions was estimated as 99%.

#### ● *Time-series Consistency*

For the activity data, data from the *Yearbook of Current Production Statistics – Chemical Industry* are consistently used throughout the time series. The emission factors are constant throughout the time series. Therefore, emissions have been estimated in a consistent manner throughout the time-series.

### d) *Category-specific QA/QC and Verification*

See section 4.2.1. d).

### e) *Category-specific Recalculations*

There have been no source-specific recalculations.

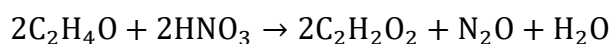
### f) *Category-specific Planned Improvements*

No improvements are planned.

## 4.3.4.2. Glyoxal Production (2.B.4.b)

### a) *Category Description*

Glyoxal is mainly used as a crosslinking agent for acrylic resins, disinfectant, gelatin hardening agent, and textile finishing agent etc. It's produced from oxidation of acetaldehyde with concentrated nitric acid, or from the catalytic oxidation of ethylene glycol, and N<sub>2</sub>O is emitted in the process of oxidation of acetaldehyde. (See below)



### b) *Methodological Issues*

#### ● *Estimation Method*

Emissions are calculated in accordance with the Tier 3 method in the 2006 IPCC Guidelines, by multiplying the amount of glyoxal produced by an emission factor. There is no production from FY2010 onward, but emissions for FY1990 to FY2011 are reported as “C” due to confidentiality reasons of Glyoxylic acid for FY2010 and FY2011.

#### ● *Emission Factors*

A country-specific emission factor per production amount based on information provided by the

manufacturer was used. This was established based on the amounts of gas emitted in the manufacturing process of each product, and measurements of N<sub>2</sub>O concentrations, and will be applied to all years.

- **Activity Data**

No statistics are available on glyoxal production amounts, and therefore the production amounts at one manufacturer that had been producing until recent were used as activity data. There is no production from FY2010 onward.

**c) Uncertainties and Time-series Consistency**

- **Uncertainty**

For the uncertainty of the emission factor, the default value of 10% in the *2006 IPCC Guidelines* was used. For the uncertainty of activity data, the default value of 2% in the *2006 IPCC Guidelines* was used. As a result, the uncertainty for emissions was estimated as 10%.

- **Time-series Consistency**

For the activity data, data from the one manufacturer that had been producing until recent are consistently used throughout the time series. The emission factors are constant throughout the time series. Therefore, emissions have been estimated in a consistent manner throughout the time-series.

**d) Category-specific QA/QC and Verification**

See section 4.2.1. d).

**e) Category-specific Recalculations**

There have been no source-specific recalculations.

**f) Category-specific Planned Improvements**

No improvements are planned.

#### 4.3.4.3. Glyoxylic acid Production (2.B.4.c)

**a) Category Description**

Glyoxylic acid is used for the production of synthetic aromas, agrochemicals, and pharmaceutical intermediates. It is produced by nitric acid oxidation of glyoxal, and N<sub>2</sub>O is emitted in the process of reduction of nitric acid.

**b) Methodological Issues**

- **Estimation Method**

Emissions are calculated in accordance with the Tier 3 method in the *2006 IPCC Guidelines*, by multiplying the amount of glyoxylic acid produced by an emission factor. There is no production from FY2012 onward.

- **Emission Factors**

A country-specific emission factor per production amount based on information provided by the manufacturer was used. This was established based on the amounts of gas emitted in the manufacturing process of each product, and measurements of N<sub>2</sub>O concentrations, and will be applied to all years.

- **Activity Data**

No statistics are available on glyoxylic acid production amounts, and therefore the production amounts at one manufacturer that had been producing until recent were used as activity data. There is no production from FY2012 onward.

**c) Uncertainties and Time-series Consistency**

- **Uncertainty**

For the uncertainty of the emission factor, the default value of 10% in the *2006 IPCC Guidelines* was used. For the uncertainty of activity data, the default value of 2% in the *2006 IPCC Guidelines* was used. As a result, the uncertainty for emissions was estimated as 10%.

- **Time-series Consistency**

For the activity data, data from the one manufacturer that had been producing until recent are consistently used throughout the time series. The emission factors are constant throughout the time series. Therefore, emissions have been estimated in a consistent manner throughout the time-series.

**d) Category-specific QA/QC and Verification**

See section 4.2.1. d).

**e) Category-specific Recalculations**

There have been no source-specific recalculations.

**f) Category-specific Planned Improvements**

No improvements are planned.

### 4.3.5. Carbide Production (2.B.5.)

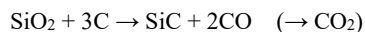
#### 4.3.5.1. Silicon Carbide Production (2.B.5.a)

**a) Category Description**

**1) CO<sub>2</sub>**

CO<sub>2</sub> is emitted by the reaction of petroleum coke with silica as raw materials in the production of silicon carbide.

CO<sub>2</sub> generating mechanism in the silicon carbide production process



**2) CH<sub>4</sub>**

In Japan, silicon carbide is produced in electric arc furnaces, and it is believed that CH<sub>4</sub> is generated from the oxidation of coke, which is used as a reducing agent in silicon carbide production.

**b) Methodological Issues****1) CO<sub>2</sub>**● **Estimation Method**

Emissions are calculated by multiplying the amount of petroleum coke used as silicon carbide feedstock by an emission factor.

● **Emission Factors**

Because Japan does not have measurement data or emission factor data, the default value 2.3 [t-CO<sub>2</sub>/t] for silicon carbide production in the *2006 IPCC Guidelines* is used.

● **Activity Data**

The activity data for CO<sub>2</sub> emissions from silicon carbide production is the amount of petroleum coke consumed, provided by Japan's only silicon carbide production facility. The data is confidential.

**2) CH<sub>4</sub>**● **Estimation Method**

Emissions were calculated by multiplying an emission factor based on actual measurements obtained from electric arc furnace facilities in Japan by the energy consumption of electric arc furnaces.

● **Emission Factors**

The emission factor of energy consumption in electric arc furnaces (12.8 kg-CH<sub>4</sub>/TJ) was determined from CH<sub>4</sub> concentrations in the flue gas, measured dry flue gas amounts per hour, and measured quantity of heat generated per hour. See section 4.4.2.b) for the process of deriving the emission factor.

● **Activity Data**

The activity data for CH<sub>4</sub> emissions from silicon carbide production is the amount of energy consumed, provided by Japan's only silicon carbide production facility. The data is confidential.

**c) Uncertainties and Time-series Consistency**● **Uncertainty****1) CO<sub>2</sub>**

For the uncertainty of the emission factor, the default value of 10% was applied as provided by the *2006 IPCC Guidelines*. For the uncertainty of activity data, the default value of 5% given by *2006 IPCC Guidelines* was used. As a result, the uncertainty for emissions was estimated as 11%.

**2) CH<sub>4</sub>**

The uncertainty of the emission factor, the default value of 10% was applied as provided by the *IPCC 2006 Guidelines*. For the uncertainty of activity data, the default value of 5% given by the *2006 IPCC Guidelines* was used. As a result, the uncertainty for emissions was estimated as 11%.

● **Time-series Consistency**

For both CO<sub>2</sub> and CH<sub>4</sub> activity data, the same sources are consistently used throughout the time series from the manufacturing facility. The emission factors for both gases are constant throughout the time series. Therefore, CO<sub>2</sub> and CH<sub>4</sub> emissions from silicon carbide have been estimated in a consistent manner throughout the time-series.

**d) Category-specific QA/QC and Verification**

See section 4.2.1. d).

**e) Category-specific Recalculations**

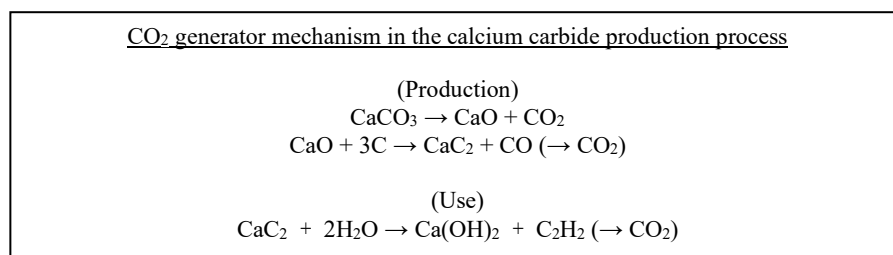
There have been no source-specific recalculations.

**f) Category-specific Planned Improvements**

No improvements are planned.

**4.3.5.2. Calcium Carbide Production and Use (2.B.5.b)****a) Category Description****1) CO<sub>2</sub>**

CO<sub>2</sub> is generated in the process of making the quicklime and is also emitted by the combustion of CO occurring from calcium carbide production. However, the former is included in emissions from Other process uses of carbonates (2.A.4.), and therefore only reducing agent-origin emissions are accounted for here. Further, CO<sub>2</sub> is generated by the combustion of acetylene, which is generated by reacting calcium carbide with water, and these emissions are reported here.

**2) CH<sub>4</sub>**

Byproduct gases (mainly CO) generated in carbide production include a small amount of CH<sub>4</sub>, all of which is recovered and burned as fuel, with none being emitted outside the system. Therefore, emissions from this source are reported as “NA”.

**b) Methodological Issues**● **Estimation Method**

CO<sub>2</sub> emissions are calculated by multiplying calcium carbide production by the following emission factor, based on the Tier 2 method in the *2006 IPCC Guidelines*.

● **Emission Factors**

For years FY1990 to FY2007, because Japan does not have measurement data or emission factor data, the below default values in the *2006 IPCC Guidelines* is used.

Table 4-20 CO<sub>2</sub> Emission factors for calcium carbide production and consumption (FY1990- FY2007)

Unit	From reducing agent in production	From use
t-CO <sub>2</sub> /t	1.09	1.10

For years after FY2008, country-specific emission factors from reducing agents during production



(changes annually) are used, which are based on measurement data from the two calcium carbide producing companies in Japan. These emission factors are confidential.

The default emission factor (1.10 t-CO<sub>2</sub>/t) for calcium carbide use is also used for FY2008 and onwards.

The calcium carbide production amount used for calculating the CO<sub>2</sub> EF includes not only CaC<sub>2</sub> but also unreactive CaO used as raw material. This is the reason for the EF being lower than the stoichiometric value derived from a reaction only involving CaC<sub>2</sub>. In Japan, CaC<sub>2</sub> is produced under conditions with excessive CaO. With CaC<sub>2</sub>, the higher the purity, the higher is the melting point. Therefore, to avoid the rise in viscosity and hardening in the cooler parts of the plant which impairs production, the melting point is suppressed through intentionally maintaining a lower purity. Purity is also kept low to reduce reactivity from the viewpoint of safety.

- **Activity Data**

Calcium carbide production data provided by the Carbide Industry Association are used as the calcium carbide production amount. It includes not only CaC<sub>2</sub> but also unreactive CaO used as raw material. The data are confidential.

**c) Uncertainties and Time-series Consistency**

- **Uncertainty**

For the uncertainty of the CO<sub>2</sub> emission factor, the 10% default value was applied as provided by the 2006 IPCC Guidelines for both reducing agent origin and from use. For the uncertainty of activity data, the default value of 5% given by the 2006 IPCC Guidelines for both reducing agent origin and from use. As a result, the uncertainty for emissions for both reducing agent origin and from use was estimated as 11%.

- **Time-series Consistency**

For activity data, the same sources are used throughout the time series. The emission factor is constant from FY1990 to FY2007, and for years from FY2008 and onward, country-specific emission factors are used. This is because there is no data available on the scale of production or improvements in manufacturing technology to establish country-specific emission factors for earlier years, and therefore default emission factors are used for FY1990 to FY2007.

**d) Category-specific QA/QC and Verification**

See section 4.2.1. d).

**e) Category-specific Recalculations**

There have been no source-specific recalculations.

**f) Category-specific Planned Improvements**

No improvements are planned.

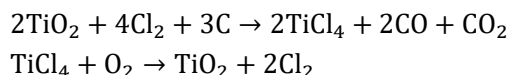
### 4.3.6. Titanium Dioxide Production (2.B.6)

**a) Category Description**

Titanium dioxide (TiO<sub>2</sub>) is a kind of white pigment, generally used in paper, plastics, rubber, ceramics,

fabrics, floor covering, printing ink, and paint etc. The two forms of TiO<sub>2</sub>, anatase TiO<sub>2</sub> and rutile TiO<sub>2</sub> (both tetragonal), differ in terms of the crystalline structure, and the anatase TiO<sub>2</sub> is produced by hydrolyzing titanium sulfate and calcination (the sulfate process), or from titanium slag. Rutile TiO<sub>2</sub> is produced through the carbothermal chlorination of synthetic rutile to produce titanium tetrachloride (TiCl<sub>4</sub>) and oxidation of the TiCl<sub>4</sub> vapors to TiO<sub>2</sub>. (the chloride route)

CO<sub>2</sub> is emitted from the oxidization of carbon electrodes in the production of titanium slag in electric furnaces, from the oxidization of black coal during the production of synthetic rutile, and from the oxidization of oil coke in the chloride route. The following reactions occur to in the chloride route.



## b) Methodological Issues

### ● Estimation Method

For rutile titanium dioxide (the chloride route), emissions are calculated by multiplying titanium dioxide production amounts (rutile TiO<sub>2</sub>) produced through the chloride route which entails CO<sub>2</sub> emissions, by an emission factor provided by the manufacturer, based on the Tier 1 method in the *2006 IPCC Guidelines*.

For rutile titanium dioxide (from synthetic rutile), emissions are calculated by multiplying synthetic rutile production amounts by the default emission factor, based on the Tier 1 method in the *2006 IPCC Guidelines*.

### ● Emission Factors

For rutile TiO<sub>2</sub> (the chloride route), an emission factor calculated as follows, based on coke input, etc into the process at the manufacturer, is used.

$$E = (CI - CO) \times CC \times 44/12$$

$$EF = E / AD$$

<i>E</i>	: CO <sub>2</sub> emissions
<i>CI</i>	: Coke input amount
<i>CO</i>	: Carry-over amount (Raw material left over without reacting)
<i>CC</i>	: Carbon content of coke
<i>EF</i>	: CO <sub>2</sub> emission factor
<i>AD</i>	: Titanium dioxide production amounts

Emission factors that can be drawn from the above equation, are only for FY2011 to FY2013, and therefore for years FY1990 – FY2010, the average for FY2011- FY2013 are used. (For years from FY2011 and onward, country-specific emission factors provided by the Japan Titanium Dioxide Industry Association are used)

CO<sub>2</sub> EF for rutile TiO<sub>2</sub> is lower than the IPCC default because in the case of Japanese manufacturers, reactions take place under high temperatures such as 1,000 degrees Celsius, and therefore a second reaction (TiO<sub>2</sub> + 2Cl<sub>2</sub> + 2CO → TiCl<sub>4</sub> + 2CO<sub>2</sub>) is simultaneously taking place, in addition to the above-mentioned reactions described in the *2006 IPCC Guidelines* (yielding 3 mol of CO<sub>2</sub> from 2 mol of TiO<sub>2</sub>), and uses CO. Because of this, and assuming that this CO is used completely in the first-mentioned reaction, 1 mol of TiO<sub>2</sub> only yields 1 mol of CO<sub>2</sub>. (There does not exist any excess carbon. CO<sub>2</sub> occurs only from input coke.)

For rutile titanium dioxide (from synthetic rutile), the default value of 1.43 t-CO<sub>2</sub>/t from the *2006 IPCC Guidelines* is used.

- **Activity Data**

For rutile titanium dioxide production amounts (the chloride route), the titanium dioxide amounts produced in the chloride route process (provided by the Japan Titanium Dioxide Industry Association) which entails CO<sub>2</sub> emissions is used.

For rutile titanium dioxide production amounts (from synthetic rutile), synthetic rutile production amounts (provided by METI) is used.

- c) **Uncertainties and Time-series Consistency**

- **Uncertainty**

For the uncertainty of emission factors for rutile titanium dioxide and synthetic rutile, the default values from the *IPCC 2006 Guidelines* of 15% and 10%, were respectively used. For the uncertainty of activity data, the default value of 5% from the *2006 IPCC Guidelines* was used for both rutile titanium dioxide and synthetic rutile. As a result, the uncertainty of emissions was estimated as 16% and 11%, respectively.

- **Time-series Consistency**

For the activity data, data from the Japan Titanium Dioxide Industry Association and METI are consistently used throughout the time series. The emission factors are constant throughout the time series. Therefore, emissions have been estimated in a consistent manner throughout the time-series.

- d) **Category-specific QA/QC and Verification**

See section 4.2.1. d).

- e) **Category-specific Recalculations**

There have been no source-specific recalculations.

- f) **Category-specific Planned Improvements**

No improvements are planned.

#### 4.3.7. Soda Ash Production (2.B.7.)

In Japan, the ammonium chloride soda process is used to produce soda ash (Na<sub>2</sub>CO<sub>3</sub>). The soda ash production process involves calcinating limestone and coke in a lime kiln, which emits CO<sub>2</sub>. Almost all lime-derived CO<sub>2</sub> is stored in the product.

In the soda ash production process, purchased CO<sub>2</sub> is sometimes input through a pipeline, but because these CO<sub>2</sub> emissions are from the ammonia industry, they are already included in Ammonia production (2.B.1.). Also, the coke consumed is listed as that for heating in the *Yearbook of the Current Survey of Energy Consumption*, and thus CO<sub>2</sub> emissions from coke are already counted under Fuel combustion (1.A.). Therefore, all emissions from this source are already included in other categories and are reported as “IE”. Coke is input as a heat-source and CO<sub>2</sub> source. The thinking on where to account for CO<sub>2</sub> emissions from coke is the same as that for Iron and steel production.

The 2006 IPCC Guidelines offer a method to calculate CO<sub>2</sub> emissions from calcinating trona (Na<sub>2</sub>CO<sub>3</sub>-NaHCO<sub>3</sub>-2H<sub>2</sub>O), but these emissions are not estimated because in Japan soda ash has never been manufactured by trona calcination.

### 4.3.8. Petrochemical and Carbon Black Production (2.B.8.)

#### 4.3.8.1. Methanol Production (2.B.8.a)

##### a) Category Description

CO<sub>2</sub> and CH<sub>4</sub> are emitted during the production of methanol.

##### b) Methodological Issues

###### ● Estimation Method

CO<sub>2</sub> and CH<sub>4</sub> emissions from methanol production are calculated using the Tier 1 method given in the 2006 IPCC Guidelines.

According to industry organizations, the production (synthesis) of methanol stopped in Japan in 1995 due to the price difference with overseas methanol. Since then all methanol has been imported, and methanol production plants disappeared from Japan in about 1995.

Accordingly, from FY1990 to FY1995, emissions are reported using the production amounts from industry organization statistics. For FY1996 and thereafter, emissions are reported as “NO” because it is assumed that methanol has not been produced (synthesized) since 1995.

###### ● Emission Factors

The default value for CO<sub>2</sub> from methanol given in the 2006 IPCC Guidelines which corresponds to Japan's country-specific production method was used. The emission factor is 0.67 [t-CO<sub>2</sub>/t] (Refer to the 2006 IPCC Guidelines vol. 3 p 3.73, Table 3.12).

The default value for CH<sub>4</sub> from methanol given in the 2006 IPCC Guidelines was used. The emission factor is 2.3 [kg-CH<sub>4</sub>/t] (Refer to the 2006 IPCC Guidelines vol. 3 p 3.74).

###### ● Activity Data

Production amounts of methanol (on calendar year basis) given by the Methanol and Formalin Association were used as activity data for CO<sub>2</sub> and CH<sub>4</sub> emissions from methanol production.

Table 4-21 Methanol production amount

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Methanol production	kt	84	75	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

##### c) Uncertainties and Time-series Consistency

###### ● Uncertainty

For the uncertainty of the emission factor, the default values from the IPCC 2006 Guidelines of -30 to +30% (CO<sub>2</sub>) and -80 to +30% (CH<sub>4</sub>) were used. For the uncertainty of activity data, the default values of similar chemical products from the IPCC 2006 Guidelines of -5 to +5% were used. As a result, the uncertainty of CO<sub>2</sub> and CH<sub>4</sub> emissions were estimated as -30 to +30% and -80 to +30%, respectively.

- **Time-series Consistency**

For activity data, the same sources are used throughout the time series. The emission factor is constant throughout the time series. Therefore, CO<sub>2</sub> and CH<sub>4</sub> emissions from methanol production have been estimated in a consistent manner throughout the time-series.

- d) **Category-specific QA/QC and Verification**

See section 4.2.1. d).

- e) **Category-specific Recalculations**

There have been no source-specific recalculations.

- f) **Category-specific Planned Improvements**

No improvements are planned.

#### 4.3.8.2. Ethylene Production (2.B.8.b)

- a) **Category Description**

- 1) **CO<sub>2</sub>, CH<sub>4</sub>**

CO<sub>2</sub> is emitted in the ethylene production process. CH<sub>4</sub> is emitted by naphtha cracking through steam cracking in the ethylene production process.

Carbon losses in the ethylene production process are accounted for under petrochemicals in the energy conversion sector of the *General Energy Statistics* (Energy Balance Table). The petrochemicals sector represents the process of production of by-products such as refinery gas, fuels, and other oil products, from the factories that produce basic chemical feedstock from naphtha and reformed material oil, by regarding it as energy conversion.

- 2) **N<sub>2</sub>O**

There is almost no nitrogen contained in naphtha, the raw material of ethylene, and the ethylene production process takes place under conditions that are almost completely devoid of oxygen. In accordance with expert judgment, there is theoretically no N<sub>2</sub>O emissions.

- b) **Methodological Issues**

- **Estimation Method**

CH<sub>4</sub> and CO<sub>2</sub> emissions from ethylene production were calculated by multiplying ethylene production by Japan's country-specific emission factor, in accordance with the Tier 1 method in the *2006 IPCC Guidelines*. CO<sub>2</sub> emissions from the energy use of industrial process off gases obtained from the feedstocks in Japan's ethylene production (steam cracking process) are considered to be included in emissions from Refinery Gas under Petrochemical - Energy Use in the *General Energy Statistics*. These emissions are already accounted for in '1.A.2.c. Manufacturing industries and construction - Chemicals'.

- **Emission Factors**

- **CO<sub>2</sub>**

The emission factor was set, based on a survey conducted by the Japan Petrochemical Industry Association in 2009 on the CO<sub>2</sub> emission factor from ethylene production.

This country-specific CO<sub>2</sub> EF was established based on CO<sub>2</sub> emissions from decoking, etc and ethylene production data. CO<sub>2</sub> emissions from the energy use of industrial process off gases obtained from the feedstocks are accounted for under '1.A. Fuel combustion,' and therefore there is a difference between the CSEF and the IPCC default value.

This emission factor is confidential.

#### ➤ CH<sub>4</sub>

Estimates of amount of exhaust gas from flare stacks at a normal operation and an unsteady operation at operating sites in Japan (assuming that 98% of the amount that enters is combusted<sup>2</sup>), and measured amount of exhaust gas from naphtha cracking furnaces and furnaces heated by re-cycled gas, were divided by the production amount to calculate emission factors for each company. The weighted average based on production from each company was then applied to establish the emission factor. (Surveyed by the Japan Petrochemical Industry Association) This emission factor is confidential.

According to the Japan Petrochemical Industry Association, fugitive emissions in plants are controlled to be below detectable levels (nearly zero) under the High Pressure Gas Safety Act. Therefore, it is considered that there are nearly no fugitive emissions from flanges, valves, and other process equipment during the steam cracking of naphtha.

#### ● Activity Data

Ethylene production amounts from the *Yearbook of Current Production Statistics – Chemical Industry* (METI) were used as activity data for emissions of CH<sub>4</sub> and CO<sub>2</sub> from ethylene production.

Table 4-22 Ethylene production amount

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Ethylene production	kt	5,966	6,951	7,566	7,549	6,999	6,474	6,261	6,764	6,687	6,780	6,286	6,459	6,186	6,282	6,043

#### c) Uncertainties and Time-series Consistency

##### ● Uncertainty

The uncertainty for both CO<sub>2</sub> and CH<sub>4</sub> emission factors for ethylene were calculated by finding the 95% confidence interval of emission factors. The estimated uncertainty for both CO<sub>2</sub> and CH<sub>4</sub> was 77%. For the uncertainty of activity data, the default value of 5% given by the *2006 IPCC Guidelines* was used. As a result, the uncertainty for both CO<sub>2</sub> and CH<sub>4</sub> was estimated as 77%.

##### ● Time-series Consistency

For activity data, the same sources are used throughout the time series. The emission factor is constant throughout the time series. Therefore, CO<sub>2</sub> and CH<sub>4</sub> emissions from ethylene production have been estimated in a consistent manner throughout the time-series.

#### d) Category-specific QA/QC and Verification

See section 4.2.1. d).

#### e) Category-specific Recalculations

There have been no source-specific recalculations.

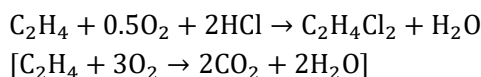
<sup>2</sup> The assumption was set based on a flaring efficiency of 98% shown in the IPCC GPG (Table 2.16 note e).

**f) Category-specific Planned Improvements**

No improvements are planned.

**4.3.8.3. 1,2-Dichloroethane and Chloroethylene (2.B.8.c)****a) Category Description****1) CO<sub>2</sub>**

1,2-dichloroethane (Ethylene Dichloride) is a precursor of polyvinyl chloride and is mainly used for chloroethylene (VCM) production. It is also used for cleaning agents, solvents, pesticides, and fumigants etc. It is manufactured by the direct chlorination process or the oxychlorination process, or by a process combining the two. The direct chlorination process involves gas-phase reaction of ethylene with chlorine to produce ethylene dichloride, and the oxychlorination process involves gas-phase reaction of ethylene with hydrochloric acid and oxygen to produce ethylene dichloride. The oxychlorination process produces CO<sub>2</sub> from the oxidation of the ethylene. (See the below)



The ethylene dichloride is cracked to produce chloroethylene monomer, a precursor of polyvinyl chloride, and hydrochloric acid. The ethylene dichloride is cracked to produce chloroethylene monomer, a precursor of polyvinyl chloride, and hydrochloric acid. Since the hydrochloric acid can be utilized in the oxychlorination process, the combined process of the two spread widely. CO<sub>2</sub> is emitted through the same chemical reactions as the above in the combined process.

**2) CH<sub>4</sub>**

1,2-dichloroethane passes through washing, refining, and thermolysis processes to become chloroethylene (C<sub>2</sub>H<sub>3</sub>Cl). A very small amount of CH<sub>4</sub> is contained in the exhaust gases of the reaction, and of the washing and refining processes.

**b) Methodological Issues**● **Estimation Method**

CO<sub>2</sub> emissions are calculated by multiplying the production amount by Japan's country-specific emission factor, based on plant-specific data, in accordance with the Tier 1 method in the *2006 IPCC Guidelines*.

For years FY1990 to FY2000, CH<sub>4</sub> emissions are calculated by multiplying the production amount by Japan's country-specific emission factor, based on plant-specific data, in accordance with the Tier 1 method in the *2006 IPCC Guidelines*. According to Vinyl Environmental Council, equipment installation for exhaust gas combustion was completed for all plants, and the CH<sub>4</sub> contained in the tail gas is below detectable levels. Therefore, emissions are reported as NO for years FY2001 and onward. (The amount combusted is reported as recovered)

● **Emission Factors**➤ **CO<sub>2</sub>**

A CO<sub>2</sub> emission factor (0.0647 t-CO<sub>2</sub>/tVCM) per chloroethylene production provided by the Vinyl Environmental Council was applied for all years.

This emission factor was established by dividing the total measured CO<sub>2</sub> emissions across all five plants producing 1,2-dichloroethane and chloroethylene in 2012, by the total chloroethylene production amounts in 2012.

The default value 0.294tCO<sub>2</sub>/tVCM also accounts for CO<sub>2</sub> emitted from combustion of auxiliary fuel, but for the above country-specific emission factor, this is removed in order to avoid double-counting with the energy sector, resulting in a lower value than the default.

#### ➤ CH<sub>4</sub>

The concentration of CH<sub>4</sub> in waste gas from three member companies of the Vinyl Environmental Council (representing approximately 70% of total 1,2-dichloroethane production in Japan) was measured, and a weighted average was calculated to establish the emission factor. (Years FY1990 to FY2000) The emission factor is 0.0050 [kg-CH<sub>4</sub>/t]. Based on the information on the production processes in each Dichloroethane producing company, the representativeness of the EF has been confirmed. (Surveyed by the Vinyl Environmental Council) The installation of equipment for exhaust gas combustion has progressed, and due to this, the fraction of CH<sub>4</sub> in the tail gas is lower than the default value and is now below detectable levels. No emission factors are set for years FY2001 and onward.

#### ● Activity Data

VCM (Chloroethylene) production amounts from the *Yearbook of Current Production Statistics - Chemical Industry* (METI) were used as activity data for CO<sub>2</sub> emissions

1,2-Dichloroethane production amounts from the *Yearbook of Current Production Statistics - Chemical Industry* were used as activity data for CH<sub>4</sub> emissions.

Table 4-23 VCM (Chloroethylene) production amount

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
VCM production amount	kt	2,316	2,648	2,976	3,098	2,850	2,253	2,009	2,286	2,315	2,616	2,621	2,706	2,664	2,713	2,690

Table 4-24 1,2-Dichloroethane production amount

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
1,2-Dichloroethane production	kt	2,683	3,014	3,346	3,639	3,155	2,841	2,558	2,733	2,730	3,003	3,012	3,158	3,113	3,297	3,263

#### c) Uncertainties and Time-series Consistency

##### ● Uncertainty

For the uncertainty of the CO<sub>2</sub> and CH<sub>4</sub> emission factors for 1,2-dichloroethane production, the default values of -50 to +20% and -10 to +10% in the *2006 IPCC Guidelines* were respectively applied. For the uncertainty of activity data, the default value of 5% given by the *2006 IPCC Guidelines* was used. As a result, the uncertainty of 1,2-dichloroethane production was estimated as -50 to +21% and -11 to +11%, respectively.

##### ● Time-series Consistency

For activity data, the same sources are used throughout the time series. The emission factor is constant throughout the time series. Therefore, CH<sub>4</sub> emissions from 1,2-Dichloroethane production have been estimated in a consistent manner throughout the time-series.



**d) Category-specific QA/QC and Verification**

See section 4.2.1. d).

**e) Category-specific Recalculations**

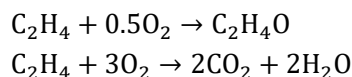
There have been no source-specific recalculations.

**f) Category-specific Planned Improvements**

No improvements are planned.

**4.3.8.4. Ethylene Oxide Production (2.B.8.d)****a) Category Description**

Ethylene oxide is produced by reacting ethylene with oxygen over a catalyst, with CO<sub>2</sub> released as a by-product. (See below) There are two methods in providing oxygen; one through providing air, and the other through providing pure oxygen separated from air.



The CO<sub>2</sub> emitted is partially vented into the atmosphere, and is partially recovered by a carbonate solution to be used in food and beverage production etc.

Generally, ethylene oxide production is a process where gases are recycled, and therefore it is necessary to partially purge the gases out of the system so to suppress the rise in pressure due to the accumulation of non-reactive fine impurities (such as argon or nitrogen) contained in the raw material gas, which results in gas emissions. This contains gases such as ethylene, methane, oxygen, or argon, and are generally flared as they are, but CH<sub>4</sub> may be emitted through leakage or venting.

**b) Methodological Issues**● **Estimation Method**➤ **CO<sub>2</sub>**

Following the Tier 3 method of the 2006 IPCC Guidelines, emissions are estimated by multiplying the total domestic production amount by a country-specific emission factor established based on factory-specific data. The difference between emissions estimated using an EF which does not reflect recovery, and emissions estimated using an EF which reflects recovery (the actual EF used for this sub-category) is reported under CO<sub>2</sub> from carbonated gas and dry ice production (2.H.2). (See below)

$$E_{\text{CO}_2} = \text{EO} \times \text{EF}_1$$

$E_{\text{CO}_2}$	: CO <sub>2</sub> emissions from ethylene oxide production
$\text{EO}$	: Ethylene oxide production amount per year
$\text{EF}_1$	: CO <sub>2</sub> emissions per ethylene oxide production amount (reflecting recovery)

$$R_{\text{CO}_2} = \text{EO} \times \text{EF}_2 - E_{\text{CO}_2}$$

$R_{\text{CO}_2}$	: CO <sub>2</sub> recovery amount from ethylene oxide production processes
$\text{EO}$	: Ethylene oxide production amount per year
$\text{EF}_2$	: CO <sub>2</sub> emissions per ethylene oxide production amount (without reflecting recovery)

➤ **CH<sub>4</sub>**

Following the Tier 1 method of the *2006 IPCC Guidelines*, emissions are estimated by multiplying the total domestic production amount by a country-specific emission factor established based on factory-specific data.

● **Emission Factors**

➤ **CO<sub>2</sub>**

EFs per production amount (recovery reflected: 0.24 t-CO<sub>2</sub>/t, recovery not reflected: 0.33 t-CO<sub>2</sub>/t) are used. (provided by the Japan Petrochemical Industry Association) The EFs are a simple average of factory-specific EFs for all factories in Japan, and are based on the carbon balance, etc of the amounts of raw or secondary material input, and amounts of product or by-product output. The production amounts per factory are confidential, and therefore a weighted average cannot be taken. Additionally, since all ethylene oxide is produced by the same process (the Oxygen method), it is considered that a simple average would not divert far from the actual conditions. In the Oxygen method applied in Japan, the selectivity of the catalyst is higher than that of the default, and therefore the EF not reflecting recovery is lower than the default value of 0.663 t-CO<sub>2</sub>/t.

➤ **CH<sub>4</sub>**

An EF based on measured data and specific to the manufacturer is used. The CH<sub>4</sub> emission data used to establish the EF is estimated by the manufacturer based on an estimation of CH<sub>4</sub> emissions into the atmosphere, which is further based on the CH<sub>4</sub> amount in the gas introduced from outside when gases are purged from the process. Data are only available from FY2004, and therefore for the preceding years, a three-year average of data from FY2004 to FY2006 will be taken and applied. The data is confidential.

● **Activity Data**

➤ **CO<sub>2</sub>**

The ethylene oxide production amounts in the *Yearbook of Current Production Statistics - Chemical Industry* (METI) are used. (Table 4-25)

Table 4-25 Ethylene oxide production amount

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Ethylene oxide production	kt	714	795	961	1,001	843	842	849	915	894	923	882	945	893	878	790

➤ **CH<sub>4</sub>**

The ethylene oxide production amount at the one manufacturer is used. The data is confidential.

c) **Uncertainties and Time-series Consistency**

● **Uncertainty**

For the uncertainty for the CO<sub>2</sub> emission factor, the default value of 10% in the *2006 IPCC Guidelines* was applied. For the uncertainty of activity data, the default value of 5% given by the *2006 IPCC Guidelines* was used. As a result, the uncertainty of emissions was estimated at 11%.

For the uncertainty for the CH<sub>4</sub> emission factor, the default value of 60% in the *2006 IPCC Guidelines* was applied. For the uncertainty of activity data, the default value of 5% given by the *2006 IPCC Guidelines* was used. As a result, the uncertainty of emissions was estimated at 60%.

● **Time-series Consistency**

For activity data, the same source – the *Yearbook of Current Production Statistics - Chemical Industry*

and data from one manufacturer are used throughout the time series. The emission factor is set based on data from the same sources. Therefore, CO<sub>2</sub> and CH<sub>4</sub> emissions from ethylene oxide production have been estimated in a consistent manner throughout the time-series.

**d) Category-specific QA/QC and Verification**

See section 4.2.1. d).

**e) Category-specific Recalculations**

There have been no source-specific recalculations.

**f) Category-specific Planned Improvements**

No improvements are planned.

**4.3.8.5. Acrylonitrile Production (2.B.8.e)**

**a) Category Description**

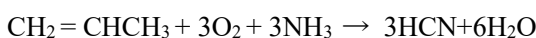
**1) CO<sub>2</sub>**

Acrylonitrile (C<sub>3</sub>H<sub>3</sub>N) is used as raw material for acrylic fiber or synthetic resin and is mainly manufactured by way of direct ammoxidation of propylene with ammonia and oxygen over a metal catalyst. (SOHIO process) On the order of 85 percent of the propylene feedstock is converted to either the primary product acrylonitrile or secondary products acetonitrile or hydrogen cyanide. (See below chemical equations 1 to 3) The remainder of the propylene feedstock is either converted to other hydrocarbons through side reactions in the ammoxidation process or converted directly to CO<sub>2</sub> by direct oxidation of the feedstock in the ammoxidation process (See below chemical equation 4)

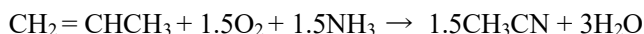
Equation 1: Acrylonitrile reaction



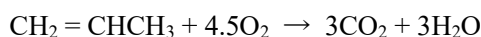
Equation 2: Hydrogen cyanide reaction



Equation 3: Acetonitrile reaction



Equation 4: Feedstock oxidation



**2) CH<sub>4</sub>**

The CH<sub>4</sub> off-gases are analyzed in the plants manufacturing acrylonitrile, but since no emissions are detected, they are reported as NA.

**b) Methodological Issues****● Estimation Method**

Emissions are calculated by multiplying the acrylonitrile production amount by Japan's country-specific emission factor, based on plant-specific data, in accordance with the Tier 3 method in the *2006 IPCC Guidelines*.

**● Emission Factors**

A CO<sub>2</sub> emission factor per production (0.73 t-CO<sub>2</sub>/t, provided by the Japan Petrochemical Industry Association) is applied for all years. This emission factor is an arithmetic mean of plant-specific CO<sub>2</sub> emission factors for all plants, based on the carbon balance of raw material and secondary material input and product and by-product output for each plant. This is done due to the fact that production data for each plant are confidential and this does not allow for taking a weighted average, and that acrylonitrile is manufactured by the same process throughout Japan (SOHIO process), which means that taking an arithmetic mean will not deviate far from actual conditions.

In the acrylonitrile manufacturing processes in Japan, acetonitrile and hydrogen cyanide are collected as products, and therefore the emission factor is close to the default value in the *2006 IPCC Guidelines* (0.79 t-CO<sub>2</sub>/t). The reason for it being slightly lower is due to efforts made to improve the efficiency of production.

**● Activity Data**

Acrylonitrile production amounts given in the *Yearbook of Current Production Statistics - Chemical Industry* (METI) were used for activity data.

Table 4-26 Acrylonitrile production amount

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Acrylonitrile production amount	kt	602	652	734	697	718	665	553	499	468	431	437	443	467	457	420

**c) Uncertainties and Time-series Consistency****● Uncertainty**

For the uncertainty of the emission factor, the default value of 60% in the *2006 IPCC Guidelines* was used. For the uncertainty of activity data, the default value of 5% in the *2006 IPCC Guidelines* was used. As a result, the uncertainty of emissions was estimated at 60%.

**● Time-series Consistency**

For activity data, the same source, the *Yearbook of Current Production Statistics - Chemical Industry*, are used throughout the time series. The emission factor is constant throughout the time series. Therefore, CO<sub>2</sub> emissions from acrylonitrile production have been estimated in a consistent manner throughout the time-series.

**d) Category-specific QA/QC and Verification**

See section 4.2.1. d).

**e) Category-specific Recalculations**

There have been no source-specific recalculations.

**f) Category-specific Planned Improvements**

No improvements are planned.

**4.3.8.6. Carbon Black Production (2.B.8.f)****a) Category Description**

Carbon black is mainly produced from the partial combustion of byproduct oil and gas from the petroleum refining and metallurgical refining processes in a high temperature atmosphere. (furnace black process) The CO<sub>2</sub> and CH<sub>4</sub> in the tail gas (off gas) emitted from the carbon black production process is released into the atmosphere.

**b) Methodological Issues**● **Estimation Method**➤ **CO<sub>2</sub>**

CO<sub>2</sub> emissions from carbon black production are calculated by multiplying the carbon black production amount by Japan's country-specific emission factor, in accordance with the Tier 1 method in the 2006 IPCC Guidelines.

➤ **CH<sub>4</sub>**

CH<sub>4</sub> emissions from carbon black production are calculated by multiplying the carbon black production amount by Japan's country-specific emission factor, established based on plant-specific data, in accordance with the Tier 1 method in the 2006 IPCC Guidelines.

● **Emission Factors**➤ **CO<sub>2</sub>**

Since it is considered that the CO<sub>2</sub> from natural gas that is used to heat the furnace (secondary feedstock origin) is already accounted for under Fuel combustion (1.A.), only CO<sub>2</sub> from the oil and gas used directly as raw material (primary feedstock origin) is accounted for here. A CO<sub>2</sub> emission factor per production (2.06 t-CO<sub>2</sub>/t) provided by the Carbon Black Association is used. This is established by taking a weighted average of total CO<sub>2</sub> measurements (subtracting out the carbon left over in the product from the carbon in the raw material, then dividing it by the weight of the product) for all five member companies' plants, with the production amounts of each company. Since these five companies cover over 95% of domestic production and sales, the emission factor is considered representative for Japan. All companies use the oil furnace process, and therefore emission factors do not differ much nor vary much annually.

➤ **CH<sub>4</sub>**

In carbon black manufacturing plants in Japan, CH<sub>4</sub> is only emitted into the atmosphere during non-steady operation, when venting is done at shutdowns and startups. According to the *Carbon Black Handbook* (Carbon Black Association), the concentrations of CH<sub>4</sub>, and the concentrations of CO, CO<sub>2</sub>, and CH<sub>4</sub> combined in the average tail gas is 0.6wt% and 21.5wt% respectively, and this is the same for during shutdowns and startups. Therefore, the CH<sub>4</sub> emission factor can be calculated from the CO<sub>2</sub> emission factor (2.06 t-CO<sub>2</sub>/t) as the below. The data is confidential.

$$EF_{CH_4} = 2.06[t-CO_2/t] \times R \times 0.6[wt\%] / 21.5[wt\%] \times 16/44$$

$EF_{CH_4}$  : EF for carbon black production

$R$  : The ratio of venting time at shutdowns and startups to the total operation time

No gas leakage occurs from the system, since inside the process the air pressure is negative, and therefore only emissions associated with venting is estimated.

#### ● **Activity Data**

Carbon black production amounts given in the *Yearbook of Current Production Statistics - Chemical Industry* (METI) were used for activity data for both CO<sub>2</sub> and CH<sub>4</sub> emissions associated with the manufacturing of carbon black.

Table 4-27 Carbon black production amount

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Carbon black production	kt	793	759	772	805	730	670	612	628	608	563	567	597	611	572	476

#### c) **Uncertainties and Time-series Consistency**

##### ● **Uncertainty**

The uncertainty for the emission factor for carbon black was calculated by finding the 95% confidence interval of emission factors. The estimated uncertainty was 55% for both CO<sub>2</sub> and CH<sub>4</sub>. For the uncertainty of activity data, the default value of 5% given by the *2006 IPCC Guidelines* was used for both CO<sub>2</sub> and CH<sub>4</sub>. As a result, the uncertainty of carbon black production emissions was estimated at 55% for both CO<sub>2</sub> and CH<sub>4</sub>.

##### ● **Time-series Consistency**

For activity data, the same source, the *Yearbook of Current Production Statistics - Chemical Industry*, are used throughout the time series. The emission factor is constant throughout the time series. Therefore, emissions have been estimated in a consistent manner throughout the time-series.

#### d) **Category-specific QA/QC and Verification**

See section 4.2.1. d).

#### e) **Category-specific Recalculations**

There have been no source-specific recalculations.

#### f) **Category-specific Planned Improvements**

No improvements are planned.

### 4.3.8.7. Styrene Production (2.B.8.g.-)

#### a) **Category Description**

CH<sub>4</sub> is emitted in the styrene production process.

#### b) **Methodological Issues**

##### ● **Estimation Method**

CH<sub>4</sub> emissions from styrene production were calculated by multiplying styrene production amount by Japan's country-specific emission factor, based on the method given in the *2006 IPCC Guidelines*.

- **Emission Factors**

Estimates of amount of exhaust gas from flare stacks at a normal operation and an unsteady operation at operating sites in Japan (assuming that 98% of the amount that enters is combusted. See footnote 2), and measured amount of waste gas from heating furnaces, were divided by the production amount to calculate emission factors for each company. The weighted average by production from each company was then applied to establish the emission factor. (Surveyed by the Japan Petrochemical Industry Association) This emission factor is confidential.

- **Activity Data**

Styrene monomer production amounts from the *Yearbook of Current Production Statistics - Chemical Industry* (METI) were used as activity data for CH<sub>4</sub> emissions from styrene production.

Table 4-28 Styrene monomer production amount

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Styrene production	kt	2,227	2,952	3,020	3,375	3,019	2,594	2,426	2,539	2,518	2,260	1,952	2,100	1,994	1,980	1,874

- c) **Uncertainties and Time-series Consistency**

- **Uncertainty**

The uncertainty for the CH<sub>4</sub> emission factor for styrene production was estimated by finding the 95% confidence interval of emission factors. The estimated uncertainty was 113%. For the uncertainty of activity data, the standard value of 5% given by the *2006 IPCC Guidelines* was used. As a result, the uncertainty of emissions was estimated as 113%.

- **Time-series Consistency**

For activity data, the same sources are used throughout the time series. The emission factor is constant throughout the time series. Therefore, CH<sub>4</sub> emissions from styrene production have been estimated in a consistent manner throughout the time-series.

- d) **Category-specific QA/QC and Verification**

See section 4.2.1. d).

- e) **Category-specific Recalculations**

There have been no source-specific recalculations.

- f) **Category-specific Planned Improvements**

No improvements are planned.

#### 4.3.8.8. Phthalic Anhydride Production (2.B.8.g.-)

- a) **Category Description**

Phthalic anhydride is used as raw material for plasticizers, synthetic resins, paints, dyes etc. CO and CO<sub>2</sub> are emitted during the oxidation of naphthalene and o-xylene in the production process of Phthalic anhydride. CO is also combusted and ultimately emitted as CO<sub>2</sub>.

### b) Methodological Issues

#### ● Estimation Method

The production amount of phthalic anhydride is multiplied by an emission factor per production amount to calculate emissions.

#### ● Emission Factors

The CO<sub>2</sub> generation rate (mol %) was calculated by assuming that carbon that did not become products or other by-products ultimately become CO<sub>2</sub>, and by using the yield of products or other by-products (mol %) per production process of phthalic anhydride (*Petrochemical Processes* (The Japan Petroleum Institute)) The EFs in each production process are calculated from the CO<sub>2</sub> emissions per production amount, based on the generation rate of CO<sub>2</sub> and products and the molecular weight of each substance. The yield is shown with an upper limit and lower limit in *Petrochemical Processes*, and therefore EFs are set using the median value.

Table 4-29 Generation rate of each substance by production process of phthalic anhydride

Production process	Product yield [mol %]	Maleic Anhydride [mol %]	Other [mol %]	CO <sub>2</sub> * [mol %]	EF * [t-CO <sub>2</sub> /t]
Oxidation of naphthalene	87-91	3-5	1	2-8	0.19
Oxidation of o-xylene	80-83	4-6	1-2	10-16	0.54

Reference: *Petrochemical Processes* (The Japan Petroleum Institute) (excluding\*)

Following this, a weighted average is taken for each year to set the EF for all of Japan. This is based on the productive capacity by year and by production process in the *Chemicals Handbook* (The Heavy and Chemical Industries News Agency)

Table 4-30 The weighted average EF based on productive capacity of phthalic anhydride

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
EFs for phthalic anhydride production	t-CO <sub>2</sub> /t	0.39	0.39	0.41	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37

Note: No information is available on the productive capacity per production process prior to FY1996, and therefore the FY1996 value is used for the preceding years.

#### ● Activity Data

The production amounts of phthalic anhydride in the *Yearbook of Current Production Statistics - Chemical Industry* (METI) are used.

Table 4-31 Phthalic anhydride production amount

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Phthalic anhydride production	kt	300	319	288	216	160	148	162	158	156	159	156	163	155	160	137

### c) Uncertainties and Time-series Consistency

#### ● Uncertainty

For the uncertainty of the emission factor, a 32% value, derived from the upper/lower limits of the theoretical value of the yield which was used to establish the emissions factor, was used. For the uncertainty of activity data, the default value of 5% given by the *2006 IPCC Guidelines* was used. As a result, the uncertainty of emissions was estimated at 32%.

#### ● Time-series Consistency

For activity data, the same sources are used throughout the time series. The emission factor is based on a consistent methodology throughout the time series.



**d) Category-specific QA/QC and Verification**

See section 4.2.1. d).

**e) Category-specific Recalculations**

There have been no source-specific recalculations.

**f) Category-specific Planned Improvements**

No improvements are planned.

**4.3.8.9. Maleic Anhydride Production (2.B.8.g.-)****a) Category Description**

Maleic anhydride is used as raw material for unsaturated polyester resins, or for resin improving agents, food additives, pharmaceutical ingredients, or synthetic raw material for organic acids such as malic acid and succinic acid. CO and CO<sub>2</sub> are emitted during the oxidation of benzene and n-butane in the production process of maleic anhydride. CO is also combusted and ultimately emitted as CO<sub>2</sub>.

**b) Methodological Issues**● **Estimation Method**

The production amount of maleic anhydride is multiplied by an emission factor per production amount to calculate emissions.

● **Emission Factors**

The CO<sub>2</sub> generation rate (mol %) was calculated by assuming that carbon that did not become products or other by-products ultimately become CO<sub>2</sub>, and by using the yield of products or other by-products (mol %) per production process of maleic anhydride (*Petrochemical Processes* (The Japan Petroleum Institute)) The EFs in each production process are calculated from the CO<sub>2</sub> emissions per production amount, based on the generation rate of CO<sub>2</sub> and products and the molecular weight of each substance. The yield is shown with an upper limit and lower limit in *Petrochemical Processes*, and therefore EFs are set using the median value.

Table 4-32 Generation rate of each substance by production process of maleic anhydride

Production process	Product yield [mol %]	CO <sub>2</sub> * [mol %]	EF * [t-CO <sub>2</sub> /t]
Oxidation of benzene	70-80	20-30	0.74
Oxidation of n-butane	55-60	40-45	1.65

Reference: *Petrochemical Processes* (The Japan Petroleum Institute) (excluding \*)

Following this, a weighted average is taken for each year to set the EF for all of Japan. This is based on the productive capacity by year and by production process in the *Chemicals Handbook* (The Heavy and Chemical Industries News Agency)

Table 4-33 The weighted average EF based on productive capacity of maleic anhydride

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
EFs for maleic anhydride production	t-CO <sub>2</sub> /t	1.20	1.20	1.23	1.11	1.11	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.06	1.06

Note: No information is available on the productive capacity per production process prior to FY1996, and therefore the FY1996 value is used for the preceding years.

- **Activity Data**

The production amounts of maleic anhydride in the *Yearbook of Current Production Statistics - Chemical Industry* (METI) are used.

Table 4-34 Maleic anhydride production amount

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Maleic anhydride production	kt	103	116	132	103	93	88	75	86	85	87	88	90	89	80	74

**c) Uncertainties and Time-series Consistency**

- **Uncertainty**

For the uncertainty of the emission factor, a 16% value, derived from the upper/lower limits of the theoretical value of the yield which was used to establish the emissions factor, was used. For the uncertainty of activity data, the default value of 5% given by the *2006 IPCC Guidelines* was used. As a result, the uncertainty of emissions was estimated at 17%.

- **Time-series Consistency**

For activity data, the same sources are used throughout the time series. The emission factor is based on a consistent methodology throughout the time series.

**d) Category-specific QA/QC and Verification**

See section 4.2.1. d).

**e) Category-specific Recalculations**

There have been no source-specific recalculations.

**f) Category-specific Planned Improvements**

No improvements are planned.

#### 4.3.8.10. Hydrogen Production (2.B.8.g.-)

**a) Category Description**

CO<sub>2</sub> is emitted from the steam reforming process of fossil fuels such as natural gas, petroleum, etc during hydrogen production. Hydrogen is produced as a by-product during petroleum refining, ethylene production, etc, and is recovered and used, however relevant emissions are already captured under other categories. Therefore, CO<sub>2</sub> generated from hydrogen production from raw materials, where the sole purpose is to obtain hydrogen, is addressed here.

**b) Methodological Issues**

- **Estimation Method**

The production amount of hydrogen is multiplied by an emission factor per production amount to calculate emissions.

- **Emission Factors**

The aggregated CO<sub>2</sub> emissions from industrial gas producers was divided by the aggregated production amounts of hydrogen to establish a CO<sub>2</sub> EF per production. Both aggregated values are based on values reported by member companies of the Japan Industrial and Medical Gases Association.

Table 4-35 Emission factors for hydrogen production

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
EFs for hydrogen production	t-CO <sub>2</sub> /10 <sup>3</sup> Nm <sup>3</sup>	0.82	0.83	0.83	0.88	0.87	0.87	0.88	0.86	0.85	0.85	0.84	0.86	0.86	0.84	0.83

#### ● Activity Data

The production amounts of hydrogen are for those processes that entail CO<sub>2</sub> emissions, and are based on values reported by member companies of the Japan Industrial and Medical Gases Association.

Table 4-36 Hydrogen production amount

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Hydrogen production	10 <sup>3</sup> Nm <sup>3</sup>	7,431	25,116	46,562	37,911	38,889	37,437	34,846	32,170	28,394	32,257	34,235	34,095	33,574	24,788	23,567

#### c) Uncertainties and Time-series Consistency

##### ● Uncertainty

The uncertainty value of 77% for ethylene production was used for the EF uncertainty. Similarly, for the uncertainty of activity data, the default value of 5% given by the 2006 IPCC Guidelines was used. As a result, the uncertainty for CO<sub>2</sub> emissions from hydrogen production was estimated as 77%.

##### ● Time-series Consistency

For activity data, the same sources are used throughout the time series. The emission factor is based on a consistent methodology throughout the time series.

#### d) Category-specific QA/QC and Verification

See section 4.2.1. d).

#### e) Category-specific Recalculations

The emission factor for FY2019 was revised, resulting in recalculations. See Chapter 10 for impact on trend.

#### f) Category-specific Planned Improvements

No improvements are planned.

### 4.3.9. Fluorochemical Production (2.B.9.)

#### 4.3.9.1. By-product Emissions: Production of HCFC-22 (2.B.9.-)

##### a) Category Description

HFC-23 is generated as a by-product of HCFC-22 production.

##### b) Methodological Issues

##### ● Estimation Method

Emissions are estimated by subtracting the recovery and destruction amount of by-product HFC-23 (measured data) from the amount of by-product HFC-23 generated at HCFC-22 production plants in Japan. The amount of by-product HFC-23 was estimated by multiplying the production of HCFC-22 by the generation rate of HFC-23 (obtained from the results of composition analysis of the interior of a reactor). Emission factors are country-specific.

The recovery/destruction units are constantly running when the plants are in operation. If any trouble arises in the units, management practices are to stop the plant operation, and for any portion of emissions without recovery/destruction, this is reflected in the data.

$$E = P_{\text{HCFC-22}} \times EF - R$$

$E$  : Emissions of by-product HFC-23 associated with the production of HCFC-22  
 $P_{\text{HCFC-22}}$  : Production of HCFC-22 [t]  
 $EF$  : Rate of generation of HFC-23 [%]  
 $R$  : Amount of recovery and destruction [t]

Table 4-37 Indices related to By-product Emissions of HFC-23: Production of HCFC-22

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Production of HCFC-22	t	60,122	81,000	95,271	65,715	46,149	45,314	54,388	47,546	51,753	49,116	48,833	52,646	56,933	57,872	44,733
Rate of generation of HFC-23	%	2.13%	2.13%	1.70%	1.90%	2.01%	1.53%	1.60%	1.41%	1.46%	1.46%	1.38%	1.47%	1.80%	1.88%	2.06%
Emission rate to production of HCFC-22	%	1.79%	1.79%	1.11%	0.06%	0.01%	0.002%	0.002%	0.002%	0.003%	0.004%	0.003%	0.005%	0.001%	0.002%	0.021%
Emissions	t	1,076.27	1,450.00	1,060.00	39.60	3.60	1.10	1.20	1.10	1.60	2.00	1.60	2.60	0.80	0.90	9.50
	kt-CO <sub>2</sub> eq.	15,929	21,460	15,688	586	53	16	18	16	24	30	24	38	12	13	141

Reference: *Documents of Fluorocarbons etc Measures Working Group, Group for Chemical Substance Policy, Manufacturing Industries Sub-Group, Industrial Structure Council, Ministry of Economy, Trade and Industry* (hereafter, *Documents of Fluorocarbons etc Measures Working Group*), *Documents of the first meeting of the Breakout Group on F-gases, FY2013 Committee for the Greenhouse Gas Emissions Estimation Methods* (hereafter, *Documents of the first meeting of the Breakout Group on F-gases (FY2013)*)

Note: Emissions decreased because all manufacturing facilities were equipped with recovery/destruction units in 2004. The low emission rate to production is due to efforts made in preventing the fall of the operating rates through the improvement in techniques of operation management of destruction facilities and maintenance. Emission reduction has further advanced since, with continuous efforts made in improvement of operation management techniques etc.

Due to the lack of data necessary to estimate emissions for the years 1990 to 1994, estimates have been done by using the combined HCFC-22 production amounts for the purpose of material for fluorocarbon polymers (estimated from the production amounts of fluorocarbon polymers and the ratio of HCFC-22 production amounts for the purpose of material for fluorocarbon polymers to the production amounts of fluorocarbon polymers (an average of 1995-2006 where data were available)) and HCFC-22 production amounts for the purpose of refrigerants (estimated from total HCFC-22 shipment amounts<sup>3</sup>, and HCFC-22 shipment amounts for the purpose of refrigerants from 1995) as data for total HCFC-22 production amounts, and by using data on the emission rate to the production of HCFC-22 from 1995, and extrapolating for these years.

### c) Uncertainties and Time-series Consistency

#### ● Uncertainty

For the uncertainty of the emissions, a 2% value from the 2006 IPCC Guidelines was applied.

#### ● Time-series Consistency

For years after 1995, the Manufacturing Industries Sub-Group, Ministry of Economy, Trade and Industry annually collects and estimates F-gas emissions. For the years 1990 to 1994, estimates have been done by extrapolation, etc of relevant data from 1995 onward, and therefore time-series consistency is taken into account to the extent possible.

<sup>3</sup> MITI, Documents of the first meeting of the Group for global warming chemicals, Risk Management Sub-Group, Chemicals Council, 1997.

**d) Category-specific QA/QC and Verification**

The data collected and estimated by the Manufacturing Industries Sub-Group, Ministry of Economy, Trade and Industry, is checked by the Committee for Greenhouse Gas Estimation Methods and is used in the inventory. Emissions are surveyed for all production plants in Japan. Composition analysis is carried out frequently, as in the case where one plant takes measurements every day. Concentration measurements are implemented at the vent of the plant.

**e) Category-specific Recalculations**

There have been no source-specific recalculations.

**f) Category-specific Planned Improvements**

No improvements are planned.

**4.3.9.2. Fugitive Emissions (2.B.9.-)****a) Category Description**

HFCs, PFCs, SF<sub>6</sub>, and NF<sub>3</sub> are emitted as fugitive emissions during manufacturing. Regarding returned gas cylinders, when residual gas is decomposed and the containment shell is cleansed, or when there is release into the atmosphere, these emissions are reported under this subcategory.

**b) Methodological Issues**● **Estimation Method**

Emissions were reported based on measurement data at each of HFCs, PFCs, SF<sub>6</sub>, and NF<sub>3</sub> manufacturing plant in Japan. Recovery, etc is hereby taken into account. The recovery/destruction units are constantly running when the plants are in operation. If any trouble arises in the units, management practices are to stop the plant operation.

The associated indices are given in the table below.

Table 4-38 Fugitive emissions from HFC production

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
HFCs Emissions	kt-CO <sub>2</sub> eq.	2	559	296	449	128	151	120	131	101	83	149	95	88	119	76

Reference: *Documents of Fluorocarbons etc Measures Working Group* (data from Japan Fluorocarbon Manufactures Association), and data provided by the Ministry of Economy, Trade and Industry, *Documents of the first meeting of the Breakout Group on F-gases and FY2013 Committee for the Greenhouse Gas Emissions Estimation Methods*

Note: With emission reduction measures such as installation of destruction units subsidized by the government, and re-evaluation of the production processes, emission reduction has advanced.

Table 4-39 Fugitive emissions from PFC production

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
PFCs Emissions	kt-CO <sub>2</sub> eq.	331	914	1,661	1,041	248	206	148	111	107	115	97	81	87	64	74

Reference: *Documents of Fluorocarbons etc Measures Working Group* (data from Japan Chemical Industry Association), *Documents of the first meeting of the Breakout Group on F-gases (FY2013)*

Note: With emission reduction measures such as installation of destruction units subsidized by the government, and re-evaluation of the production processes, emission reduction has advanced. The installation of destruction units in 2011 for lean gas emitted further contributed to the achievement of emission reduction.

Table 4-40 Indices related to fugitive emissions from SF<sub>6</sub> production

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Production of SF <sub>6</sub>	t	1,848.36	2,392.00	1,556.00	2,313.00	2,201.00	1,993.00	2,230.00	2,128.00	1,997.00	2,027.00	2,002.74	1,680.39	1,658.00	1,573.00	1,260.00
Emissions	t	152.23	197.00	36.00	40.80	8.30	5.80	5.40	4.07	2.70	2.30	2.20	1.78	2.00	1.76	2.28
	kt-CO <sub>2</sub> eq.	3,471	4,492	821	930	189	132	123	93	62	52	50	41	46	40	52

Reference: *Documents of Fluorocarbons etc Measures Working Group* (data from Japan Chemical Industry Association), *Documents of the first meeting of the Breakout Group on F-gases (FY2013)*

Note: Emissions decreased because all manufacturing facilities were equipped with recovery/destruction units in 2009. Re-evaluation of the production processes and handling at shipment has also advanced emission reduction.

Table 4-41 Indices related to fugitive emissions from NF<sub>3</sub> production

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Production of NF <sub>3</sub>	t	6.00	37.00	208.00	1,663.00	3,642.00	3,612.00	3,501.00	4,148.00	4,660.08	4,963.00	4,365.50	4,649.40	4,718.90	3,828.70	4,037.00
Emissions	t	0.16	1.00	7.00	72.10	76.90	93.10	76.40	86.40	56.09	23.50	25.10	13.61	3.37	1.12	0.88
	kt-CO <sub>2</sub> eq.	3	17	120	1,240	1,323	1,601	1,314	1,486	965	404	432	234	58	19	15

Reference: *Documents of Fluorocarbons etc Measures Working Group* (data from Japan Chemical Industry Association)

Due to the lack of data necessary to estimate emissions for the years 1990 to 1994, estimates have been done by using HFC, PFC, and SF<sub>6</sub> shipment amounts<sup>4</sup> which is thought to be proportional to HFC, PFC, and SF<sub>6</sub> production amounts, and the ratio of emissions to the HFC, PFC, SF<sub>6</sub>, and NF<sub>3</sub> production amounts from 1995, and weighted average GWPs for HFCs and PFCs from 1995, and extrapolating for these years.

#### c) *Uncertainties and Time-series Consistency*

##### ● *Uncertainty*

For the uncertainties of the emissions for all HFCs, PFCs, SF<sub>6</sub>, and NF<sub>3</sub>, a 2% value from the *2006 IPCC Guidelines* was applied.

##### ● *Time-series Consistency*

See section 4.3.9.1. c).

#### d) *Category-specific QA/QC and Verification*

See section 4.3.9.1. d).

#### e) *Category-specific Recalculations*

There have been no source-specific recalculations.

#### f) *Category-specific Planned Improvements*

No improvements are planned.

## 4.4. Metal Industry (2.C.)

This category covers CO<sub>2</sub>, CH<sub>4</sub>, HFC, PFC and SF<sub>6</sub> emissions from the manufacturing processes of metal products.

This section includes GHG emissions from the following sources: Iron and steel production (2.C.1.), Ferroalloys production (2.C.2.), Aluminum production (2.C.3.), Magnesium production (2.C.4.), Lead

<sup>4</sup> *Documents of the first meeting of the Group for global warming chemicals, Risk Management Sub-Group, Chemicals Council, 1997 (MITI)*. All further reference to 'shipment amounts' used for emission estimates for years 1990 to 1994 are from the same source.

production (2.C.5.), Zinc production (2.C.6.), and Rare Earths Production (2.C.7.).

In FY2020, emissions from Metal production were 5,742 kt-CO<sub>2</sub> eq. and represented 0.5% of Japan's total GHG emissions (excluding LULUCF). The total emissions of CO<sub>2</sub> and CH<sub>4</sub> from this category had decreased by 25.3% compared to FY1990. The total of HFCs, PFCs and SF<sub>6</sub> had decreased by 15.0% compared to 1990.

Table 4-42 Emissions from 2.C. Metal Industry

Gas			Units	1990	1995	1999	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020		
CO <sub>2</sub>	2.C.1	Iron and steel production	Use of electric arc furnaces in steel production	kt-CO <sub>2</sub>	298	328	190	190	231	152	154	167	140	160	132	143	170	175	139	91	
			Limestone and dolomite use in iron and steel production	kt-CO <sub>2</sub>	6,888	6,492	6,257	6,538	6,255	5,941	5,803	5,889	6,044	5,961	5,808	5,693	5,576	5,495	5,341	5,219	
			By-product gas flaring in iron and steel production	kt-CO <sub>2</sub>	25	56	88	102	174	243	211	212	231	222	201	193	173	163	152	120	
	2.C.3	Aluminium production	kt-CO <sub>2</sub>	58	29	16	11	11	8	8	7	5	1	NO	NO	NO	NO	NO	NO		
Total			kt-CO <sub>2</sub>	7,269	6,906	6,551	6,842	6,670	6,344	6,176	6,276	6,421	6,343	6,141	6,029	5,919	5,833	5,632	5,430		
CH <sub>4</sub>	2.C.1	Iron and steel production	Use of electric arc furnaces in steel production	kt-CH <sub>4</sub>	0.74	0.72	0.64	0.67	0.68	0.59	0.60	0.59	0.60	0.59	0.55	0.55	0.59	0.60	0.54	0.49	
			2.C.2	Ferroalloys production	kt-CH <sub>4</sub>	0.19	0.14	0.12	0.13	0.13	0.12	0.11	0.13	0.13	0.12	0.12	0.11	0.11	0.11	0.11	0.08
			Total			kt-CH <sub>4</sub>	0.92	0.85	0.77	0.80	0.80	0.71	0.72	0.72	0.73	0.71	0.67	0.66	0.70	0.71	0.65
	Total			kt-CO <sub>2</sub> eq.	23	21	19	20	20	18	18	18	18	18	17	16	17	18	16	14	
Total of CO <sub>2</sub> and CH <sub>4</sub>			kt-CO <sub>2</sub> eq.	7,292	6,927	6,570	6,862	6,691	6,361	6,194	6,294	6,439	6,361	6,158	6,045	5,937	5,851	5,648	5,444		
Gas			Units	1990	1995	1999	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020		
HFCs	2.C.4	Magnesium production	kt-CO <sub>2</sub> eq.	NO	NO	NO	NO	NO	NO	1	1	1	1	1	1	1	2	1	1		
PFCs	2.C.3	Aluminium production	kt-CO <sub>2</sub> eq.	204	171	71	44	36	25	25	22	16	3	NO	NO	NO	NO	NO	NO		
SF <sub>6</sub>	2.C.4	Magnesium production	t	6.43	5.00	27.00	43.00	48.42	12.88	8.00	8.00	7.00	8.00	10.00	13.80	10.80	12.00	11.00	13.00		
			kt-CO <sub>2</sub> eq.	147	114	616	980	1,104	294	182	182	160	182	228	315	246	274	251	296		
Total of F-gases			kt-CO <sub>2</sub> eq.	350	285	687	1,024	1,140	319	209	206	177	187	229	316	248	275	252	298		

#### 4.4.1. Iron and Steel Production (2.C.1.)

The General Energy Statistics (Energy Balance Table) is a statistic that provides a comprehensive overview of domestic energy supply and demand. As mentioned in section 4.2.1 of the *2006 IPCC Guidelines*, carbon serves a dual purpose in the iron making process, primarily as a reducing agent to convert iron oxides to iron, but also as an energy source to provide heat when carbon and oxygen react exothermically. Coke etc used as a reducing agent are included in the fuel consumption amounts in the *General Energy Statistics* and related emissions are comprehensively captured in 1.A.2.a (Energy sector - iron and steel) in Japan. Therefore, allocating emissions from the consumption of reducing agents to the energy sector does not make a difference in total emissions, but is rather more accurate, because it ensures completeness. The sum of 1.A.2.a (energy sector - iron and steel) and 2.C.1 (IPPU sector - iron and steel production) are comparable to the emissions that are calculated in line with the *2006 IPCC Guidelines* (See the table below).

Table 4-43 CO<sub>2</sub> emissions from iron and steel production (for energy and reducing agent use)

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
1.A.2.a (Energy sector - iron and steel)	kt-CO <sub>2</sub>	150,691	143,097	152,106	154,168	153,154	148,879	151,286	157,550	155,101	148,878	142,756	139,752	136,179	134,140	111,996
2.C.1 (IPPU sector - iron and steel production)	kt-CO <sub>2</sub>	7,269	6,906	6,842	6,670	6,344	6,176	6,276	6,421	6,343	6,141	6,029	5,919	5,833	5,632	5,430
Total of CO <sub>2</sub>	kt-CO <sub>2</sub>	157,960	150,003	158,948	160,839	159,498	155,054	157,562	163,970	161,444	155,019	148,785	145,671	142,012	139,771	117,426

*The 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories* (hereafter

*2019 Refinement*, See section 4.2.2.5) recommends, to avoid double counting and to ensure completeness, to cross-check the proper allocation of the emissions between the Energy and IPPU sectors, and to document where and how they are reported. It is difficult for Japan to differentiate and allocate between energy use and reducing agents use completely, but we have confirmed that all emissions from reducing agent consumption have been allocated without double-counting or omissions, for certain. Explanation on the category where it is allocated is also provided in this NIR appropriately. Japan would also like to note that the following was agreed at the 17th meeting of the Inventory Lead Reviewers (LR) meeting (para 8 (b)): "The LRs further concluded that, when the Party is using a different allocation of emissions from that recommended in the 2006 IPCC Guidelines and is reporting the emissions as "IE" under the energy or IPPU sectors, the ERT should check whether the Party has transparently reported where the emissions have been included and ensured the accuracy of the estimates. If this is not the case, the ERT should follow up with a relevant recommendation" This indicates that there is possibility to report with a different allocation.

The main types of reducing agents (fuels) and the corresponding production processes are as follows: coke (steel production, pig iron production, sinter production, and pellet production), pulverized coal/waste plastics (pig iron production). See also Table 3-10 and Table 3-61.

#### 4.4.1.1. Steel Production (2.C.1.a)

Coke oxidizes when it is used as a reduction agent in steel production, and CO<sub>2</sub> is generated. The amount of coke used has been included under consumption of fuel in the Fuel combustion category (1.A.), and the CO<sub>2</sub> generated through the oxidization of coke used as a reducing agent has already been calculated under Fuel combustion category (1.A.).

#### 4.4.1.2. Use of Electric Arc Furnaces in Steel Production (2.C.1.a)

##### a) Category Description

CO<sub>2</sub> is emitted from carbon electrodes when using electric arc furnaces to make steel. CH<sub>4</sub> is also emitted from electric arc furnaces during iron and steel production.

##### b) Methodological Issues

###### 1) CO<sub>2</sub>

###### ● Estimation Method

CO<sub>2</sub> emissions from arc furnaces for steel production are estimated by amount of carbon calculated by weight of production and import of carbon electrodes minus weight of export of carbon electrodes. This difference of the carbon is assumed to be diffused to the atmosphere as CO<sub>2</sub>. The carbon included in electric furnaces gas given in the *General Energy Statistics* are subtracted from the CO<sub>2</sub> emission in this source since these emissions are included in category 1.A. Fuel combustion.

CO<sub>2</sub> emissions from carbon electrodes during aluminium production are accounted for under 2.C.3 (See section 4.4.3) and are deducted from the emissions from this category.

###### ● Activity Data

Production of carbon electrodes given in *Yearbook of Current Production Statistics - Mineral Resources*



and Petroleum Products, Ceramics and Building Materials (METI) and import and export of carbon electrodes given in *Trade Statistics of Japan*, Ministry of Finance are used.

Table 4-44 CO<sub>2</sub> emissions from carbon electrodes of furnaces

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
#A Import	t	12,341	18,463	11,363	15,075	17,321	20,437	20,027	19,960	19,226	18,209	19,773	16,653	15,720	18,056	17,380
#B Domestic production	t	211,933	186,143	184,728	216,061	205,081	217,847	197,278	180,322	180,555	151,979	141,193	161,919	160,049	119,233	76,338
#C Export	t	87,108	92,812	107,998	138,409	139,757	154,204	135,863	128,435	121,079	103,834	90,664	104,032	100,268	72,307	44,578
#D Electric furnaces gas	t	39,983	14,300	33,201	26,700	39,017	39,949	33,898	32,146	34,760	30,444	31,273	28,049	27,806	27,022	24,397
Domestic consumptions (#A + #B - #C - #D)	t	97,184	97,493	54,892	66,028	43,629	44,132	47,544	39,700	43,941	35,910	39,029	46,491	47,695	37,959	24,743
CO <sub>2</sub> emissions	kt-CO <sub>2</sub> eq.	356	357	201	242	160	162	174	145	161	132	143	170	175	139	91

## 2) CH<sub>4</sub>

### ● Estimation Method

Emissions were calculated by multiplying an emission factor based on actual measurements obtained from electric arc furnace facilities in Japan by the energy consumption of electric arc furnaces.

### ● Emission Factors

The emission factor of energy consumption of electric arc furnaces (12.8 kg-CH<sub>4</sub>/TJ) was used. (See section 4.3.5.1.b))

### ● Activity Data

Energy consumption amounts included in the "electric furnace" category for the iron and steel industries of the *General Energy Statistics* were used.

Table 4-45 Energy consumption in electric arc furnaces

Electricity consumption	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Electric furnaces	TJ	57,564	55,986	52,457	52,747	45,793	47,185	46,195	46,786	46,156	42,919	43,045	46,109	46,697	41,978	38,160

## c) Uncertainties and Time-series Consistency

### 1) CO<sub>2</sub>

#### ● Uncertainty

Because all CO<sub>2</sub> from electric arc furnaces are assumed to escape into the atmosphere, no emission factor has been set. Therefore, by assessing the uncertainty for activity data the uncertainty for emissions is assessed. As a result of combining the uncertainties of the parameters for activity data, the uncertainty was estimated as 5%.

#### ● Time-series Consistency

For activity data (emissions), the same sources are used throughout the time series. Therefore, CO<sub>2</sub> emissions from electric arc furnaces have been estimated in a consistent manner throughout the time-series.

### 2) CH<sub>4</sub>

#### ● Uncertainty

The uncertainty for the emission factor has been estimated as 163% and the uncertainty for activity data has been estimated as 5% (see chapter 3). As a result, the uncertainty for CH<sub>4</sub> emissions has been estimated as 163%.

- **Time-series Consistency**

For activity data, the same sources are used throughout the time series. The emission factor is constant throughout the time series. Therefore, CH<sub>4</sub> emissions from electric arc furnaces in steel production have been estimated in a consistent manner throughout the time-series.

- d) **Category-specific QA/QC and Verification**

See section 4.2.1. d).

- e) **Category-specific Recalculations**

There have been no source-specific recalculations.

- f) **Category-specific Planned Improvements**

No improvements are planned.

#### 4.4.1.3. Pig Iron Production (2.C.1.b)

- 1) **CO<sub>2</sub>**

CO<sub>2</sub> generated from pig iron production is emitted when coke, pulverized coal, and waste plastics, are used as a reduction agent. The amount of coke etc used has been included under consumption of fuel in the Fuel combustion category (1.A.), and the CO<sub>2</sub> generated through the oxidization of coke, etc used as a reducing agent has already been calculated under Fuel combustion category (1.A.).

- 2) **CH<sub>4</sub>**

It is theoretically impossible for CH<sub>4</sub> generation in association with pig iron production, and it has been confirmed that CH<sub>4</sub> is not emitted from actual measurements. Therefore, emissions have been reported as “NA”.

#### 4.4.1.4. Limestone and Dolomite Use in Iron and Steel Production (2.C.1.b)

- a) **Category Description**

Limestone contains CaCO<sub>3</sub> and minute amounts of MgCO<sub>3</sub>, and dolomite contains CaCO<sub>3</sub> and MgCO<sub>3</sub>. The heating of limestone and dolomite releases CO<sub>2</sub> derived from CaCO<sub>3</sub> and MgCO<sub>3</sub>.

- b) **Methodological Issues**

- **Estimation Method**

The amounts of limestone and dolomite used in iron and steel production are multiplied by the emission factors to calculate emissions.

- **Emission Factors**

- **Limestone**

See section 4.2.3. b).

- **Dolomite**

See section 4.2.3. b).

### ● Activity Data

Of the limestone and dolomite consumption data in the *Adjusted Price Transaction Table*, all limestone and dolomite consumption categorized under 'emissive use' that are under the Iron and steel/Refining related sectors will be accounted for under this subcategory. Activity data is in dry weight, converted using the water content from limestone used for cement.

The corresponding sectors in the *Adjusted Price Transaction Table* are as follows:

Table 4-46 Corresponding sectors in the *Adjusted Price Transaction Table*

Uses	Corresponding sectors in the <i>Adjusted Price Transaction Table</i> (Limestone)	Corresponding sectors in the <i>Adjusted Price Transaction Table</i> (Dolomite)
Iron and Steel/Refining	2611-01 to 2611-04	Steel - pig iron Steel - crude ore (electric furnace)
	2631-02	Steel - cast pipe
	2631-03	Steel - cast and forged materials (iron)
	2711-01	Non-ferrous metal - copper
	2711-02	Non-ferrous metal lead and zinc
2729-03	Non-ferrous metal - non-ferrous metal cast and forged products	2711-02 Non-ferrous metal - lead and zinc

Note: The numbers before the sector names are categorization numbers in the *Adjusted Price Transaction Table*.

Table 4-47 Amounts of limestone and dolomite consumption

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Limestone consumption																
For Steel and Refinement (dry)	kt	14,430	13,590	13,619	12,577	11,815	11,542	11,669	11,895	11,732	11,504	11,263	11,053	10,920	10,654	10,379
Dolomite consumption																
For Steel and Refinement (dry)	kt	1,144	1,089	1,160	1,530	1,576	1,539	1,603	1,720	1,695	1,584	1,565	1,512	1,466	1,387	1,384

### c) Uncertainties and Time-series Consistency

#### ● Uncertainty

For the uncertainty of emission factors, a 3% default value in the *2006 IPCC Guidelines* was used for both limestone and dolomite. For the uncertainty for activity data, a 3% default value in the *2006 IPCC Guidelines* was used for both limestone and dolomite. As a result, the uncertainty for emissions was estimated as 4% for both limestone and dolomite.

#### ● Time-series consistency

Limestone and dolomite consumption data provided in the *Adjusted Price Transaction Table* is used as limestone and dolomite use activity data for all years from FY1990. The emission factors are constant for all years from FY1990. Therefore, CO<sub>2</sub> emission from limestone and dolomite use has been estimated in a consistent manner throughout the time-series.

### d) Category-specific QA/QC and Verification

See section 4.2.1. d).

### e) Category-specific Recalculations

Recalculations of CO<sub>2</sub> emissions occurred due to on updates made to limestone (FY2018 and FY2019) and dolomite (FY2019) consumption data in the *Adjusted Price Transaction Table*. See Chapter 10 for impact on trend.

### f) Category-specific Planned Improvements

No improvements are planned.

#### 4.4.1.5. By-product Gas Flaring in Iron and Steel Production (2.C.1.b)

##### a) Category Description

CO<sub>2</sub> is emitted from the flaring of by-product gas (blast furnace gas and converter furnace gas) during emergencies or maintenance in iron and steel production.

##### b) Methodological Issues

###### ● Estimation Method

Emissions are estimated by multiplying the amount of the flaring of by-product gas by the gross calorific value and carbon emission factor for each by-product gas based on Tier 1 methodology provided in the *2019 Refinement*. (See below equation)

According to the survey by the Japan Iron and Steel Federation, part of the amounts of the flaring of the blast furnace gas and converter furnace gas are included in the *General Energy Statistics* (ANRE), and associated emissions are already accounted for the Fuel combustion category (1.A.). Therefore, CO<sub>2</sub> emissions from flaring unaccounted in the *General Energy Statistics* are accounted for under this sub-category.

$$E = \sum_i (AD \times GCV \times EF \times 44/12)$$

$E$  : CO<sub>2</sub> emissions from the flaring of by-product gas [kt-CO<sub>2</sub>]

$i$  : Type of by-product gas

$AD$  : Amount of by-product gas unaccounted in the *General Energy Statistics* [MNm<sup>3</sup>]

$GCV$  : Gross calorific values [MJ/m<sup>3</sup>]

$EF$  : Carbon emission factor [t-C/GJ]

###### ● Emission Factors

The same emission factors as those used to calculate CO<sub>2</sub> emissions from the Fuel combustion category (1.A.) are used. (See Table 3-11)

###### ● Activity Data

Of the total amount of the flaring of by-product gas surveyed by the Japan Iron and Steel Federation (hereafter, 'total flaring amount'), the amount unaccounted in the *General Energy Statistics* (hereafter, 'unaccounted amount') is used as activity data. Since 'unaccounted amount' is available only for FY2020, the other fiscal years are estimated by multiplying the 'total flaring amount' by the ratio of the 'unaccounted amount' for FY2020. Additionally, since 'total flaring amount' are available only for FY1990, FY2000, FY2010 and FY2020, the other fiscal years are estimated by multiplying the amount of by-product gas provided in the *General Energy Statistics* by the ratio of flaring. The flaring ratio for years other than FY1990, FY2000, FY2010 and FY2020 are estimated by interpolating between the flaring ratio for these years.

Table 4-48 Estimated amounts of the by-product gas flaring unaccounted in the *General Energy Statistics*

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Blast furnace gas	Million Nm <sup>3</sup>	23	22	22	29	36	33	32	34	32	28	26	24	22	19	14
Converter furnace gas	Million Nm <sup>3</sup>	14	41	80	139	195	169	170	191	184	167	160	144	135	126	100

##### c) Uncertainties and Time-series Consistency

###### ● Uncertainty

For the uncertainty of emission factors, the upper limit and lower limit values of the 95% confidence

interval for the carbon emission factors of converter furnace gas were applied. Also, since the values in the *General Energy Statistics* are used for estimation of the activity data, the default values (-10% to +10%) in the *2019 Refinement* are adopted for the uncertainty of activity data. As a result, the uncertainty of the emissions from flaring of by-product gas is evaluated as 11%.

- ***Time-series consistency***

The activity data are estimated in a consistent manner based on the data provided by the Japan Iron and Steel Federation, and the *General Energy Statistics* from FY1990. The emission factor is based on the *General Energy Statistics* from FY1990.

- d) ***Category-specific QA/QC and Verification***

See section 4.2.1. d).

- e) ***Category-specific Recalculations***

CO<sub>2</sub> emissions were newly estimated. See Chapter 10 for impact on trend.

- f) ***Category-specific Planned Improvements***

No improvements are planned.

#### **4.4.1.6. Direct Reduced Iron Production (2.C.1.c)**

CO<sub>2</sub> and CH<sub>4</sub> are generated during the production of direct reduced iron, through the oxidation of natural gas or coal used as reductants. However, there has not been any production of direct reduced iron in Japan, and therefore, it has been reported as “NO”.

#### **4.4.1.7. Sinter Production (2.C.1.d)**

CO<sub>2</sub> and CH<sub>4</sub> from the manufacturing of sinter are generated by the combustion of ore powder with coke fines; these emissions come under the Fuel combustion category (1.A.). As they are already calculated in this 1.A. category, they are reported as “IE”.

CO<sub>2</sub> emissions from limestone and dolomite used when making sinter are counted under “4.4.1.4. Limestone and dolomite use in Iron and Steel Production”.

#### **4.4.1.8. Pellet Production (2.C.1.e)**

CO<sub>2</sub> and CH<sub>4</sub> from the manufacturing of pellets are generated by the combustion of fine ore powder with coke; these emissions come under the Fuel combustion category (1.A.). As they are already calculated in this 1.A. category, they are reported as “IE”.

CO<sub>2</sub> emissions from limestone and dolomite used when making pellets are counted under “4.4.1.4. Limestone and dolomite use in Iron and Steel Production”.

#### 4.4.2. Ferroalloys Production (2.C.2.)

##### a) Category Description

###### 1) CO<sub>2</sub>

Ferroalloys are produced in Japan, and the CO<sub>2</sub> that is generated in association with the ferroalloys production is emitted as a result of the oxidization of coke used as a reducing agent. Consumption of coke is included in consumption of fuel under the Fuel combustion category (1.A.), and CO<sub>2</sub> generated as a consequence of the oxidization of coke used as a reduction agent has already been calculated under the Fuel combustion category (1.A.). The thinking on where to account for CO<sub>2</sub> emissions from coke is the same as that for Iron and steel production. Regarding reducing agents for ferroalloys production, see Table 3-10. Residual carbon in the ferroalloys is oxidized when the ferroalloys are used in the production of iron and steel, and are released into the atmosphere as CO<sub>2</sub>.

CO<sub>2</sub> emissions from limestone and dolomite that are used as slag forming materials have already been accounted for under iron and steel production (2.C.1.) as CO<sub>2</sub> emissions occurring from limestone and dolomite used during production.

Therefore, CO<sub>2</sub> emissions have been reported as “IE”.

Regarding carbon in the ore, it is thought that the primary raw materials for ferroalloys in Japan (currently, imported manganese ores, nickel ores, and chromium ores) are rarely imported as carbonate ores<sup>5</sup>. Public sources of information such as *Mineral Resources Material Flow* (Japan Oil, Gas and Metals National Corporation) do not provide data on distribution amounts that can be used for estimation, and therefore these emissions are not estimated.

###### 2) CH<sub>4</sub>

Ferroalloys are manufactured in Japan in electric arc furnaces, small-scale blast furnaces, and Thermit furnaces. CH<sub>4</sub> generated in association with ferroalloy production is thought to be generated when the oxidization of coke, a reduction agent, takes place.

##### b) Methodological Issues

###### ● Estimation Method

CH<sub>4</sub> emissions from ferroalloy production were calculated by multiplying an emission factor based on actual measurements obtained from electric arc furnace facilities in Japan by the energy consumption of electric arc furnaces.

###### ● Emission Factors

The value for the emission factor of electric arc furnaces (12.8 kg-CH<sub>4</sub>/TJ) was used because these furnaces produce ferroalloys.

The EF is established using measured CH<sub>4</sub> concentration, measured dry gas emissions per hour, calories per hour, calories per electricity, and therefore needs to be per electricity (in TJ). Additionally, electricity consumption is determined by the operation of the furnaces and type of ferroalloy produced, and therefore we have used the electricity consumption, not production, as more accurate and available activity data. This EF reflects the average operation of furnaces/type of ferroalloy at the

<sup>5</sup> Most of the manganese ores distributed in Japan are high grade manganese oxide ores (MnO<sub>2</sub>) and it is thought that low grade manganese carbonates ores are rarely distributed.

time of measurement in Japan. The equation below shows the process of deriving the emission factor.

$$EF = C_{CH_4} \times G \times MW / V_m / H$$

- EF* : Emission factor [kg-CH<sub>4</sub>/TJ]  
*C<sub>CH<sub>4</sub></sub>* : Measured CH<sub>4</sub> concentration in the emitted gas [ppm]  
*G* : Measured dry gas emissions per hour [m<sup>3</sup>N/h]  
*MW* : Molecular weight of CH<sub>4</sub> = 16 [g/mol]  
*V<sub>m</sub>* : Volume of 1 mole of ideal gas at standard pressure = 22.4 [10<sup>-3</sup>m<sup>3</sup>/mol]  
*H* : Calories per hour [MJ/h]

Some of the parameters were established using measurements which were conducted generally in line with the guidance in the *2006 IPCC Guidelines*, for instance with making efforts to cover a representative sample.

#### ● *Activity Data*

Energy consumption amounts included in the "ferroalloy" category for the iron and steel industries of the *General Energy Statistics* were used.

Table 4-49 Energy consumption for ferroalloy production

Electricity consumption	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Electric furnaces (for Ferroalloys)	TJ	14,456	10,699	10,181	10,072	9,510	8,938	10,038	9,956	9,102	9,228	8,507	8,362	8,894	8,766	6,404

#### c) *Uncertainties and Time-series Consistency*

##### ● *Uncertainty*

The uncertainty for the emission factor has been estimated as 163% and the uncertainty for activity data has been estimated as 5% (see chapter 3). As a result, the uncertainty for CH<sub>4</sub> emissions has been estimated as 163%.

##### ● *Time-series Consistency*

For activity data, the same sources are used throughout the time series. The emission factor is constant throughout the time series. Therefore, CH<sub>4</sub> emissions from furnaces for ferroalloy have been estimated in a consistent manner throughout the time-series.

#### d) *Category-specific QA/QC and Verification*

See section 4.2.1. d).

#### e) *Category-specific Recalculations*

There have been no source-specific recalculations.

#### f) *Category-specific Planned Improvements*

No improvements are planned.

### 4.4.3. Aluminum Production (2.C.3.)

#### 4.4.3.1. By-product emissions (2.C.3.-)

##### a) *Category Description*

CO<sub>2</sub> generated in association with aluminum smelting is emitted in conjunction with the oxidation of

the anode paste used as a reducing agent. PFCs are emitted during aluminum refining, due to the use of a fluoride melt consisting mainly of cryolite during electrolysis.

### b) Methodological Issues

#### ● Estimation Method

CO<sub>2</sub> emissions were estimated by multiplying the production amount of primary aluminum refining by the CO<sub>2</sub> emission factor per production amount, based on the Tier 1 method in the *2006 IPCC Guidelines*.

PFC emissions were estimated by multiplying the production amount of primary aluminum refining by Japan's country-specific emission factors calculated using the equation prescribed in the *2019 Refinements*. According to the Japan Aluminium Association, there is no aluminum production with low voltage anode effects in Japan.

Due to the lack of data necessary to estimate emissions for the years 1990 to 1994, estimates have been done by extrapolation etc of relevant data for these years.

#### ● Emission Factors

The default CO<sub>2</sub> EF (1.7 t-CO<sub>2</sub>/t (Soderberg technology)) in the *2006 IPCC Guidelines* was used.

The equation prescribed in the Tier 2a method of the *2019 Refinement*, and its associated slope coefficients set by technology, together with the weight fraction of gases was used to determine PFC emission factors, as shown in the table below. For the years 1990 to 1994, the emission factor for 1995 is used.

Table 4-50 PFC emission factors and aluminum production amounts

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
PFC-14 (CF <sub>4</sub> ) EF	kg-PFC-14/t	1.181	1.181	0.804	0.663	0.647	0.646	0.644	0.643	0.643	NA	NA	NA	NA	NA	NA
PFC-116 (C <sub>2</sub> F <sub>6</sub> ) EF	kg-PFC-116/t	0.091	0.091	0.062	0.051	0.050	0.050	0.050	0.050	0.050	NA	NA	NA	NA	NA	NA
Production of aluminium	t	34,100	17,338	6,500	6,490	4,670	4,670	4,075	2,950	588	0	0	0	0	0	0

Reference: *Yearbook of Minerals and Non-Ferrous Metals Statistics* (METI), *Documents of Fluorocarbons etc Measures Working Group*

#### ● Activity Data

The aluminum production amounts given in the *Yearbook of Minerals and Non-Ferrous Metals Statistics* compiled by the Ministry of Economy, Trade and Industry (1995 to 1997), and the *Documents of Fluorocarbons etc Measures Working Group* (previously the Group for Prevention of Global Warming, Chemical and Bio Sub-Group, Industrial Structure Council, Ministry of Economy, Trade and Industry) (1998 and beyond), were used. (Production ended in 2014.)

For the years 1990 to 1994, aluminum production amounts given in the *Yearbook of Minerals and Non-Ferrous Metals Statistics* compiled by the Ministry of Economy, Trade and Industry were used.

### c) Uncertainties and Time-series Consistency

#### ● Uncertainty

For the uncertainty of the CO<sub>2</sub> emission factor and uncertainty of the activity data, the respective default values of 10% and 2% in the *2006 IPCC Guidelines* were applied. As a result, the uncertainty of the emissions was determined to be 10%.

For the uncertainty of the PFC emission factor and uncertainty of the activity data, the respective default values of -47% to +28% in the *2019 Refinement* and 2% in the *2006 IPCC Guidelines* were applied. As



a result, the uncertainty of the emissions was determined to be  $-47\%$  to  $+28\%$ .

● **Time-series Consistency**

See section 4.3.9.1. c)

**d) Category-specific QA/QC and Verification**

See section 4.3.9.1. d)

**e) Category-specific Recalculations**

There have been no source-specific recalculations.

**f) Category-specific Planned Improvements**

No improvements are planned.

**4.4.3.2. F-gases used in foundries (2.C.3.-)**

Emission from this source was reported as “NO” as it has been confirmed that Japan had no record of the use of SF<sub>6</sub> in aluminum forging processes.

**4.4.4. Magnesium Production (2.C.4.)**

**a) Category Description**

HFCs and SF<sub>6</sub> are emitted in magnesium foundries, due to its use as cover gas to prevent oxidation of molten magnesium.

**b) Methodological Issues**

Emissions are an aggregation of all HFCs and SF<sub>6</sub> used by magnesium foundries. The data that has been reported is given in documentation prepared by the Fluorocarbons etc Measures Working Group, Group for Chemical Substance Policy, Manufacturing Industries Sub-Group of the Ministry of Economy, Trade and Industry’s Industrial Structure Council, for emissions of HFCs and SF<sub>6</sub> used in magnesium foundries. The associated indices are given in the table below.

Table 4-51 Indices related to HFCs and SF<sub>6</sub> emitted from magnesium foundries

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Consumption of HFC-134a	t	0	0	0	0	0	0.7	0.9	0.9	0.9	0.6	0.8	1.0	1.2	1.0	0.9
Consumption of SF <sub>6</sub>	t	6.4	5.0	43.0	48.4	12.9	8.0	8.0	7.0	8.0	10.0	13.8	10.8	12.0	11.0	13.0

Reference: Documents of Fluorocarbons etc Measures Working Group, Documents of the first meeting of the Breakout Group on F-gases (FY2013)

Due to the lack of data necessary to estimate emissions for the years 1990 to 1994, estimates have been done by using other die cast production amounts (excluding aluminium and zinc) which is thought to be proportional to molten magnesium amounts, and the consumption amount of SF<sub>6</sub> from 1995, and extrapolating for these years.

**c) Uncertainties and Time-series Consistency**

● **Uncertainty**

The uncertainty of emissions was set at the 5% value of the upper limit for the Tier 2 method in the 2006 IPCC Guidelines.

● **Time-series Consistency**

See section 4.3.9.1. c).

**d) Category-specific QA/QC and Verification**

See section 4.3.9.1. d).

**e) Category-specific Recalculations**

There have been no source-specific recalculations.

**f) Category-specific Planned Improvements**

No improvements are planned.

**4.4.5. Lead Production (2.C.5.)**

CO<sub>2</sub> generated from lead production are emitted by the oxidization of coke used as reductants. The amount of coke consumed as reductant used in lead production is included under "Direct heating purposes" (a fuel category under non-ferrous bare metal industry) in the *Yearbook of the Current Survey of Energy Consumption*. Since emissions are already accounted for under 1.A.2. Manufacturing industries and construction in the Energy sector, emissions are reported as IE. The thinking on where to account for CO<sub>2</sub> emissions from coke is the same as that for Iron and steel production.

**4.4.6. Zinc Production (2.C.6.)**

Similar to lead, CO<sub>2</sub> generated from zinc production are emitted by the oxidization of coke used as reductants. The amount of coke consumed as reductants used in zinc production is included under "Direct heating purposes" (a fuel category under non-ferrous bare metal industry) in the *Yearbook of the Current Survey of Energy Consumption*. Since emissions are already accounted for under 1.A.2. Manufacturing industries and construction in the Energy sector, emissions are reported as IE. The thinking on where to account for CO<sub>2</sub> emissions from coke is the same as that for Iron and steel production.

When Smithsonite (ZnCO<sub>3</sub>) which includes carbon in the ore are used as raw material, there is the possibility of CO<sub>2</sub> arising from the ore in the reduction process. However, there are currently no cases of Smithsonite use in Japan.

**4.4.7. Rare Earths Production (2.C.7.)**

CO<sub>2</sub> is emitted into the atmosphere from the consumption of carbon anodes in the electrolytic reaction which converts the raw material, rare earth oxides, to rare earth metals by molten salt electrolysis during rare earth metal and alloy smelting.

PFCs are also emitted from the reaction of the fluoride melt with the carbon in the anodes during the

anode effects due to the use of a fluoride melt consisting of rare earth fluorides and lithium fluoride. CO<sub>2</sub> and PFCs emissions estimated based on information provided by the Japan Society of Newer Metals regarding the rare earths smelting in Japan, and the Tier 1 methodology provided in the *2019 Refinement* does not exceed 3,000 t-CO<sub>2</sub> eq, which is the threshold to estimate in this GHG inventory decided by the Committee for GHG Emissions Estimation Methods. Therefore, it was reported as "NE" (considered insignificant) (See Annex 5).

#### 4.5. Non-energy Products from Fuels and Solvent Use (2.D.)

This category covers CO<sub>2</sub> emissions from the use of non-energy products from fuels and solvents. This section includes GHG emissions from the following sources: Lubricant use (2.D.1.), Paraffin wax use (2.D.2.), and Other (2.D.3.).

In FY2020, emissions from this category were 2,344 kt-CO<sub>2</sub> eq. and represented 0.2% of Japan's total GHG emissions (excluding LULUCF). The emissions had increased by 14.9% compared to FY1990.

Table 4-52 Emissions from 2.D. Non-energy Products from Fuels and Solvent Use

Gas		Units	1990	1995	1999	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020		
CO <sub>2</sub>	2.D.1	Lubricant use	kt-CO <sub>2</sub>	343	353	350	350	324	303	284	259	263	243	230	233	253	252	243		
	2.D.2	Paraffin wax use	kt-CO <sub>2</sub>	50	37	41	36	36	35	30	27	28	26	25	24	24	26	27	23	
	2.D.3	Other	Urea-based catalysts	kt-CO <sub>2</sub>	NO	NO	NO	NO	0.12	0.98	1.57	2.46	3.51	4.76	5.69	5.79	6.87	8.04	9.41	9.99
			NMVOc incineration	kt-CO <sub>2</sub>	1,648	1,986	2,233	2,273	2,504	2,410	2,385	2,261	2,385	2,234	2,213	2,323	2,426	2,371	2,273	2,068
	Total			kt-CO <sub>2</sub>	2,040	2,377	2,624	2,659	2,865	2,748	2,701	2,551	2,685	2,527	2,486	2,583	2,689	2,658	2,561	2,344

##### 4.5.1. Lubricant Use (2.D.1.)

###### a) Category Description

CO<sub>2</sub> is emitted from the oxidation of lubricants and grease during use. Emissions from the total loss type of engine oil are reported in the energy sector (See 1.A.3.), and emissions from other types than the above-mentioned type of engine oil are reported under this sector.

###### b) Methodological Issues

###### ● Estimation Method

Emissions were calculated by multiplying lubricant and grease consumption amounts per oil type, by the carbon content and oxidation during use (ODU) factor per oil type, based on the Tier 2 method given in the *2006 IPCC Guidelines*. (See below)

$$E = \sum_i (LC_i \times CC_i \times ODU_i \times 44/12)$$

$E$  : Emissions from the oxidation of lubricants and grease during use [kt-CO<sub>2</sub>]

$LC_i$  : Lubricant and grease consumption amounts [TJ]

$CC_i$  : Carbon content of fuel [kt-C/TJ]

$ODU_i$  : ODU factor for oil

$i$  : Type of lubricant and grease

###### ● Emission Factors

For carbon content, the carbon emission factors of lubricants and heavy oil products in the *General Energy Statistics* (ANRE) are used. For the ODU factor, the default values in the *2006 IPCC Guidelines* are used. (lubricants: 0.2, grease: 0.05)

- **Activity Data**

For lubricants, the consumption amounts for types other than total loss types of engine oil are calculated by subtracting the consumption amounts of the total loss type from the total of consumption amounts of engine oil. (See section 3.2.8. Activity data)

For grease, the consumption amounts are calculated by multiplying the domestic sales amounts in the *Yearbook of Mineral Resources and Petroleum Products Statistics* and the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, by the calorific values of heavy oil products in the *General Energy Statistics*. However, for years FY1992 to FY1999, the domestic sales data are not available from these statistics. Therefore, the domestic sales for these years are estimated by subtracting the total of exports and stocks at the end of the year, from the total of stocks at the start of the year and production and imports, which are respectively shown in these statistics.

Table 4-53 Consumption of engine oil (for types other than total loss types) and grease

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Consumption of engine oil (for types other than total loss types)	TJ	23,449	24,385	24,144	22,298	20,768	19,476	17,756	17,788	17,384	15,998	15,168	15,389	16,790	16,754	16,184
Consumption of grease	TJ	3,152	2,503	2,435	2,658	2,622	2,573	2,397	2,478	2,486	2,464	2,337	2,164	2,146	1,945	1,863

- c) **Uncertainties and Time-series Consistency**

- **Uncertainty**

For the uncertainty of emission factors, a 50% default value in the *2006 IPCC Guidelines* was applied for both lubricants and grease. For the uncertainty of the activity data, a 5% default value in the *2006 IPCC Guidelines* was applied for both lubricants and grease. As a result, the uncertainty of emissions was assessed to be 50% for both lubricants and grease.

- **Time-series Consistency**

For activity data, the same source the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* etc are used throughout the time series. The emission factors are constant throughout the time series.

- d) **Category-specific QA/QC and Verification**

See section 4.2.1. d).

- e) **Category-specific Recalculations**

Recalculations occurred for FY2018 and FY2019, due to updates made to the consumption of lubricants. See Chapter 10 for impact on trend.

- f) **Category-specific Planned Improvements**

No improvements are planned.

#### 4.5.2. Paraffin Wax Use (2.D.2.)

- a) **Category Description**

CO<sub>2</sub> is emitted from the oxidation of paraffin wax during use.

**b) Methodological Issues****● Estimation Method**

Emissions were calculated based on the Tier 1 method given in the *2006 IPCC Guidelines*. (See below)

$$E_{CO_2} = PW \times CC_{Wax} \times ODU_{Wax} \times 44/12$$

$E_{CO_2}$  : Emissions from paraffin wax during use [t-CO<sub>2</sub>]

$PW$  : Paraffin wax consumption amounts [TJ]

$CC_{Wax}$  : Carbon content of paraffin wax [kg-C/GJ]

$ODU_{Wax}$  : ODU factor for paraffin wax

**● Emission Factors**

For carbon content, the carbon emission factor of heavy oil products in the *General Energy Statistics* (ANRE) is used. For the ODU factor, the default value in the *2006 IPCC Guidelines* is used. (0.2)

**● Activity Data**

The consumption amounts are calculated by multiplying the domestic sales amounts in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* and *Yearbook of Mineral Resources and Petroleum Products Statistics*, by the calorific values of heavy oil products in the *General Energy Statistics*.

**c) Uncertainties and Time-series Consistency****● Uncertainty**

For the uncertainty of emission factors, a 100% default value in the *2006 IPCC Guidelines* was applied. For the uncertainty of the activity data, a 5% default value in the *2006 IPCC Guidelines* was applied. As a result, the uncertainty of emissions was assessed to be 100%.

**● Time-series Consistency**

For activity data, the same source—the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* etc are used throughout the time series. The emission factors are constant throughout the time series.

**d) Category-specific QA/QC and Verification**

See section 4.2.1. d).

**e) Category-specific Recalculations**

Recalculations occurred for FY2018 and FY2019, due to updates made to the *General Energy Statistics*. See Chapter 10 for impact on trend.

**f) Category-specific Planned Improvements**

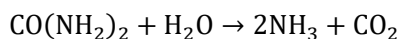
No improvements are planned.

### 4.5.3. Other (2.D.3.)

#### 4.5.3.1. Urea used as a catalyst (2.D.3.-)

##### a) Category Description

The urea SCR system for cars is a technology to reduce NOx emissions, by the reduction of NOx in exhaust gas using ammonia and decomposing it into N<sub>2</sub> and H<sub>2</sub>O. By spraying urea aqueous into high temperature exhaust gas, this is hydrolyzed to yield ammonia gas, and CO<sub>2</sub> is emitted as follows.



##### b) Methodological Issues

###### ● Estimation Method

Emissions were calculated based on the *2006 IPCC Guidelines*. (See below)

$$E_{\text{CO}_2} = AD \times 12/60 \times P \times 44/12$$

*AD* : Consumption amount of urea-based additives in urea SCR systems [kt]

*P* : Ratio of urea in urea-based additives [%] (Default value: 32.5%)

###### ● Emission Factors

For the Ratio of urea in urea-based additives (*P*), the default value of 32.5% in the *2006 IPCC Guidelines* is used.

###### ● Activity Data

The cumulative number of cars with urea SCR systems (data provided by the Japan Automobile Manufacturers Association) is first multiplied by the consumption amount of diesel oil per car, and then further multiplied by ratio of consumption amount of urea-based additives to diesel, to yield the consumption amount of urea-based additives. This is then multiplied by the ratio of imports to the domestic total consumption to finally yield the consumption amount of urea-based additives for imports only<sup>6</sup>.

$$AD = N \times L \times R \times D \times I$$

*AD* : Consumption amount of urea -based additives in urea SCR systems [kt]

*N* : Cumulative number of cars with urea SCR systems [thousand cars]

*L* : Consumption amount of diesel oil per car [kL/car]

*R* : Ratio of consumption amount of urea-based additives to diesel [%]

*D* : Density of diesel oil [t/kL]

*I* : Ratio of imports [%]

<sup>6</sup> Domestically produced urea is from CO<sub>2</sub> recovered from ammonia production processes, and therefore the CO<sub>2</sub> associated with it is already included in 2.B.1. Ammonia production emissions.

Table 4-54 Parameters used to calculate the consumption amount of urea -based additives, and their sources and methods of establishment

Item	Sources and methods of establishment
Cumulative number of cars with urea SCR systems [thousand cars]	Data provided by the Japan Automobile Manufacturers Association
Consumption amount of diesel oil per car [kL/car]	Calculated by dividing the total consumption amount of diesel based on the <i>Statistical Yearbook of Motor Vehicle Transport</i> and <i>Statistical Yearbook of Motor Vehicle Fuel Consumption</i> (Ministry of Land, Infrastructure, Transport and Tourism) by the total number of registered cars
Ratio of consumption amount of urea-based additives to diesel [%]	2%, as a median value of 1 to 3 % in the <i>2006 IPCC Guidelines</i>
Density of diesel oil [t/kL]	0.8831 t/kL, based on the <i>Handbook on the General Energy Statistics</i> (RIETI)
Ratio of imports [%]	Ratio of urea imports to (domestic shipment amounts + imports) for each year, based on the <i>Yearbook of Fertilizer Statistics (Pocket Edition)</i> (Ministry of Agriculture, Forestry and Fisheries)

### c) *Uncertainties and Time-series Consistency*

#### ● *Uncertainty*

For the uncertainty of emission factor, a 5% default value in the *2006 IPCC Guidelines* (cars - combustion origin) was applied. For the uncertainty of the activity data, a 5% default value in the *2006 IPCC Guidelines* was applied. As a result, the uncertainty of emissions was assessed to be 7%.

#### ● *Time-series Consistency*

For activity data, the same source-data provided by the Japan Automobile Manufacturers Association etc are used throughout the time series. The emission factors are constant throughout the time series.

### d) *Category-specific QA/QC and Verification*

See section 4.2.1. d).

### e) *Category-specific Recalculations*

There have been no source-specific recalculations.

### f) *Category-specific Planned Improvements*

No improvements are planned.

## 4.5.3.2. NMVOC Incineration (2.D.3.-)

### a) *Category Description*

CO<sub>2</sub> is emitted in the process of NMVOC incineration from facilities etc that use solvents.

### b) *Methodological Issues*

#### ● *Estimation Method*

CO<sub>2</sub> emissions from NMVOC incineration were calculated, for five use types - Paint, Cleansing agents, Printing, Chemical products, and Other, by estimating the domestic supply of solvents, the emissions into the atmosphere, the material recycle amounts, and then subtracting emissions into the atmosphere and the material recycle amounts from the domestic supply of solvents, to yield the amounts incinerated.

CO<sub>2</sub> emissions from the incineration of some used solvents are already accounted for in the energy sector (alternative fuel use) and waste sector (waste incineration without energy recovery), and therefore are subtracted out from emissions in this category.

$$E_{CO_2} = \sum_i (I_i \times C_i \times 44/12)$$

$E_{CO_2}$  : CO<sub>2</sub> emissions from NMVOC incineration [t]  
 $I_i$  : NMVOC incineration amounts for use type i [t]  
 $C_i$  : Average carbon content of NMVOCs for use type i

$$I_i = S_i - E_i - R_i$$

$I_i$  : NMVOC incineration amounts for use type i [t]  
 $S_i$  : Domestic supply of solvents for use type i [t]  
 $E_i$  : NMVOC emissions into the atmosphere for use type i [t]  
 $R_i$  : Material recycle amounts for use type i [t]

### ● **Emission Factors**

The average carbon content is calculated by weighting it by the composition rate of each NMVOC substance emitted from each source. (Same values are used as those for conversion to indirect CO<sub>2</sub>) The carbon contents of each substance is obtained from molecular formulae, and the type of substance and composition rate of NMVOCs are estimated based on the national emission inventory for volatile organic compounds (VOC) by the Ministry of Environment and other information. From FY2015, an average carbon content for this category (0.64) is used.

### ● **Activity Data**

Parameters are set as follows:

#### ➤ **Domestic supply of solvents for use type i**

For paint, the data for total amount of solvents in paint from the *Compilation of Estimation Results of VOC Emissions from Paint* (Japan Paint Manufacturers Association), and shipment amounts of thinners for paint given in the *Survey on the Actual Conditions of the Paint Manufacturing Industry* (Japan Paint Manufacturers Association) etc, were used. For cleansing agents, printing, chemical products, and other, the data for national sales amounts of solvents by use from the *VOC Emission Inventory Report* (Ministry of the Environment, March 2007), and demand for 'other' use of acetone from the *Petrochemical Industry of Japan* (The Heavy and Chemical Industries News Agency) etc, were used. (For years lacking data, interpolation or extrapolation using product sales amounts etc was applied to estimate)

#### ➤ **NMVOC emissions into the atmosphere for use type i**

For NMVOC emissions into the atmosphere  $E_i$ , NMVOC emissions by source was used. (For details of estimation methods, see Annex 3)

#### ➤ **Material recycle amounts for use type i**

The material recycle amounts of solvents for use type i in the year FY2011 was first estimated by multiplying the supply of solvents for use type i in the year FY2011, by the ratio of external recycle amounts for use type i in the year FY2011 (*Survey on Organic Solvents Use and Emission Treatment*, Japan Solvent Recycling Industry Association, May, 2012) to the solvent supply amounts for use type i in the year FY2011. This was then multiplied by the growth rate (based on the *Survey on Solvent Recycle Amounts*, Japan Solvent Recycling Industry Association) of solvent collection amounts from FY2011.



Table 4-55 NMVOC incineration amounts by use type

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Paints	kt	266	289	331	339	296	262	264	263	260	285	303	329	308	304	298
Cleaning agents	kt	85	100	90	108	65	67	44	45	48	46	53	55	55	57	59
Printing solvents	kt	172	195	237	234	231	235	235	232	220	219	210	210	202	191	166
Chemical products	kt	51	79	131	150	182	183	179	190	183	193	201	204	210	197	176
Other	kt	155	208	209	302	336	336	331	366	346	367	381	394	399	388	343

### c) *Uncertainties and Time-series Consistency*

#### ● *Uncertainty*

For the uncertainty of emission factor, a 2%, uncertainty of the specially controlled industrial waste (waste oil) was applied. For the uncertainty of activity data, a 60%, uncertainty of the specially controlled industrial waste (waste oil) was applied. As a result, the uncertainty of emissions was assessed to be 60%.

#### ● *Time-series Consistency*

Consistent activity data and emission factors are used throughout the time series as much as possible.

### d) *Category-specific QA/QC and Verification*

See section 4.2.1. d).

### e) *Category-specific Recalculations*

The amounts of domestic supply of solvents and NMVOC emissions into the atmosphere were updated due to updates in the *VOC Inventory* and the *Yearbook of Current Production Statistics - Chemical Industry*, etc, resulting in recalculations for FY2015 to FY2018. See Chapter 10 for impact on trend.

### f) *Category-specific Planned Improvements*

No improvements are planned.

#### 4.5.3.3. Road Paving with Asphalt (2.D.3.-)

Roads in Japan are paved with asphalt, but almost no CO<sub>2</sub> are thought to be emitted in the process. It is not possible, however, to be completely definitive about the absence of emissions. Emissions have also never been actually measured, and as no default emission factor is available, it is not currently possible to calculate emissions.

#### 4.5.3.4. Asphalt Roofing (2.D.3.-)

Asphalt roofing is manufactured in Japan, but information on the manufacturing process and activity data is inadequate, and it is not possible to definitively conclude that CO<sub>2</sub> is not emitted from the manufacturing of asphalt roofing. Emissions have also never been actually measured, and as no default emission factor is available, it is not currently possible to calculate emissions.

#### 4.6. Electronics Industry (2.E.)

This category covers HFC, PFC, SF<sub>6</sub>, and NF<sub>3</sub> emissions from the manufacturing of the electronic devices. This section includes GHG emissions from the following sources: Semiconductor (2.E.1.), Liquid Crystals (2.E.2.), Photovoltaics (2.E.3.), and Heat transfer fluid (2.E.4.).

In 2020, emissions from Electronics industry were 2,595 kt-CO<sub>2</sub> eq., and represented 0.2% of Japan's total GHG emissions (excluding LULUCF). The emissions had increased by 36.3% compared to 1990.

Table 4-56 Emissions from 2.E. Electronics Industry

Gas	Units		1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
HFCs	2.E.1	Semiconductor	kt-CO <sub>2</sub> eq.	1	271	283	224	165	142	122	109	113	113	117	123	113	99	108
	2.E.2	Liquid crystals	kt-CO <sub>2</sub> eq.	0.001	0.3	2	3	3	3	2	2	2	2	2	2	2	2	1
	Total		kt-CO <sub>2</sub> eq.	1	271	285	227	168	145	124	112	115	115	119	125	115	101	109
PFCs	2.E.1	Semiconductor	kt-CO <sub>2</sub> eq.	1,423	3,933	6,771	4,594	2,214	1,863	1,624	1,556	1,617	1,582	1,721	1,847	1,776	1,676	1,811
	2.E.2	Liquid crystals	kt-CO <sub>2</sub> eq.	31	87	214	152	46	59	68	76	90	86	71	84	79	75	77
	Total		kt-CO <sub>2</sub> eq.	1,455	4,020	6,986	4,746	2,261	1,922	1,692	1,631	1,707	1,669	1,792	1,931	1,856	1,752	1,888
SF <sub>6</sub>	2.E.1	Semiconductor	t	13.56	17.54	27.58	23.69	9.86	8.62	8.05	7.96	7.66	8.07	8.43	8.77	7.99	7.62	8.13
	2.E.2	Liquid crystals	t	4.81	6.22	38.48	31.22	11.79	8.68	7.55	7.45	8.38	8.39	6.87	7.13	7.32	6.45	6.09
	Total		t	18.36	23.77	66.05	54.91	21.65	17.30	15.60	15.41	16.04	16.46	15.30	15.90	15.31	14.08	14.22
	Total		kt-CO <sub>2</sub> eq.	419	542	1,506	1,252	494	394	356	351	366	375	349	363	349	321	324
NF <sub>3</sub>	2.E.1	Semiconductor	t	1.59	9.78	5.79	9.36	11.09	10.16	10.29	6.38	7.67	8.41	10.65	11.26	11.83	13.00	14.81
	2.E.2	Liquid crystals	t	0.15	0.91	3.83	4.10	1.53	1.41	1.21	1.24	1.52	1.29	1.14	1.28	1.23	1.09	1.10
	Total		t	1.73	10.69	9.61	13.47	12.62	11.57	11.50	7.63	9.20	9.70	11.79	12.54	13.05	14.08	15.91
	Total		kt-CO <sub>2</sub> eq.	30	184	165	232	217	199	198	131	158	167	203	216	225	242	274
Total of All Gases			kt-CO <sub>2</sub> eq.	1,904	5,016	8,941	6,457	3,140	2,661	2,370	2,225	2,346	2,326	2,463	2,634	2,544	2,416	2,595

##### 4.6.1. Semiconductor (2.E.1.)

###### a) Category Description

HFCs, PFCs, SF<sub>6</sub>, and NF<sub>3</sub> are emitted from the manufacturing of semiconductors.

###### b) Methodological Issues

###### ● Estimation Method

The Tier 2a method of the *2006 IPCC Guidelines* is used to estimate emissions from semiconductors. These emissions are estimated with purchased amount of F-gases, process supply rates, use rates of F-gases, fractions of gas destroyed, by-product generation rates and fractions of gas destroyed for by-products. Default values are applied for the use rate of F-gases and the by-product generation rates.

Regarding the treatment of the 10% residue after process supply, these emissions are reported under this category when there is a 90% recharging and subsequent shipment. In cases of decomposing the residual 10% and cleansing the containment shell, or release into the atmosphere, these emissions are reported under "2.B.9. Fluorochemical production – fugitive emissions".

Japan Electronics and Information Technology Industries Association data are used for F-gases purchased.

Methods below are applied for each gas.

$$E = FC \times P \times (1 - U) \times (1 - a \times d)$$

$E$  : HFC-23, PFCs (PFC-14, PFC-116, PFC-218, PFC-c318), SF<sub>6</sub>, and NF<sub>3</sub> emissions

$FC$  : Purchased amount of gas

- $P$  : Process supply rate  
 $U$  : Use rate of gas  
 $a$  : Fraction of gas controlled  
 $d$  : Fraction of gas destroyed

$$BPE = FC \times B \times P \times (1 - a \times d)$$

- $BPE$  : By-produced PFC-14 etc emissions  
 $FC$  : Purchased amount of gas  
 $B$  : By-production rate  
 $P$  : Process supply rate  
 $a$  : Fraction of gas controlled  
 $d$  : Fraction of gas destroyed

Relevant indices are shown in Table below. The fraction of gas controlled is not reported here due to confidentiality reasons.

Table 4-57 Indices related to emissions of F-gases from manufacturing of semiconductors

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
HFC-23 purchased	t	0.1	47.8	49.4	42.1	67.1	68.4	66.7	66.7	77.2	86.2	83.2	84.3	85.2	72.7	81.0
PFC-14 purchased	t	113.3	313.0	299.9	231.5	265.3	248.3	222.4	218.1	253.6	285.5	317.1	365.1	376.3	369.1	406.9
PFC-116 purchased	t	75.8	209.5	561.2	393.2	194.3	159.9	139.4	117.8	105.5	96.4	102.3	126.1	92.6	80.4	86.0
PFC-218 purchased	t	0.01	0.03	9.9	181.8	167.0	137.0	115.5	106.1	117.2	110.9	107.6	130.1	127.0	107.9	105.9
PFC-c318 purchased	t	0.2	0.6	38.6	24.8	35.8	36.8	39.7	42.2	52.6	63.3	70.4	106.6	166.8	208.3	265.9
SF <sub>6</sub> purchased	t	70.1	90.8	131.9	96.8	76.7	65.2	63.7	57.6	64.9	68.0	73.4	86.5	87.2	84.3	95.9
NF <sub>3</sub> purchased	t	8.8	54.4	106.3	406.7	860.7	834.5	880.5	905.4	1,055.3	1,232.1	1,310.1	1,597.4	1,876.3	2,009.7	2,282.7
Process supply rate	%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%
Use rate of PFC etc	%	10 - 98 %														
Fraction of PFCs, and SF <sub>6</sub> destroyed	%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%
Fraction of NF <sub>3</sub> destroyed	%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%
CF <sub>4</sub> etc by-production rate	%	2 - 20 %														
By-product CF <sub>4</sub> etc removal rate	%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%
HFC emissions	kt-CO <sub>2</sub> eq.	1	271	283	224	165	142	122	109	113	113	117	123	113	99	108
PFC emissions	kt-CO <sub>2</sub> eq.	1,423	3,933	6,771	4,594	2,214	1,863	1,624	1,556	1,617	1,582	1,721	1,847	1,776	1,676	1,811
SF <sub>6</sub> emissions	kt-CO <sub>2</sub> eq.	309	400	629	540	225	196	184	181	175	184	192	200	182	174	185
NF <sub>3</sub> emissions	kt-CO <sub>2</sub> eq.	27	168	100	161	191	175	177	110	132	145	183	194	203	224	255

Reference: the Documents of Fluorocarbons etc Measures Working Group, and data provided by the Ministry of Economy, Trade and Industry, Documents of the first meeting of the Breakout Group on F-gases (FY2013)

Table 4-58 Use rate of gases during semiconductor manufacturing

Gas	Use rate
HFC-23	60%
PFC-14	10%
PFC-116	40%
PFC-218	60%
PFC-c318	90%
SF <sub>6</sub>	80%
NF <sub>3</sub>	80%
NF <sub>3</sub> remote	98%

Reference: Default values from the 2006 IPCC Guidelines (Table 6.3 Tier 2a)

Table 4-59 CF<sub>4</sub> and C<sub>2</sub>F<sub>6</sub> by-production rate during semiconductor manufacturing

Gas	CF <sub>4</sub> by-production rate	C <sub>2</sub> F <sub>6</sub> by-production rate
HFC-23	7%	NA
PFC-116	20%	NA
PFC-218	10%	NA
PFC-c318	10%	10%
NF <sub>3</sub>	9%	NA
NF <sub>3</sub> remote	2%	NA

Reference: Default values from the 2006 IPCC Guidelines (Table 6.3 Tier 2a)

Due to the lack of data necessary to estimate emissions for the years 1990 to 1994, estimates have been done by using available domestic HFC, PFC, and SF<sub>6</sub> shipment amount, and NF<sub>3</sub> production

amount data which is thought to be proportional to HFC, PFC, SF<sub>6</sub>, and NF<sub>3</sub> emissions, and extrapolating for these years.

**c) Uncertainties and Time-series Consistency**

● **Uncertainty**

For the uncertainties of the emission factors, *2006 IPCC Guidelines* default values of 100%, 80%, 300%, and 70% were respectively applied for HFCs, PFCs, SF<sub>6</sub>, and NF<sub>3</sub>. For the uncertainties of the activity data, 10% was applied for all HFCs, PFCs, SF<sub>6</sub>, and NF<sub>3</sub>, using the upper limit value in the *2006 IPCC Guidelines*. As a result, the uncertainties of the emissions for HFCs, PFCs, SF<sub>6</sub>, and NF<sub>3</sub>, were determined to be 100%, 81%, 300%, and 71%, respectively.

● **Time-series Consistency**

See section 4.3.9.1. c).

**d) Category-specific QA/QC and Verification**

See section 4.3.9.1. d).

**e) Category-specific Recalculations**

There have been no source-specific recalculations.

**f) Category-specific Planned Improvements**

No improvements are planned.

**4.6.2. Liquid Crystals (2.E.2.)**

**a) Category Description**

HFCs, PFCs, SF<sub>6</sub>, and NF<sub>3</sub> are emitted from the manufacturing of liquid crystals.

**b) Methodological Issues**

● **Estimation Method**

Methods applied to semiconductors are also applied to emissions from manufacturing of liquid crystals. In principle, default values are applied for the use rate of F-gases and the by-product generation rates. World LCD Industry Cooperation Committee has established a voluntary action plan to reduce PFC emissions and has engaged in reducing PFC emissions. In these activities, IPCC methods should be applied.

Relevant indices are shown in Table below. The fraction of gas controlled is not reported here due to confidentiality reasons.

Table 4-60 Indices related to emissions of F-gases from manufacturing of liquid crystals

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
HFC-23 purchased	t	0.0003	0.1	0.7	1.6	1.1	1.2	1.0	1.3	1.5	1.1	1.1	1.1	1.3	1.2	0.9
PFC-14 purchased	t	7.5	20.7	47.3	77.8	93.7	124.3	121.1	154.5	191.7	177.1	151.8	185.0	176.4	164.0	174.9
PFC-116 purchased	t	0.1	0.4	2.7	9.9	0	0	0	0	0	0	0	0	0	0	0
PFC-c318 purchased	t	0	0	0	0.8	1.6	1.9	1.7	1.4	1.8	1.1	1.1	1.1	0.6	0.9	0.9
SF <sub>6</sub> purchased	t	8.9	11.5	85.3	101.4	176.9	129.0	104.1	107.4	126.2	126.6	109.6	116.4	117.0	98.6	95.1
NF <sub>3</sub> purchased	t	1.3	8.1	106.9	232.2	764.1	718.0	668.0	783.8	918.9	808.0	691.9	813.2	767.0	664.5	718.1
Process supply rate	%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%
Use rate of PFCs etc	%	40 - 97 %														
Fraction of PFCs, and SF <sub>6</sub> destroyed	%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%
Fraction of NF <sub>3</sub> destroyed	%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%
CF <sub>4</sub> etc by-production rate	%	0.9 - 7 %														
By-product CF <sub>4</sub> etc removal rate	%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%
HFC emissions	kt-CO <sub>2</sub> eq.	0.0007	0.3	2	3	3	3	2	2	2	2	2	2	2	2	1
PFC emissions	kt-CO <sub>2</sub> eq.	31	87	214	152	46	59	68	76	90	86	71	84	79	75	77
SF <sub>6</sub> emissions	kt-CO <sub>2</sub> eq.	110	142	877	712	269	198	172	170	191	191	157	163	167	147	139
NF <sub>3</sub> emissions	kt-CO <sub>2</sub> eq.	3	16	66	71	26	24	21	21	26	22	20	22	21	19	19

Reference: Documents of Fluorocarbons etc Measures Working Group, Documents of the first meeting of the Breakout Group on F-gases (FY2013)

Table 4-61 Use rate of gases during liquid crystal manufacturing

Gas	Use rate
HFC-23	80%
PFC-14	40%
PFC-116	0%
PFC-c318	90%
SF <sub>6</sub>	40%
NF <sub>3</sub>	70%
NF <sub>3</sub> remote	97%

Reference: Default values from the 2006 IPCC Guidelines (Table 6.4 Tier 2a). Since there is no default for PFC-116, 0% was used so as not to underestimate emissions.

Table 4-62 CHF<sub>3</sub>, CF<sub>4</sub>, and C<sub>2</sub>F<sub>6</sub>, by-production rate during liquid crystal manufacturing

Gas	CHF <sub>3</sub> by-production rate	CF <sub>4</sub> by-production rate	C <sub>2</sub> F <sub>6</sub> by-production rate
HFC-23	NA	7%	5%
PFC-c318	2%	0.9%	NA

Reference: Default values from the 2006 IPCC Guidelines (Table 6.4 Tier 2a)

Due to the lack of data necessary to estimate emissions for the years 1990 to 1994, estimates have been done by using available domestic HFC, PFC, SF<sub>6</sub> shipment, and NF<sub>3</sub> production amount data which is thought to be proportional to HFC, PFC, SF<sub>6</sub>, and NF<sub>3</sub> emissions, and extrapolating for these years.

### c) Uncertainties and Time-series Consistency

#### ● Uncertainty

See section 4.6.1. c).

#### ● Time-series Consistency

See section 4.3.9.1. c).

### d) Category-specific QA/QC and Verification

See section 4.3.9.1. d).

### e) Category-specific Recalculations

There have been no source-specific recalculations.

**f) Category-specific Planned Improvements**

No improvements are planned.

**4.6.3. Photovoltaics (2.E.3.)**

Photovoltaics manufacturing using PFCs is only done by one company inside Japan. Therefore, emissions are confidential and included in PFC emissions from semiconductor manufacturing and reported as “IE”.

**4.6.4. Heat Transfer Fluid (2.E.4.)**

In the process of electronics manufacturing, fluorinated compounds are used for temperature control. These fluorinated compounds are released through evaporative losses during the cooling of process equipment etc. Emissions were reported as “IE” since PFCs in this category are included in the total reported in 4.7.5. Solvents (2.F.5.), where liquid PFCs etc are collectively captured.

**4.7. Product Uses as Substitutes for ODS (2.F.)**

This category covers HFC and PFC emissions from the use of the products that are substitutes for ozone depleting substances (ODS). This section includes GHG emissions from the following sources: Refrigeration and air conditioning (2.F.1.), Foam blowing agents (2.F.2.), Fire protection (2.F.3.), Aerosols (2.F.4.), and Solvents (2.F.5.).

In 2020, emissions from this category were 52,855 kt-CO<sub>2</sub> eq., and represented 4.6% of Japan’s total GHG emissions (excluding LULUCF). The emissions are 11.6 times of 1990.

Table 4-63 Emissions from 2.F. Product uses as substitutes for ODS

Gas		Units	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
HFCs	2.F.1	Refrigeration and air conditioning	kt-CO <sub>2</sub> eq.	NO	925	2,976	8,875	20,493	23,153	26,369	29,024	32,553	35,893	38,972	41,167	43,234	45,815	47,678
	2.F.2	Foam blowing agents	kt-CO <sub>2</sub> eq.	1	497	484	937	1,749	1,923	2,081	2,229	2,373	2,484	2,651	2,801	2,922	2,979	2,925
	2.F.3	Fire protection	kt-CO <sub>2</sub> eq.	NO	NO	5	7	8	8	9	9	9	9	10	10	10	10	10
	2.F.4	Aerosols	kt-CO <sub>2</sub> eq.	NO	1,502	3,117	1,695	666	634	561	489	503	540	587	600	544	572	659
	2.F.5	Solvents	kt-CO <sub>2</sub> eq.	NO	NO	NO	6	60	86	94	109	122	126	130	116	117	122	127
		Total	kt-CO <sub>2</sub> eq.	1	2,923	6,582	11,521	22,977	25,805	29,113	31,860	35,560	39,052	42,349	44,694	46,827	49,498	51,398
PFCs	2.F.5	Solvents	kt-CO <sub>2</sub> eq.	4,550	12,572	3,200	2,815	1,721	1,605	1,583	1,518	1,537	1,517	1,465	1,484	1,505	1,558	1,457
Total of All Gases			kt-CO <sub>2</sub> eq.	4,551	15,495	9,782	14,336	24,698	27,410	30,696	33,378	37,097	40,569	43,814	46,178	48,332	51,056	52,855

**4.7.1. Refrigeration and Air Conditioning Equipment (2.F.1.)****4.7.1.1. Domestic Refrigeration Production, Use and Disposal (2.F.1.-)****a) Category Description****1) HFCs**

HFCs are emitted from the production, use (including failure of devices), and disposal of domestic refrigeration.

## 2) PFCs

Emission from this source in the “production” category was reported as “NO” as Japan had no record of their use in the production of the products. The emission was also reported as “NO” in the “use” and “disposal” categories, because it was unlikely that PFCs were used in imported products, or refrigerants were refilled.

### b) Methodological Issues

#### ● Estimation Method

1) Fugitive refrigerants during manufacturing, 2) fugitive refrigerants during use (including failure of devices), and 3) refrigerants contained at the time of disposal minus the amount of HFCs collected under law were estimated separately and then were summed up.

Emissions from use and disposal were estimated by summing up the values calculated for each year of the production of devices. Emission factors are country-specific.

$$E_{total} = M_{manufacturing} \times k + \sum (N_{operated} \times m_{operation} \times x_{operation}) + \sum (N_{disposed} \times m_{disposal}) - R$$

$E_{total}$	: HFC emissions from domestic refrigeration
$M_{manufacturing}$	: Total refrigerant contained at production
$k$	: Fugitive refrigerant ratio at production
$N_{operated}$	: Number of operated devices containing HFCs
$m_{operation}$	: Refrigerant contained per operated device
$x_{operation}$	: Fugitive refrigerant ratio from use
$N_{disposed}$	: Number of disposed devices containing HFCs
$m_{disposal}$	: Refrigerant contained per disposed device
$R$	: Collected amount of HFCs

The associated indices are given in the table below.

Table 4-64 Indices related to emissions of HFCs from domestic refrigeration

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Total HFCs charged in the year of production	t	NO	520	590	0.3	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Fugitive refrigerant ratio at production	%	1%	1%	1%	0.2%	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Number of operated HFC devices	1,000 devices	NO	7,829	33,213	41,796	28,085	24,509	20,984	17,637	14,520	11,691	9,182	7,045	5,280	3,862	2,747
Refrigerant charged per device at production	g	150	150	125	125	125	125	125	125	125	125	125	125	125	125	125
Operational fugitive ratio (including failure)	%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%
Number of HFC devices disposed	1,000 devices	NO	NO	177	1,839	3,588	3,600	3,456	3,204	2,850	2,451	2,027	1,620	1,249	929	672
Amount of HFCs collected under law	t/year	—	—	—	52	111	160	169	189	166	144	138	132	136	132	128
Emissions from manufacturing	kt-CO <sub>2</sub> eq.	NO	7	8	0.001	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Emissions from stocks	kt-CO <sub>2</sub> eq.	NO	5	18	22	15	13	11	9	8	6	5	4	3	2	1
Emissions from disposal	kt-CO <sub>2</sub> eq.	NO	NO	31	246	460	391	352	279	251	213	149	87	18	NO	NO
Emissions	kt-CO <sub>2</sub> eq.	NO	12	57	269	475	404	364	289	258	219	154	91	21	2	1

Reference: the Documents of Fluorocarbons etc Measures Working Group, Documents of the first meeting of the Breakout Group on F-gases (FY2013)

Note: Emissions from disposal were estimated by summing up the values calculated for each year of the production of devices, and therefore the refrigerant contained per disposed device cannot be easily provided. However, based on the premise that refrigerators are sealed tight, the refrigerant contained per disposed device in the estimation model is considered equal to refrigerant charged per device.

Due to the lack of data necessary to estimate emissions for the years 1990 to 1994, estimates have been done by using domestic refrigeration shipment amounts, the ratio of devices with HFCs, and HFCs charged per shipment amount (derived from shipment amounts from 1995, the ratio of devices with HFCs from 1995, and total HFCs charged during production from 1995), fugitive refrigerant ratio at production from 1995, refrigerant charged per device at production from 1995, operational fugitive ratio from 1995, number of HFC devices disposed from 1995, and extrapolating etc for these years.

**c) Uncertainties and Time-series Consistency**

● **Uncertainty**

For the uncertainties of the emission factors, the 30% upper limit value for electrical equipment in the 2006 IPCC Guidelines was applied for production and use. For the uncertainties of the activity data, the 10% value of the Tier 2 method for metal industry in the 2006 IPCC Guidelines was applied for production, use, and disposal. As a result, the uncertainties of the emissions for production and use were determined to be 32%, and 10% for disposal.

● **Time-series Consistency**

See section 4.3.9.1. c).

**d) Category-specific QA/QC and Verification**

See section 4.3.9.1. d).

**e) Category-specific Recalculations**

There have been no source-specific recalculations.

**f) Category-specific Planned Improvements**

No improvements are planned.

**4.7.1.2. Commercial Refrigeration Production, Use and Disposal (2.F.1.-)**

**4.7.1.2.a. Commercial Refrigeration**

**a) Category Description**

**1) HFCs**

HFCs are emitted from the manufacturing, operation, maintenance, accidents, and disposal of commercial refrigeration.

**2) PFCs**

Emissions from manufacturing were reported as “NO” since Japan has no record from past to present of PFC use in the manufacturing of products. The emissions were also reported as “NO” for use and disposal, because according to survey results of Fluorocarbons in imported products in the past three years, no use of PFC was detected, and it is unlikely that PFCs are refilled into imported products. The Japan Refrigeration and Air Conditioning Industry Association (<https://www.jraia.or.jp/english/index.html>) confirmed with its member companies that no use of PFC was found in imported commercial refrigeration also for the previous years.

**b) Methodological Issues**

● **Estimation Method**

Estimation is mainly conducted using a model, by taking into account the type of device and year of production etc, and based on the principles of the 2006 IPCC Guidelines. Using the number of devices produced per type and amount of refrigerant per type contained etc for each year, emissions of each species of F-gases from 1) manufacturing, 2) installation, 3) operation and 4) disposal are estimated for the devices below, and then aggregated.



centrifugal refrigerating machine, screw refrigerating machine, refrigerator-freezer unit, transport refrigerator-freezer unit, separately placed showcase, built-in showcase, ice making machinery, water fountain, commercial refrigerator-freezer, all-in-one air conditioning system, gas heat pump, chilling unit

Emission factors were determined by a large sample survey conducted on the amount of refrigerant charge and the occurrence of failure in a certain time-period, by each type of equipment<sup>7</sup>. (260,000 sample units, conducted from 2007 to 2009).

Methods below are applied to each type of device and refrigerant.

➤ **Emissions from manufacturing**

$$E_{\text{manufacturing}} = \Sigma (N_{\text{produced}} \times m_{\text{manufacturing}} \times X_{\text{manufacturing}})$$

$E_{\text{manufacturing}}$	: Emissions from manufacturing
$N_{\text{produced}}$	: Number of devices produced
$m_{\text{manufacturing}}$	: Amount of refrigerant contained
$X_{\text{manufacturing}}$	: Fugitive refrigerant ratio from manufacturing

➤ **Emissions from installation**

$$E_{\text{installation}} = \Sigma (N_{\text{installation}} \times m_{\text{installation}} \times X_{\text{installation}})$$

$E_{\text{installation}}$	: Emissions from installation
$N_{\text{installation}}$	: Number of devices charged at installation site
$m_{\text{installation}}$	: Amount of refrigerant contained
$X_{\text{installation}}$	: Fugitive refrigerant ratio from installation

➤ **Emissions from operation**

$$E_{\text{operation}} = \Sigma (N_{\text{operated}} \times m_{\text{operation}} \times X_{\text{operation}}) - R_{\text{operation}}$$

$E_{\text{operation}}$	: Emissions from maintenance
$N_{\text{operated}}$	: Number of devices operated
$m_{\text{operation}}$	: Amount of refrigerant contained
$X_{\text{operation}}$	: Fugitive refrigerant ratio from operation
$R_{\text{operation}}$	: Amount collected during servicing

➤ **Emissions from disposal**

$$E_{\text{disposal}} = \Sigma (N_{\text{disposed}} \times X_{\text{disposal}}) - R_{\text{disposal}}$$

$E_{\text{disposal}}$	: Emissions from disposal
$N_{\text{disposed}}$	: Number of devices disposed
$X_{\text{disposal}}$	: Average amount of refrigerant contained
$R_{\text{disposal}}$	: Amount collected after use

Note: In estimating the emissions from maintenance, the yearly decrease is reflected in the “amount of refrigerant contained.” The “number of devices operated” and “number of devices disposed” are estimated from the amount of shipment and lifetime of device.

The associated indices are given in the table below.

<sup>7</sup> For details, refer to document 1-1 and 1-2 of the 21<sup>st</sup> meeting of the Group for Prevention of Global Warming, Chemical and Bio Sub-Group, Industrial Structure Council, Ministry of Economy Trade and Industry, held on March 17, 2009.

Table 4-65 Indices related to emissions of HFCs from commercial refrigeration

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Number of HFC devices produced	1,000 devices	NO	214	374	1,413	1,122	1,198	1,212	1,303	1,250	1,228	1,296	1,350	1,355	1,400	1,167
Average amount of refrigerant charged at production	g/device	372	372	597	3,378	3,280	3,360	3,462	3,413	3,539	3,473	3,358	3,329	3,480	3,627	3,691
Fugitive refrigerant ratio at production	%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.1%	0.3%	0.2%	0.2%	0.2%	0.2%	0.2%
Number of devices charged in production place	1,000 devices	NO	9	32	138	171	190	239	225	260	240	246	249	229	217	190
Average amount of refrigerant during installation	g/device	17,806	17,806	9,221	23,914	24,527	24,276	22,826	20,754	20,394	20,073	19,520	18,388	18,816	18,801	18,487
Fugitive refrigerant ratio during installation	%	1%	1%	1%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%
Number of devices operated	1,000 devices	NO	375	1,957	6,770	11,743	12,678	13,616	14,568	15,414	16,134	16,859	17,571	18,183	18,738	18,950
Amount of refrigerant during operation	g/device	1,012	1,012	1,043	4,549	5,981	6,192	6,440	6,596	6,799	6,950	7,041	7,074	7,123	7,167	7,188
Fugitive refrigerant ratio during use	%	7.3%	7.3%	7.4%	5.3%	6.0%	6.1%	6.2%	6.2%	6.3%	6.4%	6.4%	6.3%	6.3%	6.2%	6.2%
Number of devices disposed	1,000 devices	NO	1	23	127	397	453	512	576	663	748	816	887	972	1,063	1,143
Amount of HFCs collected under law during maintenance	t	NO	NO	NO	NO	548	571	671	682	759	772	861	979	1,016	1,066	990
Amount of HFCs collected under law after use	t	NO	NO	NO	183	269	352	522	689	668	735	952	1,158	1,296	1,499	1,712
Emissions from manufacturing	kt-CO <sub>2</sub> eq.	NO	3	9	150	198	220	269	225	256	228	229	209	191	181	153
Emissions from stocks	kt-CO <sub>2</sub> eq.	NO	40	258	3,415	10,524	12,233	14,231	15,850	17,638	18,998	20,150	20,880	21,425	21,696	21,778
Emissions from disposal	kt-CO <sub>2</sub> eq.	NO	4	51	586	2,777	3,141	3,466	3,741	4,739	6,033	7,336	8,319	9,644	11,583	13,184
Emissions	kt-CO <sub>2</sub> eq.	NO	47	318	4,151	13,499	15,594	17,965	19,815	22,633	25,259	27,716	29,408	31,260	33,460	35,115

Reference: The *Documents of Fluorocarbons etc Measures Working Group*, and data provided by the Ministry of Economy Trade and Industry, *Documents of the first meeting of the Breakout Group on F-gases (FY2013)*

Note 1: From 2002 onward, “amount of refrigerant” and “fugitive refrigerant ratio from operation” increased because devices became larger with the increase of commercial package AC devices.

Note 2: The weighted average GWP for manufacturing in 2020 is 2,161, 2,568 for stocks, and 2,192 for disposal. Emissions are calculated by gas but are reported as an unspecified mix due to confidentiality reasons.

Table 4-66 Type of HFC and emission factors during use, by type of commercial refrigeration

Type of commercial refrigeration	Type of HFC	Amount of refrigerant	Emission factor *	Share in the number of devices operated (2010)
Small-size refrigerators (built-ins etc)	R-404A, HFC-134a etc	0.1 - 3 kg	2%	40%
Separately installed showcases	R-404A, R-407C etc	20 - 41 kg	16%	3%
Mid-size refrigerators (excluding Separately installed showcases)	R-404A, R-407C etc	2 - 30 kg	13 - 17%	6%
Large-size refrigerators	HFC-134a, R404A etc	300 - 2,300 kg	7 - 12%	0.05%
All-in-one air conditioning systems for buildings	R-410A, R-407C etc	37 kg	3.5%	7%
Other commercial air conditioning devices (excluding All-in-one air conditioning systems for buildings)	R-410A, R-407C etc	3 - 43 kg	3 - 5%	44%

Reference: *Documents of the 2nd Refrigerant Policy Working Group, Group for Prevention of Global Warming, Chemical and Bio Sub-Group, Industrial Structure Council, Ministry of Economy Trade and Industry* (July 26, 2010), and data provided by the Ministry of Economy Trade and Industry

Note: \* Includes for emissions during servicing, accidents, and breakdowns

Due to the lack of data necessary to estimate emissions for the years 1990 to 1994, estimates have been done by using HFC shipment amounts which is thought to be proportional to the number of HFC devices produced and number of devices charged in production place, and the average amount of refrigerant charged at production from 1995, fugitive refrigerant ratio at production from 1995, average amount of refrigerant during installation from 1995, fugitive refrigerant ratio during installation from 1995, amount of refrigerant during operation from 1995, fugitive refrigerant ratio during use from 1995, and extrapolating, etc for these years.

The *2006 IPCC Guidelines* specifies estimation methods for fugitive emissions from refrigerant containers, however, upon consideration of emissions from non-refillable cylinders (NRCs) that are not captured under other sources, the emissions estimated does not exceed 500 kt-CO<sub>2</sub> eq. This combined

with there being no statistics or survey data that can be used as activity data, estimation is not required, as determined by the Committee for Greenhouse Gas Emissions Estimation Methods. It is therefore reported as NE (considered insignificant) (See Annex 5). The fugitive emissions from NRCs were estimated by multiplying the refrigerant amount charged at the time of shipment of unrecovered NRCs by the ratio of the refrigerant remaining in used NRCs. The refrigerant amount charged at the time of shipment of unrecovered NRC was estimated by multiplying the total domestic shipment amount by NRCs, by the ratio of unrecovered NRCs.

#### ***c) Uncertainties and Time-series Consistency***

##### **● *Uncertainty***

For the uncertainties of the emission factors, the 30% upper limit value for electrical equipment in the 2006 IPCC Guidelines was applied for manufacturing. For use, a 5% value based on a METI survey was applied. For the uncertainties of the activity data, the 10% value of the Tier 2 method for metal industry in the 2006 IPCC Guidelines was applied for all manufacturing, use, and disposal. As a result, the uncertainties of the emissions for manufacturing, use, and disposal were determined to be 32%, 11%, and 10%, respectively.

##### **● *Time-series Consistency***

See section 4.3.9.1. c). From 1995 onward, production amount is taken from the same industry organization of device manufacturers, and the EFs are values reported by the Ministry of Trade and Industry in 2009.

#### ***d) Category-specific QA/QC and Verification***

See section 4.3.9.1. d).

#### ***e) Category-specific Recalculations***

There have been no source-specific recalculations.

#### ***f) Category-specific Planned Improvements***

No improvements are planned.

### **4.7.1.2.b. Automatic Vending machine Production, Use and Disposal**

#### ***a) Category Description***

##### ***1) HFCs***

HFCs are emitted from manufacturing, accidents, and disposals of automatic vending machines.

##### ***2) PFCs***

Emission from this source in the “production” category was reported as “NO” as Japan had no record of their use in production. The emissions were also reported as “NO” in the “use” and “disposal” categories, because it was unlikely that PFCs were used in imported products or refrigerants were refilled.

## b) Methodological Issues

### ● Estimation Method

Emissions of F-gases from 1) manufacturing, 2) accidents and 3) disposals are estimated, based on production and shipment amounts and amounts of refrigerants charged. Emission factors are country-specific.

#### ➤ Emissions from manufacturing

$$E_{\text{manufacturing}} = \Sigma (N_{\text{produced}} \times m_{\text{manufacturing}} \times x_{\text{manufacturing}})$$

$E_{\text{manufacturing}}$	: Emissions from manufacturing
$N_{\text{produced}}$	: Number of devices produced
$m_{\text{manufacturing}}$	: Amount of refrigerant contained
$x_{\text{manufacturing}}$	: Fugitive refrigerant ratio from manufacturing

#### ➤ Emissions from accidents

$$E_{\text{accident}} = \Sigma (N_{\text{operated}} \times m_{\text{operation}} \times A \times x_{\text{accident}})$$

$E_{\text{accident}}$	: Emissions from accident
$N_{\text{operated}}$	: Number of devices operated
$m_{\text{operation}}$	: Amount of refrigerant contained
$A$	: Incidence rate
$x_{\text{accident}}$	: Average fugitive rate in accident

#### ➤ Emissions from disposals

$$(a) \text{ until 2001} \quad E_{\text{disposal}} = \Sigma \{N_{\text{disposed}} \times m_{\text{disposal}} \times (1 - \eta)\}$$

$$(b) \text{ from 2002 onward} \quad E_{\text{disposal}} = \Sigma (N_{\text{disposed}} \times m_{\text{disposal-avg}}) - R$$

$E_{\text{disposal}}$	: Emissions from disposal
$N_{\text{disposed}}$	: Number of devices disposed
$m_{\text{disposal}}$	: Amount of refrigerant contained
$\eta$	: Collection rate
$M_{\text{disposal-avg}}$	: Average amount of refrigerant contained
$R$	: Amount collected

For HFC emissions from automatic vending machines, the values shown in the *Documents of the Fluorocarbons etc Measures Working Group, Group for Chemical Substance Policy, Manufacturing Industries Sub-Group, Industrial Structure Council, Ministry of Economy Trade and Industry* is reported. The associated indices are given in the table below.

Table 4-67 Indices related to emissions of HFCs from automatic vending machines

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Number of HFC devices produced	1,000 devices	NO	NO	272	355	173	124	30	10	8	7	7	6	6	5	2
Refrigerant charged per device	g	NO	NO	300	220	219	219	219	219	219	219	219	219	219	219	219
Fugitive refrigerant ratio at production	%	NO	0.4%	0.4%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%
Number of devices operated	1,000 devices	NO	NO	284	1,999	2,279	2,055	1,759	1,530	1,068	748	431	330	187	140	66
Incidence rate	%	NO	0.004	0.004	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Fugitive refrigerant ratio (failure)	%	NO	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Fugitive refrigerant ratio (fixing)	%	NO	0.009	0.009	0.005	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
Number of devices disposed	1,000 devices	NO	NO	NO	NO	286	347	277	273	299	266	264	196	188	148	77
Emissions	t	NO	NO	0.39	0.57	16.41	19.43	15.49	15.23	16.57	14.75	14.57	10.85	10.38	8.16	4.23
	kt-CO <sub>2</sub> eq.	NO	NO	1	1	29	34	22	22	24	21	21	16	15	12	6

Reference: *Documents of Fluorocarbons etc Measures Working Group, Documents of the first meeting of the Breakout Group on F-gases (FY2013)*

For the years 1990 to 1994, it was confirmed that no automatic vending machines with HFCs were used, and therefore emissions for these years are reported as NO. (Ministry of the Environment press release, July 31, 2000, *Projections of disposal etc of refrigerant CFCs, HCFCs, and HFCs (Reference material 1)*)

**c) *Uncertainties and Time-series Consistency***

● ***Uncertainty***

For the uncertainties of the emission factors, the 30% upper limit value for electrical equipment in the *2006 IPCC Guidelines* was applied for all manufacturing, use, and disposal. For the uncertainties of the activity data, the 10% value of the Tier 2 method for metal industry in the *2006 IPCC Guidelines* was applied for all manufacturing, use, and disposal. As a result, the uncertainties of the emissions for all manufacturing, use, and disposal were determined to be 32%.

● ***Time-series Consistency***

See section 4.3.9.1. c).

**d) *Category-specific QA/QC and Verification***

See section 4.3.9.1. d).

**e) *Category-specific Recalculations***

There have been no source-specific recalculations.

**f) *Category-specific Planned Improvements***

No improvements are planned.

**4.7.1.3. Transport Refrigeration Production, Use and Disposal (2.F.1.-)**

**a) *Category Description***

**1) *HFCs***

HFCs are emitted from the manufacturing, operation, and disposal of transport refrigeration.

**2) *PFCs***

Same as 4.7.1.2.a Commercial Refrigeration.

**b) *Methodological Issues***

● ***Estimation Method***

Same as 4.7.1.2.a Commercial Refrigeration. The associated indices are given in the table below.

Table 4-68 Indices related to emissions of HFCs from transport refrigeration (railways)

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Number of HFC devices produced <sup>1)</sup>	devices	0	0	30	0	0	0	0	0	0	0	0	0	0	0	0
Refrigerant HFC charged per device at production <sup>1)</sup>	kg	0	0	3	3	3	3	3	3	3	3	3	3	3	3	3
Fugitive refrigerant ratio at production	%	0%	0%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%
Fugitive refrigerant ratio during use	%	0%	0%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%
Number of HFC devices disposed	devices	0	0	6	1	14	9	13	14	17	21	23	11	11	1	0
Refrigerant stock in device disposed	kg	0	0	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Collection rate	%	0	0	0%	31%	31%	29%	34%	34%	32%	38%	39%	38%	39%	38%	41%
Emissions from manufacturing	kt-CO <sub>2</sub> eq.	NO	NO	0.001	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Emissions from stocks	kt-CO <sub>2</sub> eq.	NO	NO	0.1	0.4	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Emissions from disposal	kt-CO <sub>2</sub> eq.	NO	NO	NO	NO	0.1	0.04	0.1	0.1	0.1	0.1	0.1	0.04	0.04	0.00	NO
Emissions (railways)	kt-CO <sub>2</sub> eq.	NO	NO	0.1	0.4	1	1	1	1	1	1	1	1	1	1	1

Reference: *Railway Statistical Yearbook*, IPCC default values. 1) are based on information from manufacturers.

Table 4-69 Indices related to emissions of HFCs from transport refrigeration (vessels)

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Fugitive refrigerant ratio at production	%	0%	0%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%
Fugitive refrigerant ratio during use	%	0%	0%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%
Collection rate	%	0%	0%	0%	31%	31%	29%	34%	34%	32%	38%	39%	38%	39%	38%	41%
Emissions from manufacturing	kt-CO <sub>2</sub> eq.	NO	NO	0.01	0.1	0.1	0.2	0.3	0.4	0.3	0.2	0.4	0.4	0.3	0.3	0.3
Emissions from stocks	kt-CO <sub>2</sub> eq.	NO	NO	1	24	77	95	124	162	176	191	207	224	250	274	298
Emissions from disposal	kt-CO <sub>2</sub> eq.	NO	NO	NO	NO	0.02	0.1	0.1	0.8	1.8	1.7	2.6	4.1	5.4	5.9	5.9
Emissions (vessels)	kt-CO <sub>2</sub> eq.	NO	NO	1	24	77	95	124	163	178	193	210	228	256	281	304

Reference: IPCC default values, *Report on Maritime Affairs*, etc.

### c) Uncertainties and Time-series Consistency

#### ● Uncertainty

Same as 4.7.1.2.a Commercial Refrigeration.

#### ● Time-series Consistency

Same as Fluorochemical Production – By-product Emissions: Production of HCFC-22 (2.B.9.-). See section 4.3.9.1. c).

### d) Category-specific QA/QC and Verification

Same as Fluorochemical Production – By-product Emissions: Production of HCFC-22 (2.B.9.-). See section 4.3.9.1. d).

### e) Category-specific Recalculations

Updates in the *Railway Statistical Yearbook* for 2019 resulted in recalculations. See Chapter 10 for impact on trend.

### f) Category-specific Planned Improvements

No improvements are planned.

#### 4.7.1.4. Industrial Refrigeration Production, Use and Disposal (2.F.1.-)

##### 1) HFCs

HFCs emissions have been reported as “IE”, as they are included in 4.7.1.2. Commercial Refrigeration (2.F.1.-).

##### 2) PFCs

Emission from this source in the “production” category was reported as “NO” since Japan had no record of their use in the production of the products. The emission was also reported as “NO” in the “use” and “disposal” categories, because it was unlikely that PFCs were used in imported products or refrigerants were refilled.

#### 4.7.1.5. Stationary Air-Conditioning (Household) Production, Use and Disposal (2.F.1.-)

##### a) Category Description

##### 1) HFCs

HFCs are emitted from the manufacturing, operation, and disposals of household stationary air-conditioning devices.

##### 2) PFCs

Emission from this source in the “production” category was reported as “NO” since Japan had no record of their use in production. The emission was also reported as “NO” in the “use” and “disposal” categories, because it was unlikely that PFCs were used in imported products or refrigerants were refilled.

##### b) Methodological Issues

##### ● Estimation Method

In accordance with the IPCC Guidelines, emissions of each species of F-gases from 1) manufacturing, 2) operation, 3) disposals are estimated, based on production and shipment amounts and amounts of refrigerants charged. Emission factors are country-specific. The HFC-125 IEF fluctuation between 2009 and 2010 (-9.9%), and 2014 and 2015 (5.6%) is affected by the change in amounts collected at disposal.

##### ➤ Emissions from manufacturing

$$E_{\text{manufacturing}} = \Sigma (N_{\text{produced}} \times m_{\text{manufacturing-avg}} \times X_{\text{manufacturing}})$$

$E_{\text{manufacturing}}$	: Emissions from manufacturing
$N_{\text{produced}}$	: Number of devices produced
$m_{\text{manufacturing-avg}}$	: Average amount of refrigerant contained
$X_{\text{manufacturing}}$	: Fugitive refrigerant ratio from manufacturing

##### ➤ Emissions from operation

$$E_{\text{operation}} = \Sigma (N_{\text{operated}} \times m_{\text{operation-avg}} \times X_{\text{operation}})$$

$E_{\text{operation}}$	: Emissions from operation
$N_{\text{operated}}$	: Number of devices operated
$m_{\text{operation-avg}}$	: Average amount of refrigerant contained
$X_{\text{operation}}$	: Fugitive refrigerant ratio from operation

➤ **Emissions from disposal**

$$E_{disposal} = \Sigma (N_{disposed} \times m_{disposal-avg}) - R$$

$E_{disposal}$	: Emissions from disposal
$N_{disposed}$	: Number of devices disposed
$m_{disposal-avg}$	: Average amount of refrigerant contained
$R$	: Amount collected

Note: In the estimation of emissions from operation, the yearly decrease is reflected in the “average amount of refrigerant contained.” The “number of devices for shipment” and “number of devices disposed” are estimated from amount of shipment and lifetime of device.

The associated indices are given in the table below.

Table 4-70 Indices related to emissions of HFCs from stationary air-conditioning (household)

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Number of HFC devices produced	1,000 devices	NO	NO	1,077	3,981	3,169	3,155	3,263	3,581	3,076	8,166	8,528	9,055	9,815	9,344	10,096
Refrigerant charged per device	g	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Fugitive refrigerant ratio at production	%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
Number of devices operated	1,000 devices	NO	NO	1,726	26,091	61,540	68,769	75,833	83,349	89,020	94,197	99,157	104,067	109,193	113,317	117,693
Average refrigerant charged during use	g/device	NO	NO	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Fugitive refrigerant ratio during use	%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%
Number of devices disposed	1,000 devices	NO	NO	2	83	764	1,075	1,456	1,907	2,423	2,990	3,567	4,145	4,688	5,220	5,720
Average refrigerant stock in device disposed	g/device	NO	NO	954	911	841	827	814	803	796	792	795	796	804	815	825
Amount of HFCs collected under law	t/year	-	-	-	10	231	264	322	466	508	570	700	892	1,181	1,367	1,599
Emissions from manufacturing	kt-CO <sub>2</sub> eq.	NO	NO	4	17	12	10	10	8	7	9	7	6	6	6	6
Emissions from stocks	kt-CO <sub>2</sub> eq.	NO	NO	72	1,089	2,569	2,871	3,165	3,424	3,534	3,549	3,523	3,480	3,425	3,345	3,258
Emissions from disposal	kt-CO <sub>2</sub> eq.	NO	NO	3	139	916	1,322	1,833	2,301	2,984	3,767	4,486	5,059	5,437	5,939	6,336
Emissions	kt-CO <sub>2</sub> eq.	NO	NO	80	1,245	3,498	4,204	5,008	5,733	6,524	7,325	8,015	8,546	8,868	9,290	9,600

Reference: Documents of Fluorocarbons etc Measures Working Group, Documents of the first meeting of the Breakout Group on F-gases (FY2013)

For the years 1990 to 1994, it was confirmed that no household stationary air-conditioning with HFCs were used, and therefore emissions for these years are reported as NO. (Ministry of the Environment press release, July 31, 2000, *Projections of disposal etc of refrigerant CFCs, HCFCs, and HFCs* (Reference material 1))

**c) Uncertainties and Time-series Consistency**

● **Uncertainty**

See section 4.7.1.2.a.c).

● **Time-series Consistency**

See section 4.3.9.1. c).

**d) Category-specific QA/QC and Verification**

See section 4.3.9.1. d).

**e) Category-specific Recalculations**

There have been no source-specific recalculations.

**f) Category-specific Planned Improvements**

No improvements are planned.



#### 4.7.1.6. Mobile Air-Conditioning Production, Use and Disposal (2.F.1.-)

##### a) Category Description

###### 1) HFCs

HFCs are emitted from manufacturing, operation, breakdowns, accidents, and disposals of mobile air-conditioning devices (car air conditioners, and railway and vessel air conditioners).

###### 2) PFCs

Emission from this source in the “production” category was reported as “NO” since Japan had no record of their use in production. The emission was also reported as “NO” in the “use” and “disposal” categories, because it was unlikely that PFCs were used in imported products or refrigerants were refilled.

##### b) Methodological Issues

###### ● Estimation Method

In accordance with the IPCC Guidelines, emissions of each species of F-gases from 1) manufacturing, 2) operation, 3) breakdowns, 4) accidents and 5) disposals are estimated. Emission factors are country-specific. The below thinking is applied for each type of car.

###### ➤ Emissions from manufacturing

$$E_{\text{manufacturing}} = \Sigma (N_{\text{produced}} \times m_{\text{manufacturing}} \times X_{\text{manufacturing}})$$

$E_{\text{manufacturing}}$	: Emissions from manufacturing
$N_{\text{produced}}$	: Number of devices produced
$m_{\text{manufacturing}}$	: Amount of refrigerant contained
$X_{\text{manufacturing}}$	: Fugitive refrigerant ratio from manufacturing

###### ➤ Emissions from operation

$$E_{\text{operation}} = \Sigma (N_{\text{operated}} \times m_{\text{operation}} \times X_{\text{operation}})$$

$E_{\text{operation}}$	: Emissions from operation
$N_{\text{operated}}$	: Number of cars operated
$m_{\text{operation}}$	: Amount of refrigerant contained
$X_{\text{operation}}$	: Fugitive refrigerant ratio from operation

Note: In the estimation of emissions from operation, the yearly decrease is reflected in the “amount of refrigerant contained.”

###### ➤ Emissions from breakdowns

$$E_{\text{breakdowns}} = \Sigma (N_{\text{operated}} \times m_{\text{operation}} \times A \times X_{\text{accident}})$$

$E_{\text{breakdowns}}$	: Emissions from maintenance
$N_{\text{operated}}$	: number of cars operated
$m_{\text{operation}}$	: amount of refrigerant contained
$A$	: rate of breakdowns
$X_{\text{accident}}$	: fugitive refrigerant ratio from breakdowns

➤ **Emissions from accident**

$$E_{\text{accident}} = \Sigma (N_{\text{destroyed}} \times m_{\text{operation}})$$

$E_{\text{accident}}$  : Emissions from accident  
 $N_{\text{destroyed}}$  : number of cars in completely destroyed  
 $m_{\text{operation}}$  : amount of refrigerant contained at time of accident

➤ **Emissions from disposal**

$$(a) \text{ until 2001} \quad E_{\text{disposal}} = \Sigma \{N_{\text{disposed}} \times m_{\text{disposal}} \times (1 - \eta)\}$$

$$(b) \text{ from 2002 onward} \quad E_{\text{disposal}} = \Sigma (N_{\text{disposed}} \times m_{\text{disposal-avg}}) - R$$

$E_{\text{disposal}}$  : Emissions from disposal  
 $N_{\text{disposed}}$  : number of cars disposed  
 $m_{\text{disposal}}$  : amount of refrigerant contained  
 $\eta$  : collection rate  
 $m_{\text{disposal-avg}}$  : average amount of refrigerant contained  
 $R$  : amount collected

Relevant indices are shown in Table below.

Table 4-71 Indices related to emissions of HFC-134a from car air conditioners

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Number of cars produced	1,000 devices	0	9,745	9,761	10,407	9,292	8,136	9,856	9,613	9,753	9,273	9,205	9,639	9,362	8,140	4,866
Fugitive refrigerant during production	g	4	4	4	3	1	1	1	1	1	1	1	1	1	1	1
Number of cars operated with HFC air conditioners	1,000 devices	0	15,655	42,374	60,364	66,043	67,366	70,406	72,054	72,813	73,272	73,856	74,236	74,087	72,683	69,741
Average refrigerant charged per device	g	700	700	615	548	497	497	497	497	497	497	497	497	497	497	497
Fugitive refrigerant ratio during use per year per device (normal car)	g	15	15	15	10	10	10	10	10	10	10	10	10	10	10	10
Rate of breakdown incidences	%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%
Fugitive refrigerant ratio from breakdown cars	%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%
Number of cars completely destroyed	1,000 devices	0	50	136	193	211	216	225	231	233	234	236	238	237	233	223
Average refrigerant charged in completely destroyed cars	g	681	681	610	522	448	439	426	417	409	404	400	394	388	383	377
Number of cars disposed	1,000 devices	0	116	789	2,058	2,895	2,235	2,709	2,835	2,839	2,694	2,666	2,927	2,941	2,920	2,763
Average refrigerant charged at time of disposal	g	676	676	593	522	444	427	404	412	393	380	370	360	349	347	339
Amount of HFC collected (under law from FY2002)	t/year	-	-	-	531	898	645	786	785	773	710	682	720	718	694	625
Emissions from manufacturing	kt-CO <sub>2</sub> eq.	NO	49	49	45	13	9	11	11	10	10	10	10	10	8	5
Emissions from stocks	kt-CO <sub>2</sub> eq.	NO	704	1,798	2,331	2,222	2,226	2,274	2,276	2,255	2,230	2,215	2,189	2,151	2,086	1,978
Emissions from disposal	kt-CO <sub>2</sub> eq.	NO	112	669	778	555	444	442	548	492	449	436	477	443	458	446
Emissions	kt-CO <sub>2</sub> eq.	NO	865	2,516	3,153	2,791	2,679	2,728	2,835	2,757	2,690	2,661	2,676	2,604	2,553	2,429

Reference: Documents of Fluorocarbons etc Measures Working Group, Documents of the first meeting of the Breakout Group on F-gases (FY2013)

Table 4-72 Indices related to emissions of HFCs from air conditioners (railways)

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Fugitive refrigerant ratio at production	%	0%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%
Fugitive refrigerant ratio during use	%	0%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
Emissions from manufacturing	kt-CO <sub>2</sub> eq.	NO	0.003	0.03	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.05	0.1	0.1	0.1	0.1
Emissions from stocks	kt-CO <sub>2</sub> eq.	NO	0.4	1.6	6.9	15.5	17.1	18.4	19.8	21.3	22.7	24.1	25.5	27.2	28.8	30.4
Emissions from disposal	kt-CO <sub>2</sub> eq.	NO	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.05	0.05	0.1	0.1	0.1
Emissions (railways)	kt-CO <sub>2</sub> eq.	NO	0.4	2	7	16	17	19	20	21	23	24	26	27	29	31

Reference: Railway Statistical Yearbook, Yearbook of Railway Car Production Statistics, IPCC default values etc.

Table 4-73 Indices related to emissions of HFCs from air conditioners (vessels)

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Fugitive refrigerant ratio at production	%	0%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%
Fugitive refrigerant ratio during use	%	0%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%
Collection rate	%	0%	0%	0%	0%	31%	29%	34%	34%	32%	38%	39%	38%	39%	38%	41%
Emissions from manufacturing	kt-CO <sub>2</sub> eq.	NO	0.0003	0.004	0.1	0.2	0.3	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1
Emissions from stocks	kt-CO <sub>2</sub> eq.	NO	0.1	1.0	25.8	107.9	124.0	137.5	146.8	155.9	161.9	170.1	175.8	180.9	186.5	190.0
Emissions from disposal	kt-CO <sub>2</sub> eq.	NO	NO	NO	NO	0.01	0.03	0.01	0.1	0.3	0.2	0.4	0.6	0.8	1.2	1.6
Emissions (vessels)	kt-CO <sub>2</sub> eq.	NO	0.1	1	26	108	124	138	147	156	162	171	176	182	188	192

Reference: IPCC default values, *Report on Maritime Affairs, etc.*

For car air conditioners, due to the lack of data necessary to estimate emissions for the years 1992 to 1994 in which HFCs were used, estimates have been done by using HFC shipment amounts which is thought to be proportional to the number of car produced, and the fugitive refrigerant during production from 1995, average refrigerant charged per device from 1995, fugitive refrigerant ratio during use per year per device (normal car) from 1995, rate of breakdown incidences from 1995, fugitive refrigerant ratio from breakdown cars from 1995, number of cars completely destroyed in 1995, the number of cars operated with HFC air conditioners from 1995, average refrigerant charged in completely destroyed cars from 1995, number of cars disposed from 1995, average refrigerant charged at the time of disposal from 1995, and extrapolating, etc for these years.

#### c) *Uncertainties and Time-series Consistency*

##### ● *Uncertainty*

See section 4.7.1.2.b.c).

##### ● *Time-series Consistency*

See section 4.3.9.1. c).

#### d) *Category-specific QA/QC and Verification*

See section 4.3.9.1. d).

#### e) *Category-specific Recalculations*

Recalculations occurred for 2012 to 2019, due to updates in the *Yearbook of Railway Car Production Statistics*. Recalculations occurred for 2019, due to updates in the *Railway Statistical Yearbook*. See Chapter 10 for impact on trend.

#### f) *Category-specific Planned Improvements*

No improvements are planned.

## 4.7.2. Foam Blowing Agents (2.F.2.)

### 4.7.2.1. Closed Cells (2.F.2.-)

#### 4.7.2.1.a. Urethane Foam (2.F.2.-)

##### a) *Category Description*

HFC-134a, HFC-245fa, and HFC-365mfc are emitted as a result of foam blowing agent use.

## b) Methodological Issues

### ● Estimation Method

In accordance with the IPCC Guidelines (closed-cell foams), emissions were calculated assuming that 10% of the emission from foam blowing agents used each year occurred within the first year after production, with the remainder emitted over 20 years at the rate of 4.5% per year. The data on the amount of foam blowing agents used each year was provided by the Japan Urethane Foam Association, Japan Urethane Raw Materials Association.

It is difficult to separate the “use” emission from that at the time of “disposal” because urethane foams were disposed of at various times. Accordingly, the emissions in the “use” and “disposal” categories were combined and reported under the “use” category, while the emission in the “disposal” category was reported as “IE”.

$$E = E_{\text{manufacturing}} + E_{\text{use}}$$

$$= (M \times EF_{\text{FYL}}) + (\text{Bank} \times EF_{\text{AL}})$$

$E$	:	HFC emissions [t]
$E_{\text{manufacturing}}$	:	Emissions during production [t]
$E_{\text{use}}$	:	Emissions during use [t]
$M$	:	Amount of HFC used [t]
$EF_{\text{FYL}}$	:	Leakage during foam blowing [%]
$\text{Bank}$	:	Total amount used up to the previous year [t]
$EF_{\text{AL}}$	:	Percentage of annual emissions during use [%]

Table 4-74 Indices related to emissions of HFCs from urethane foam

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
HFC-134a use	t	NO	NO	167	224	66	65	34	28	14	12	NO	NO	NO	NO	NO
HFC-245fa use	t	NO	NO	NO	3,893	2,365	2,597	2,613	2,570	2,533	2,230	2,577	2,596	2,365	1,626	618
HFC-365mfc use	t	NO	NO	NO	1311	900	960	977	921	866	779	794	802	744	702	203
Leakage during foam blowing	%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
Annual emissions rate during use	%	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%
HFC-134a emissions	kt-CO <sub>2</sub> eq.	NO	NO	24	112	133	137	137	138	138	139	138	138	138	138	127
HFC-245fa emissions	kt-CO <sub>2</sub> eq.	NO	NO	NO	490	1,144	1,277	1,399	1,516	1,631	1,718	1,857	1,978	2,075	2,108	2,080
HFC-365mfc emissions	kt-CO <sub>2</sub> eq.	NO	NO	NO	130	318	355	391	421	450	474	503	532	556	579	565

Reference: *Documents of Fluorocarbons etc Measures Working Group*, and data provided by the METI, *Documents of the first meeting of the Breakout Group on F-gases (FY2013)*

Note: As regards HFC-245fa and HFC-365mfc, their use increased because they replaced HCFC-141b whose production ended in January 2004.

For the years 1990 to 1994, it was confirmed that no urethane foam with HFCs was used, and therefore emissions for these years are reported as NO. (Ministry of the Environment, “FY2011 PRTR (Pollutant Release and Transfer Register) Estimation methods for releases from sources not required to report”)

## c) Uncertainties and Time-series Consistency

### ● Uncertainty

For the uncertainties of the emissions for both manufacturing and use, the 2006 IPCC Guidelines value of 50% was used.

### ● Time-series Consistency

See section 4.3.9.1. c).

**d) Category-specific QA/QC and Verification**

See section 4.3.9.1. d).

**e) Category-specific Recalculations**

There have been no source-specific recalculations.

**f) Category-specific Planned Improvements**

No improvements are planned.

**4.7.2.1.b. Extruded Polystyrene Foam (2.F.2.-)****a) Category Description**

HFC-134a is emitted as a result of foam blowing agent use.

**b) Methodological Issues****● Estimation Method**

Emissions were calculated assuming that 25% of the emission of foam blowing agents occurs within the first year after production, with the remainder emitted at the rate of 0.75% per year. The amount of foam blowing agents used each year was provided by the Extruded Polystyrene Foam Industry Association. This assumption is consistent with the *2006 IPCC Guidelines* and the estimation method under PRTR for the amount of transferred HCFC at polystyrene foam production sites.

It is difficult to separate the “use” emission from that at the time of “disposal” because heat insulation material is disposed of at various times such as the renovation and dismantling of buildings, and in times of disaster. Since disposed polystyrene foam is considered to be emitting HFCs as same as that in use, these emissions are combined and reported under “use”, while the emissions from “disposal” were reported as “IE”.

$$E = E_{\text{manufacturing}} + E_{\text{use}}$$

$$= (M \times EF_{\text{FYL}}) + (Bank \times EF_{\text{AL}})$$

$E$	: HFC-134a emissions [t]
$E_{\text{manufacturing}}$	: Emissions during production [t]
$E_{\text{use}}$	: Emissions during use [t]
$M$	: Amount of HFC-134a used in particular year [t]
$EF_{\text{FYL}}$	: Leakage during foam blowing (25%)
$Bank$	: Total amount used in the past up to the previous year [t]
$EF_{\text{AL}}$	: Annual emission rate during use [%]

Table 4-75 Indices related to emissions of HFC-134a from extruded polystyrene foam

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
HFC-134a use	t	NO	NO	NO	26	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Foam production rate	%	-	-	-	75%	75%	75%	75%	75%	75%	75%	75%	75%	75%	75%	75%
Annual emission rate during use	%	-	-	-	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%
Emissions during production	t	NO	NO	NO	6.50	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Emissions during use	t	NO	NO	NO	9.00	9.23	9.23	9.23	9.23	9.23	9.23	9.23	9.23	9.23	9.23	9.23
Emissions	t	NO	NO	NO	15.50	9.23	9.23	9.23	9.23	9.23	9.23	9.23	9.23	9.23	9.23	9.23
Emissions during production	kt-CO <sub>2</sub> eq.	NO	NO	NO	9	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Emission during use	kt-CO <sub>2</sub> eq.	NO	NO	NO	13	13	13	13	13	13	13	13	13	13	13	13
Emissions	kt-CO <sub>2</sub> eq.	NO	NO	NO	22	13	13	13	13	13	13	13	13	13	13	13

Reference: *Documents of Fluorocarbons etc Measures Working Group, Documents of the first meeting of the Breakout Group on F-gases (FY2013) etc*

For the years 1990 to 1994, it was confirmed that no extruded polystyrene foam with HFCs was used, and therefore emissions for these years are reported as NO. (Ministry of the Environment, “FY2011 PRTR (Pollutant Release and Transfer Register) Estimation methods for releases from sources not required to report”)

### c) Uncertainties and Time-series Consistency

#### ● Uncertainty

See section 4.7.2.1.a. c).

#### ● Time-series Consistency

See section 4.3.9.1. c).

### d) Category-specific QA/QC and Verification

See section 4.3.9.1. d).

### e) Category-specific Recalculations

There have been no source-specific recalculations.

### f) Category-specific Planned Improvements

No improvements are planned.

## 4.7.2.2. Open Cells (2.F.2.-)

### 4.7.2.2.a. High Expanded Polyethylene Foam (2.F.2.-)

#### a) Category Description

HFC-134a and HFC-152a is emitted as a result of foam blowing agent use.

#### b) Methodological Issues

#### ● Estimation Method

In accordance with the IPCC Guidelines (open-cell foams), emissions were calculated assuming that all of the emissions from foam blowing agents used occurred at the time of production. The amount of blowing agents used each year was provided by the High Expanded Polyethylene Foam Industry Association.

Table 4-76 Indices related to emissions of HFC-134a from high expanded polyethylene foam

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
HFC-134a use	t	1	346.00	322.00	128.00	98.11	98.11	98.11	98.11	98.11	98.11	98.11	98.11	98.11	98.11	98.11
Emissions	t	1	346.00	322.00	128.00	98.11	98.11	98.11	98.11	98.11	98.11	98.11	98.11	98.11	98.11	98.11
	kt-CO <sub>2</sub> eq.	1	495	460	183	140	140	140	140	140	140	140	140	140	140	140

Reference: *Documents of Fluorocarbons etc Measures Working Group*, and data provided by the METI, *Documents of the first meeting of the Breakout Group on F-gases (FY2013)*

Table 4-77 Indices related to emissions of HFC-152a from high expanded polyethylene foam

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
HFC-152a use	t	0.04	14.00	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Emissions	t	0.04	14.00	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	kt-CO <sub>2</sub> eq.	0.005	2	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

Reference: *Documents of Fluorocarbons etc Measures Working Group*, *Documents of the first meeting of the Breakout Group on F-gases (FY2013)*

Due to the lack of data necessary to estimate emissions for the years 1990 to 1994, estimates have been done by using domestic HFC shipment amounts which is thought to be proportional to use amounts of foam blowing agents, and extrapolating for these years.

#### c) *Uncertainties and Time-series Consistency*

##### ● *Uncertainty*

See section 4.7.2.1.a. c).

##### ● *Time-series Consistency*

See section 4.3.9.1. c).

#### d) *Category-specific QA/QC and Verification*

See section 4.3.9.1. d).

#### e) *Category-specific Recalculations*

There have been no source-specific recalculations.

#### f) *Category-specific Planned Improvements*

No improvements are planned.

### 4.7.3. Fire Protection (2.F.3.)

#### a) *Category Description*

HFCs are emitted by the use of halogen fire extinguishers.

#### b) *Methodological Issues*

##### ● *Estimation Method*

HFC-23 and HFC-227ea are used for the production of fire extinguishers. However, as of 2004, only HFC-227ea is filled in the bottles for fire extinguishing equipment, and for HFC-23, each company purchases pre-filled HFC-23 fire extinguisher bottles, and therefore no emissions occur at production. HFCs emissions from this category was reported as "NO" by expert judgment since HFC-227ea was a

very small amount, 0.0007 [t] when emission from production in FY2004 was estimated.

For use, in 1995, almost no HFC filled fire extinguishers existed on the market, and therefore it is assumed that there was no use, resulting in NO for 1995 and earlier years. For 1996 and following years, calculations were performed using the following equation and based on the HFC extinguishing agent stocks.

$$E = Bank \times EF$$

$E$  : HFC emissions [t]

$Bank$  : HFC extinguishing agent stocks [t]

$EF$  : Emission factor during use

Concerning the emission at the time of disposal of fire extinguishers, it is reported as “NO” because the use of HFC for fire extinguishers has just started, and also the expected lifetime of buildings is 30-40 years, and therefore they are unlikely to be disposed of as of present.

### ● Emission Factors

There are still no findings on the emission factor of HFC extinguishing agents when using them. The emission rate (0.00088) determined from refills of halons (provided by the Fire and Disaster Management Agency), which are similar extinguishing agents, was adopted as the emission factor for this category.

Table 4-78 References for the Emission factor of fire extinguishers  
(The emission ratio of halon fire extinguishers)

	Unit	2002	2003	2004	2005	2006	2007	Average
Installations of halon 1301 (A)	t	17,094	17,090	17,060	16,994	17,075	16,889	17,034
Refills of halon 1301 (B)	t	13	13	22	13	14	15	15
(B) / (A)	-	0.00076	0.00076	0.00129	0.00076	0.00082	0.00089	0.00088

### ● Activity Data

HFC stock amounts provided by the Fire Defense Agency were used as activity data for HFC emissions from fire extinguishing agents use.

Table 4-79 The amounts of the HFC extinguishing agent stocks

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Stocks of HFC-23	t	NO	NO	306.38	478.27	523.12	527.85	532.64	536.67	546.25	559.43	566.54	572.59	579.21	579.97	580.09
HFC-23 emissions	t	NO	NO	0.27	0.42	0.46	0.46	0.47	0.47	0.48	0.49	0.50	0.50	0.51	0.51	0.51
	kt-CO <sub>2</sub> eq.	NO	NO	4	6	7	7	7	7	7	7	7	7	8	8	8
Stocks of HFC-227ea	t	NO	NO	225.28	391.73	522.44	543.81	596.44	639.97	685.75	738.32	753.66	800.21	809.63	845.84	862.29
HFC-227ea emissions	t	NO	NO	0.20	0.34	0.46	0.48	0.52	0.56	0.60	0.65	0.66	0.70	0.71	0.74	0.76
	kt-CO <sub>2</sub> eq.	NO	NO	1	1	1	2	2	2	2	2	2	2	2	2	2
Total emissions	kt-CO <sub>2</sub> eq.	NO	NO	5	7	8	8	9	9	9	9	10	10	10	10	10

### c) Uncertainties and Time-series Consistency

#### ● Uncertainty

For the uncertainties of the emissions, the 2006 IPCC Guidelines value of 16% was used.

#### ● Time-series Consistency

Calculations are performed with a method consistently used from FY1995, based on an emission factor and activity data received from the Fire Defense Agency. For years 1990 to 1994, emissions are reported as NO, in light of the fact that HFC filled fire extinguishers were not in use in 1995.



**d) Category-specific QA/QC and Verification**

See section 4.2.1. d).

**e) Category-specific Recalculations**

Recalculations occurred for FY2019, due to updates in the stocks of HFC-23. See Chapter 10 for impact on trend.

**f) Category-specific Planned Improvements**

No improvements are planned.

**4.7.4. Aerosols (2.F.4.)****4.7.4.1. Metered Dose Inhalers (2.F.4.-)****a) Category Description**

HFCs are emitted from the manufacturing and use of metered dose inhalers (MDIs).

**b) Methodological Issues****● Estimation Method**

In accordance with the IPCC Guidelines, emissions were calculated on the assumption that from the amount used each year, 50% of the emission occurred in the year of production, with the remaining 50% emitted in the following year.

The amount of purchased gas, the amount of the use of domestically manufactured MDI and the use of imported MDI, and the amount of disposal of MDI were provided by the Federation of Pharmaceutical Manufacturers' Associations of Japan (FPMAJ). FPMAJ estimates the amount of HFC disposal by mainly including destructed MDI that were defective products.

$$E_n = E_{\text{manufacturing}} + E_{\text{potential}(n-1)} \times EF_{\text{first}} + E_{\text{potential}(n)} \times (1 - EF_{\text{first}}) - R_{(n)}$$

$E_n$	: F-gas (HFC-134a, HFC-227ea) emissions in year n [t]
$E_{\text{manufacturing}}$	: Fugitive emissions during manufacturing [t]
$E_{\text{potential}(n-1)}, E_{\text{potential}(n)}$	: F-gas potential emissions in year n - 1 or in year n [t]
$EF_{\text{first}}$	: 50[%]
$R_{(n)}$	: Amount of disposal of F-gas contained in MDI [t]

$$E_{\text{potential}} = U_{\text{domestic}} + U_{\text{import}}$$

$U_{\text{domestic}}$	: Use amount of domestically manufactured MDI [t]
$U_{\text{import}}$	: Use amount of imported MDI [t]

The associated indices are given in the table below.

Table 4-80 Indices related to emissions of HFC-134a from MDI

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Usage of domestic MDI	t	NO	NO	1.40	0.90	1.07	0.79	0.77	0.60	0.90	0.59	0.91	0.60	0.75	0.74	0.75
Usage of imported MDI	t	NO	NO	42.00	70.70	57.05	54.00	48.30	46.04	42.36	41.34	39.16	34.17	35.03	32.73	34.55
Amount collected and destroyed	t	NO	NO	0.10	1.90	2.52	2.41	0.76	0.72	0.23	3.56	0.42	0.13	0.03	0.07	0.04
HFC-134a emissions	t	NO	NO	37.20	62.75	55.52	54.15	51.26	47.23	44.91	39.35	40.72	37.38	35.35	34.66	34.48
	kt-CO <sub>2</sub> eq.	NO	NO	53	90	79	77	73	68	64	56	58	53	51	50	49

Reference: *Documents of Fluorocarbons etc Measures Working Group*, and data provided by the METI, *Documents of the first meeting of the Breakout Group on F-gases (FY2013)*

Table 4-81 Indices related to emissions of HFC-227ea from MDI

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Usage of domestic MDI	t	NO	NO	NO	41.00	35.96	30.92	25.77	25.11	21.02	22.96	21.41	17.84	18.43	19.63	20.06
Usage of imported MDI	t	NO	NO	3.60	2.10	0.42	0.77	0.73	0.73	0.38	18.75	20.16	27.48	26.17	37.86	39.85
Amount collected and destroyed	t	NO	NO	NO	1.20	0.80	0.86	0.80	0.77	0.54	0.70	0.23	0.33	0.32	0.09	0.02
HFC-227ea emissions	t	NO	NO	1.80	48.05	33.14	34.30	29.83	26.93	23.93	31.70	32.05	43.95	45.41	51.54	59.16
	kt-CO <sub>2</sub> eq.	NO	NO	6	155	107	110	96	87	77	102	135	142	146	166	190

Reference: *Documents of Fluorocarbons etc Measures Working Group*, and data provided by the Ministry of Economy Trade and Industry, *Documents of the first meeting of the Breakout Group on F-gases (FY2013)*

Note: The production of MDIs using HFC-134a started in 1997, and those using HFC-227ea started in 2001 (with production using imported HFC-227ea starting in 2000).

Due to the lack of data necessary to estimate emissions for the years 1990 to 1994, emissions have been estimated to be NO for these years, since for HFC-134a, 1995 and 1996 amounts of usage of domestic MDI and usage of imported MDI are each zero, and for HFC-227ea, 1995 to 1999 amounts of usage of domestic MDI and usage of imported MDI are each zero.

### c) *Uncertainties and Time-series Consistency*

#### ● *Uncertainty*

For the uncertainties of the emission factors, 0% was applied for all production, use and disposal, due to the fact that the amount of emissions is equal to the amount of MDI used. For the uncertainties of the activity data, the 10% value of the Tier 2 method for metal industry in the *2006 IPCC Guidelines* was applied for all production, use and disposal. As a result, the uncertainties of the emissions for all production, use and disposal were determined to be 10%.

#### ● *Time-series Consistency*

See section 4.3.9.1. c).

### d) *Category-specific QA/QC and Verification*

See section 4.3.9.1. d).

### e) *Category-specific Recalculations*

There have been no source-specific recalculations.

### f) *Category-specific Planned Improvements*

No improvements are planned.

## 4.7.4.2. Aerosols (2.F.4.-)

### a) *Category Description*

HFCs are emitted from the manufacturing and use of aerosols.

### b) *Methodological Issues*

#### ● *Estimation Method*

In accordance with the *2006 IPCC Guidelines*, emissions were calculated on the assumption that 50% of the emission from the amount of aerosol filled in the products (potential emissions) occurred in the

year of production, with the remaining 50% emitted in the following year. Fugitive emissions from manufacturing is considered as the balance between the amount used for production and the actual measurement amount filled in the products, and it is included in the emissions. The data on the amount used for production and the amount filled in the products were provided by the Aerosol Industry Association of Japan. HFC is considered to be actually remaining in disposed aerosols at some level. However, the amount of emission at the time of “disposal” was reported as “IE” since it is included in the calculation for the “use” category.

$$E_n = E_{\text{manufacturing}} + E_{\text{potential}(n-1)} \times EF_{\text{first}} + E_{\text{potential}(n)} \times (1 - EF_{\text{first}})$$

$E_n$  : HFC emissions in year n [t]  
 $E_{\text{manufacturing}}$  : Fugitive emissions during manufacturing [t]  
 $E_{\text{potential}(n-1)}, E_{\text{potential}(n)}$  : HFC potential emissions in year n-1 or in year n [t]  
 $EF_{\text{first}}$  : 50[%]

$$E_{\text{manufacturing}(n)} = M_{(n)} - E_{\text{potential}(n)}$$

$E_{\text{manufacturing}(n)}$  : Fugitive emissions during manufacturing [t]  
 $M_{(n)}$  : HFC consumed during manufacturing in year n [t]  
 $E_{\text{potential}(n)}$  : HFC potential emissions [t]

The associated indices are given in the table below.

Table 4-82 Indices related to emissions of HFC-134a from aerosols

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Potential emissions	t	NO	1,300.00	2,044.10	604.40	199.92	190.00	167.70	168.00	223.00	206.00	236.00	193.00	159.00	226.00	246.00
Fugitive emissions during production	t	NO	NO	80.20	24.90	8.08	7.00	8.30	7.00	12.00	15.00	22.00	35.00	38.50	37.00	48.00
Emissions in the year produced, during use	t	NO	650.00	1,022.05	302.20	99.96	95.00	83.85	84.00	111.50	103.00	118.00	96.50	79.50	113.00	123.00
Remaining (emissions in the next year)	t	NO	650.00	1,022.05	302.20	99.96	95.00	83.85	84.00	111.50	103.00	118.00	96.50	79.50	113.00	123.00
HFC-134a emissions	t	NO	1,050.00	2,137.10	908.15	223.04	201.96	187.15	174.85	207.50	229.50	243.00	249.50	214.50	229.50	284.00
	kt-CO <sub>2</sub> eq.	NO	1,502	3,056	1,299	319	289	268	250	297	328	347	357	307	328	406

Reference: *Documents of Fluorocarbons etc Measures Working Group, Documents of the first meeting of the Breakout Group on F-gases (FY2013) etc*

Note: Fugitive emissions from 1992 to 1997 are included in potential emissions.

Table 4-83 Indices related to emissions of HFC-152a from aerosols

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Potential emissions	t	NO	NO	34.10	1,299.50	558.00	502.00	542.00	320.00	353.00	279.00	328.00	276.00	226.00	142.00	27.00
Fugitive emissions during production	t	NO	NO	1.10	28.90	638.00	729.50	464.00	249.00	185.00	108.50	68.00	89.00	75.00	45.50	17.00
Emissions in the year produced, during use	t	NO	NO	17.05	649.75	279.00	251.00	271.00	160.00	176.50	139.50	164.00	138.00	113.00	71.00	13.50
Remaining (emissions in the next year)	t	NO	NO	17.05	649.75	279.00	251.00	271.00	160.00	176.50	139.50	164.00	138.00	113.00	71.00	13.50
HFC-152a emissions	t	NO	NO	18.15	1,216.95	1,299.00	1,259.50	986.00	680.00	521.50	424.50	371.50	391.00	326.00	229.50	101.50
	kt-CO <sub>2</sub> eq.	NO	NO	2	151	161	156	122	84	65	53	46	48	40	28	13

Reference: *Documents of Fluorocarbons etc Measures Working Group, Documents of the first meeting of the Breakout Group on F-gases (FY2013) etc*

Note: The production of aerosols using HFC-152a started in 2000.

Table 4-84 Indices related to emissions of HFC-245fa from aerosols

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Potential emissions	t	NO	NO	NO	0.80	0.39	2.03	1.09	0.17	1.10	0.28	NO	NO	NO	NO	NO
Fugitive emissions during production	t	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Emissions in the year produced, during use	t	NO	NO	NO	0.40	0.19	1.02	0.55	0.09	0.55	0.14	NO	NO	NO	NO	NO
Remaining (emissions in the next year)	t	NO	NO	NO	0.40	0.19	1.02	0.55	0.09	0.55	0.14	NO	NO	NO	NO	NO
HFC-245fa emissions	t	NO	NO	NO	0.55	0.35	1.21	1.56	0.63	0.64	0.69	0.14	NO	NO	NO	NO
	kt-CO <sub>2</sub> eq.	NO	NO	NO	1	0.4	1	2	1	1	1	0.1	NO	NO	NO	NO

Reference: *Documents of Fluorocarbons etc Measures Working Group, Documents of the second meeting of the Breakout Group on F-gases, FY2014 Committee for the Greenhouse Gas Emissions Estimation Methods etc*

Table 4-85 Indices related to emissions of HFC-365mfc from aerosols

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Potential emissions	t	NO	NO	NO	1.12	NO	NO	0.27	NO	0.24	0.24	NO	NO	NO	NO	NO
Fugitive emissions during production	t	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Emissions in the year produced, during use	t	NO	NO	NO	0.56	NO	NO	0.14	NO	0.12	0.12	NO	NO	NO	NO	NO
Remaining (emissions in the next year)	t	NO	NO	NO	0.56	NO	NO	0.14	NO	0.12	0.12	NO	NO	NO	NO	NO
HFC-365mfc emissions	t	NO	NO	NO	0.74	NO	NO	0.14	0.14	0.12	0.24	0.12	NO	NO	NO	NO
	kt-CO <sub>2</sub> eq.	NO	NO	NO	1	NO	NO	0.1	0.1	0.1	0.2	0.1	NO	NO	NO	NO

Reference: *Documents of Fluorocarbons etc Measures Working Group, Documents of the second meeting of the Breakout Group on F-gases, FY2014 Committee for the Greenhouse Gas Emissions Estimation Methods etc*

The 2006 IPCC Guidelines specifies estimation methods for HFC-43-10mee emissions from this sub-category, however, emissions do not exceed the 3,000 t-CO<sub>2</sub> eq threshold for estimation, determined by the Committee for Greenhouse Gas Emissions Estimation Methods, and therefore is reported as NE (considered insignificant). (See Annex 5)

Due to the lack of data necessary to estimate emissions for the years 1990 to 1994, estimates have been done by domestic HFC shipment amounts which are thought to be proportional to potential emissions, and extrapolating etc for these years.

#### c) *Uncertainties and Time-series Consistency*

##### ● *Uncertainty*

For the uncertainties of the emission factors, 0% was applied for all production, use and disposal, due to the fact that the amount of emissions is equal to the amount of aerosols used. For the uncertainties of the activity data, the 10% value of the Tier 2 method for metal industry in the 2006 IPCC Guidelines was applied for all production, use, and disposal. As a result, the uncertainties of the emissions for all production, use and disposal were determined to be 10%.

##### ● *Time-series Consistency*

See section 4.3.9.1. c).

#### d) *Category-specific QA/QC and Verification*

See section 4.3.9.1. d).

#### e) *Category-specific Recalculations*

There have been no source-specific recalculations.

#### f) *Category-specific Planned Improvements*

No improvements are planned.

### 4.7.5. Solvents (2.F.5.)

#### a) *Category Description*

Liquid HFC-365mfc is used as an industrial dry cleaning solvent by the name of Solkane Dry, and is released into the atmosphere through volatilization etc. HFCs and PFCs are also emitted from the use of solvents for the cleaning of general electronic parts, and semiconductor/liquid crystal manufacturing. The liquid PFCs used were C<sub>5</sub>F<sub>12</sub> (PFC-41-12) and C<sub>6</sub>F<sub>14</sub> (PFC-51-14). Data on HFCs used as solvents in the cleaning of general electronic parts, and semiconductor/liquid crystal manufacturing are

confidential; therefore, these are reported as included under the total of PFCs.

## b) Methodological Issues

### ● Estimation Method

#### ➤ HFCs

The annual use amount of Solkane Dry is estimated by multiplying the aggregate number of dry cleaning machines using Solkane Dry (from the domestic manufacturers, and subtracting out the number of machines disposed), by the average solvent amount used. All that is used (=solvent amount replenished) is assumed to have been emitted.

$$E = (N_{special} - D_{special}) \times U_{special} + (N_{partial} - D_{partial}) \times U_{partial}$$

$E$	: HFC-365mfc emissions
$N_{special}$	: Aggregate number of dry cleaning machines specialized for Solkane Dry use
$D_{special}$	: Aggregate number of specialized machines disposed
$U_{special}$	: Average solvent amount used in specialized machines
$N_{partial}$	: Aggregate number of dry cleaning machines partially using Solkane Dry
$D_{partial}$	: Aggregate number of partial-use machines disposed
$U_{partial}$	: Average solvent amount used in partial-use machines

The average solvent amount used in dry cleaning machines using Solkane Dry is set based on the actual amounts of Solkane Dry sold and actual number of operating machines at a large manufacturer. (See the Table below) For the average solvent amount used in Solkane Dry-specialized dry cleaning machines in years 2011 and before, the average value for 2012 to 2017 is used. For the dry cleaning machines partially using Solkane Dry, the average solvent amount used is set by multiplying the amount for specialized machines by a ratio.

Since there is no shipment of dry cleaning machines using Solkane Dry for 2002 and before, emissions only start occurring in 2003.

Table 4-86 Number of dry cleaning machines using Solkane Dry and average solvent amount used

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Cumulative number of specialized and mixed-use machines	units	0	0	0	12	121	170	192	216	234	246	259	268	272	283	292
Average solvent use per year (specialized)	kg/unit	0	0	0	673	673	673	653	678	713	699	692	602	602	602	602

#### ➤ PFCs

Assuming that almost all of the total amount of liquid PFC shipment was used in cleaners and for cleaning purposes each year, the entire amount was reported in the "use" category as the amount of emissions. (Average GWP for 2020 is 4,209. Emissions are calculated by gas but are reported as an unspecified mix due to confidentiality reasons.) Emission from manufacturing was reported as "NO" since there is no practice to blend before use. Emission at the time of disposal was reported as "IE" on the assumption, from the point of view of conservativeness, that the entire amount including that was disposed of, was emitted during use, because of the difficulty in determining the status of the disposal of PFCs. It is confirmed that no disposals were identified in 1995.

Emissions from PFCs contained in railway rectifiers (Refer to 2.G.2. for details) are subtracted from liquid PFC emissions to yield the total PFC emissions.

Due to the lack of data necessary to estimate emissions for the years 1990 to 1994, estimates have been done by using domestic PFC shipment amounts which is thought to be proportional to PFC emissions,

and extrapolating for these years.

**c) Uncertainties and Time-series Consistency**

● **Uncertainty**

For the uncertainties of the HFC emission factors, -5% to +5% was applied. For the uncertainties of the activity data, the 10% value of the Tier 2 method for metal industry in the *2006 IPCC Guidelines* was applied. As a result, the uncertainties of the emissions were determined to be -11% to +11%.

For the uncertainties of the PFC emission factors, 0% was applied, due to the fact that the amount of emissions is equal to the amount of solvent used. For the uncertainties of the activity data, the 10% value of the Tier 2 method for metal industry in the *2006 IPCC Guidelines* was applied. As a result, the uncertainties of the emissions were determined to be 10%.

● **Time-series Consistency**

See section 4.3.9.1. c).

**d) Category-specific QA/QC and Verification**

See section 4.3.9.1. d).

**e) Category-specific Recalculations**

There have been no source-specific recalculations.

**f) Category-specific Planned Improvements**

No improvements are planned.

**4.7.6. Other Applications (2.F.6.)**

Refrigerants filled in research and medical equipment are captured and included in other refrigerant categories.

**4.8. Other Product Manufacture and Use (2.G.)**

This category covers N<sub>2</sub>O, PFC, and SF<sub>6</sub> emissions from other product manufacture and use. This section includes GHG emissions from the following sources: Electrical equipment (2.G.1.), Military applications (2.G.2.), Accelerators (2.G.2.), Other - Railway silicon rectifiers (2.G.2.), Medical applications (2.G.3.), and Use during Semiconductor/Liquid Crystal Manufacturing (2.G.3.).

In FY2020, emissions from this category were 1,836 kt-CO<sub>2</sub> eq. and represented 0.2% of Japan's total GHG emissions (excluding LULUCF). The total emissions of N<sub>2</sub>O from this category had increased by 45.8% compared to FY1990. The total of PFCs and SF<sub>6</sub> had decreased by 84.0% compared to 1990.

Table 4-87 Emissions from 2.G. other product manufacture and use

Gas		Units	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
N <sub>2</sub> O	2.G.3 Medical applications	kt-N <sub>2</sub> O	0.93	1.41	1.10	0.86	0.32	0.31	0.29	0.25	1.11	0.22	0.22	0.23	0.21	0.27	0.28
	2.G.3 Use during semiconductor/ liquid crystal manufacturing	kt-N <sub>2</sub> O	0.05	0.10	0.15	0.38	0.60	0.59	0.74	0.95	0.99	1.13	1.22	1.18	1.03	1.04	1.14
	Total	kt-N <sub>2</sub> O	0.98	1.51	1.25	1.23	0.92	0.91	1.03	1.20	2.10	1.35	1.44	1.41	1.24	1.31	1.42
	Total	kt-CO <sub>2</sub> eq.	291	449	371	368	275	270	308	359	627	402	429	420	370	390	424
Gas		Units	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
PFCs	2.G.2 Other-Railway silicon rectifiers	t	NO	NO	NO	0.03	0.47	0.64	NO	1.11	0.97	0.84	2.24	2.10	4.22	5.22	6.07
	2.G.1 Electrical equipment	t	355.81	460.46	127.62	39.45	27.29	30.99	31.53	28.19	26.39	26.76	28.74	27.19	25.09	25.12	25.06
SF <sub>6</sub>	2.G.2 Military applications	t	NO	NO	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23
	2.G.2 Accelerators	t	30.77	35.16	34.49	35.69	33.83	34.14	35.05	35.12	35.06	34.27	33.39	33.91	34.50	34.58	33.17
	Total	t	386.58	495.62	163.34	76.36	62.35	66.36	67.81	64.54	62.68	62.26	63.36	62.33	60.82	60.93	59.46
Total of F-gases		kt-CO <sub>2</sub> eq.	8,814	11,300	3,724	1,741	1,426	1,519	1,546	1,482	1,438	1,427	1,466	1,441	1,426	1,438	1,412

#### 4.8.1. Electrical Equipment (2.G.1.)

##### a) Category Description

SF<sub>6</sub> are emitted during the manufacturing and use of electrical equipment.

##### b) Methodological Issues

###### ● Estimation Method

Emissions from producing electrical equipment were calculated by multiplying the amount of SF<sub>6</sub> purchased by assembly fugitive rate. Emissions from the use of electrical equipment were calculated based on the fugitive rate during the use of electrical equipment. Emission factors are country-specific. Emissions from the inspection and disposal of electrical equipment were obtained by actual measurements of SF<sub>6</sub>.

In CRF, the emission was reported as “IE” after including the emission from disposal into the use of electrical equipment.

###### ➤ Emissions from the production

$$E_{\text{manufacturing}} = AD \times EF_{\text{manufacturing}}$$

$E_{\text{manufacturing}}$  : SF<sub>6</sub> emissions from the production  
 $AD$  : SF<sub>6</sub> purchased  
 $EF_{\text{manufacturing}}$  : Assembly fugitive rate [%]

###### ➤ Emission from the use

$$E_{\text{use}} = \text{Stock} \times EF_{\text{use}}$$

$E_{\text{use}}$  : SF<sub>6</sub> emission from the use  
 $\text{Stock}$  : Stocks of SF<sub>6</sub>  
 $EF_{\text{use}}$  : Rate of emitted SF<sub>6</sub> into the environment during the use of electrical equipment (0.1%)

###### ➤ Emission from the inspection

$$E_{\text{inspection}} = E_{\text{measured}}$$

$E_{\text{inspection}}$  : SF<sub>6</sub> emission from the inspection  
 $E_{\text{measured}}$  : Actual measurements of SF<sub>6</sub>

➤ **Emission from the disposal**

$$E_{\text{disposed}} = E_{\text{measured}}$$

$E_{\text{disposed}}$  : SF<sub>6</sub> emission from the disposal

$E_{\text{measured}}$  : Actual measurements of SF<sub>6</sub>

The associated indices are given in the table below.

Table 4-88 Indices related to emissions of SF<sub>6</sub> from electrical equipment

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Emissions during manufacturing	kt-CO <sub>2</sub> eq.	7,047	9,120	2,291	523	157	169	146	125	137	163	179	141	119	112	100
SF <sub>6</sub> emissions during use, maintenance, and disposal	kt-CO <sub>2</sub> eq.	1,065	1,378	619	376	465	538	573	517	465	447	476	479	454	460	472

Reference: the *Documents of Fluorocarbons etc Measures Working Group*, and data provided by the METI, *Documents of the first meeting of the Breakout Group on F-gases (FY2013)*

Due to the lack of data necessary to estimate emissions for the years 1990 to 1994, estimates have been done by using domestic SF<sub>6</sub> shipment amounts which is thought to be proportional to amounts of SF<sub>6</sub> purchased and stocks of SF<sub>6</sub>, amounts of SF<sub>6</sub> charged to electrical equipment from 1995, the assembly fugitive rate from 1995, and the operational fugitive rate from 1995, and extrapolating for these years.

**c) Uncertainties and Time-series Consistency**

● **Uncertainty**

For the uncertainties of the emission factors, -30 to +30% was applied for manufacturing and use, and -20 to +40% was applied for disposal, in accordance with the *2006 IPCC Guidelines*' default value. For the uncertainties of the activity data, the 10% value of the Tier 2 method for metal industry in the *2006 IPCC Guidelines* was applied for all manufacturing, use, and disposal. As a result, the uncertainty of the emissions for manufacturing and use was determined to be -32 to +32%, and -22 to +41% for disposal.

● **Time-series Consistency**

See section 4.3.9.1. c).

**d) Category-specific QA/QC and Verification**

See section 4.3.9.1. d).

**e) Category-specific Recalculations**

There have been no source-specific recalculations.

**f) Category-specific Planned Improvements**

No improvements are planned.



## 4.8.2. SF<sub>6</sub> and PFCs from Other Product Use (2.G.2.)

### 4.8.2.1. Military applications (2.G.2.-)

#### a) Category Description

SF<sub>6</sub> is used as an insulating medium in the radar systems of AWACS (Airborne Warning and Control System). When the plane ascends, SF<sub>6</sub> is automatically released from the system and into the atmosphere to maintain the appropriate pressure difference between the system and the outside air. When the plane descends, SF<sub>6</sub> is automatically charged into the system from an SF<sub>6</sub> container on board.

#### b) Methodological Issues

##### ● Estimation Method

Emissions are calculated using a method corresponding to the Tier 2 method (user mass-balance method) in the 2006 IPCC Guidelines.

$$E = D + M - R - I$$

- E* : SF<sub>6</sub> Emissions
- D* : Decrease of SF<sub>6</sub> in the container on board the AWACS
- M* : SF<sub>6</sub> leakage during acquisition/replacement of SF<sub>6</sub> container on AWACS
- R* : SF<sub>6</sub> collected/destroyed
- I* : Net increase in AWACS fleet charge

The four-fleet AWACS was officially authorized for use on March 24, 1999, and therefore SF<sub>6</sub> emissions are considered to have started in 1999.

#### c) Uncertainties and Time-series Consistency

##### ● Uncertainty

No emission factor is set, and therefore the uncertainty of emissions is assessed by assessing the uncertainty of activity data. A 10% uncertainty of metal production is taken for the uncertainty of activity data. As a result, the uncertainty of emissions is 10%.

##### ● Time-series Consistency

Emissions are estimated in a manner consistent across the time-series methodologically, and from the point of view of data source.

#### d) Category-specific QA/QC and Verification

See section 4.2.1. d).

#### e) Category-specific Recalculations

There have been no source-specific recalculations.

#### f) Category-specific Planned Improvements

No improvements are planned.

#### 4.8.2.2. Accelerators (2.G.2.-)

##### a) Category Description

SF<sub>6</sub> is used in university and research facility-operated particle accelerators, and in industrial/medical accelerators (for cancer therapy) as an insulating gas. When the equipment requires maintenance, the SF<sub>6</sub> is transferred into storage tanks, and therefore losses occur primarily during gas transfer.

##### b) Methodological Issues

###### ● Estimation Method

Emissions are calculated using the Tier 1 method in the *2006 IPCC Guidelines*.

$$E = N \times U \times C \times EF$$

- $E$  : SF<sub>6</sub> Emissions
- $N$  : Number of accelerators
- $U$  : SF<sub>6</sub> use factor
- $C$  : SF<sub>6</sub> charge factor
- $EF$  : SF<sub>6</sub> emission factor

The SF<sub>6</sub> use factor, SF<sub>6</sub> charge factor, SF<sub>6</sub> emission factor, and number of accelerators used for estimating emissions are shown below by type of accelerator.

Table 4-89 SF<sub>6</sub> use factor, SF<sub>6</sub> charge factor, SF<sub>6</sub> emission factor by type of accelerator

Item	University and research operated particle accelerators	Industrial particle accelerators	Medical particle accelerators <sup>1)</sup>	Small-scale electron accelerators
SF <sub>6</sub> use factor	33%	100%	100%	100%
SF <sub>6</sub> charge factor [kg]	2,400	1,300	0.5	400 <sup>2)</sup>
SF <sub>6</sub> emission factor [kg/kg]	See below Table	0.07	2.0	0.07

Note: 1) Among the medical particle accelerators, cyclotrons and synchrotrons are not considered to use SF<sub>6</sub>, and therefore are not estimated for.

Reference: *2006 IPCC Guidelines* default values excluding the 2) value are from results of interviews with main accelerator manufacturers.

Table 4-90 SF<sub>6</sub> emission factor for particle accelerators at university/research facilities

Item	1990-2004	2005-2009	2010-2014	2015-2019	2019-2020
SF <sub>6</sub> emission factor [kg/kg]	0.070	0.063	0.063	0.052	0.045

Reference: Calculated based on JAEA-Technology 2010-023: Operation and Management of the High-pressure Gas Facility for the Tandem Accelerator, and 2011-2018 Environmental Reports (Japan Atomic Energy Agency).

Table 4-91 Number of accelerators by type

Item	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Number of particle accelerators (University/Research facilities)	188	214	212	209	218	216	231	225	222	241	245	242	239	239	239
Number of particle accelerators (Industrial use)	143	164	145	181	174	179	184	188	190	193	183	191	198	198	198
Number of particle accelerators (Medical use)	531	641	754	857	926	986	1,028	1,068	1,081	1,108	1,114	1,146	1,132	1,132	1,132
Number of small-scale (below 1MeV) electron accelerators	243	276	314	282	218	215	203	201	197	201	196	192	196	198	200

Reference: *Statistics on the Use of Radiation in Japan* (Japan Radioisotope Association), except for the *Nuclear Yearbook* (The Japan Atomic Industrial Forum) etc for small-scale electron accelerators

##### c) Uncertainties and Time-series Consistency

###### ● Uncertainty

For the EF, a -50 to +400% uncertainty from the *2006 IPCC Guidelines* (particle accelerators - medical use) was applied. A -10 to +10% uncertainty of metal production is taken for the uncertainty of activity data. As a result, the uncertainty of emissions is -51 to +400%.

- **Time-series Consistency**

Emissions are estimated in a manner consistent across the time-series methodologically, and from the point of view of data source.

**d) Category-specific QA/QC and Verification**

See section 4.2.1. d).

**e) Category-specific Recalculations**

The number of accelerators were corrected for 2018 and 2019, resulting in recalculations. See Chapter 10 for impact on trend.

**f) Category-specific Planned Improvements**

No improvements are planned.

#### 4.8.2.3. Soundproof windows (2.G.2.-)

The 2006 IPCC Guidelines specifies estimation methods for this this sub-category, however, emissions do not exceed the 3,000 t-CO<sub>2</sub> eq threshold for estimation, determined by the Committee for Greenhouse Gas Emissions Estimation Methods, and therefore is reported as NE (considered insignificant). (See Annex 5)

#### 4.8.2.4. Adiabatic properties: shoes and tyres (2.G.2.-)

PFC and SF<sub>6</sub> use for rubber with adiabatic properties are not found in Japan, and therefore emissions are reported as NO.

#### 4.8.2.5. Other - Railway Silicon Rectifiers (2.G.2.-)

**a) Category Description**

PFCs are emitted at disposal of railway silicon rectifiers.

**b) Methodological Issues**

- **Estimation Method**

Based on the number of devices containing PFC-51-14, the amount of PFC-51-14 contained, and lifetime of the devices installed on ground and on car respectively, given in the *Survey on Management Methods of Halons/Liquid PFCs etc* (2006), and the *Survey on Destruction of Halons/PFCs etc* (2010), the amount of PFC-51-14 disposed after use in railway silicon rectifiers in each fiscal year was estimated. This was done by multiplying the number of railway silicon rectifiers disposed per year, by the amount of PFC contained in each device. PFC emissions are calculated by subtracting the amount of PFC-51-14 destroyed in a specific fiscal year from the PFC disposed after use in railway silicon rectifiers in the same fiscal year.

$$E = M_{disposal} - R$$

$E$  : PFC emissions at disposal of railway silicon rectifiers

$M_{disposal}$  : PFC disposed after use in railway silicon rectifiers  
 $R$  : PFC destroyed

### c) *Uncertainties and Time-series Consistency*

#### ● *Uncertainty*

For the uncertainty of the emission factor from railway silicon rectifiers, the 0% value for solvents was applied since it is a similar source category. For the uncertainties of the activity data, the 10% value of the Tier 2 method for metal industry in the *2006 IPCC Guidelines* was applied. As a result, the uncertainties of the emissions were determined to be 10%.

#### ● *Time-series Consistency*

Emissions are estimated in a manner consistent across the time-series methodologically, and from the point of view of data source.

### d) *Category-specific QA/QC and Verification*

See section 4.2.1. d).

### e) *Category-specific Recalculations*

There have been no source-specific recalculations.

### f) *Category-specific Planned Improvements*

No improvements are planned.

## 4.8.3. N<sub>2</sub>O from Product Uses (2.G.3.)

### 4.8.3.1. Medical Applications (2.G.3.a)

#### a) *Category Description*

Nitrous oxide is emitted during anesthetics (laughing gas) use. Since 2006, some hospitals have installed N<sub>2</sub>O destruction units, and the reductions achieved are reflected in the total emissions. CO<sub>2</sub> is not used as an anesthetic in Japan.

#### a) *Methodological Issues*

##### ● *Estimation Method*

In relation to emissions of N<sub>2</sub>O from use of anesthetics, the actual amount of N<sub>2</sub>O shipped as an anesthetic by pharmaceutical manufacturers or importers has been reported for 2005 and preceding years. For 2006 and beyond, the amount of N<sub>2</sub>O collected is calculated using the amount of laughing gas used in domestic hospitals equipped with N<sub>2</sub>O destruction units for anesthesia, and a destruction rate of 99.9 %. This is subtracted from the N<sub>2</sub>O shipped for medical use to yield the amount of N<sub>2</sub>O emitted.

$$E = S - (U \times DR)$$

$E$  : Amount of N<sub>2</sub>O emitted during the use of laughing gas

$S$  : N<sub>2</sub>O shipped for medical use

$U$  : Amount of laughing gas used in hospitals equipped with N<sub>2</sub>O destruction units

$DR$  : Destruction rate

- **Emission Factors**

It is assumed that all of the N<sub>2</sub>O used as medical gas escapes into the atmosphere, unless collected. Therefore, no emission factor has been established.

- **Activity Data**

The amount of shipments of N<sub>2</sub>O for anesthetics (on calendar year basis) is given in the Ministry of Health, Labour and Welfare's *Statistics of Production by Pharmaceutical Industry*. This is used for 2005 and preceding years, and for 2006 to 2009, the amount of N<sub>2</sub>O collected in three, and from 2010 and onward collected in four domestic hospitals equipped with N<sub>2</sub>O destruction units is subtracted from the above-mentioned shipment.

Table 4-92 Laughing gas shipment amount and N<sub>2</sub>O collected in domestic hospitals

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Laughing gas shipment amount	kg-N <sub>2</sub> O	926,030	1,411,534	1,099,979	859,389	320,110	314,155	292,971	253,218	1,111,265	219,011	219,011	234,691	211,842	265,728	283,333
N <sub>2</sub> O collected in domestic hospitals	kg-N <sub>2</sub> O	NO	NO	NO	NO	914	779	450	509	NO	NO	NO	NO	NO	NO	NO

- b) **Uncertainties and Time-series Consistency**

- **Uncertainty**

Because all N<sub>2</sub>O used for anesthetics are assumed to escape into the atmosphere, no emission factor has been set. Therefore, the uncertainty for activity data is also the uncertainty for emissions. As *Statistics of Production by Pharmaceutical Industry* is a fundamental statistic based on statistical law, a 5% uncertainty was given for this emission source.

- **Time-series Consistency**

The amount of shipments are taken from the *Statistics of Production by Pharmaceutical Industry* in a consistent manner throughout the time series.

- c) **Category-specific QA/QC and Verification**

See section 4.2.1. d).

- d) **Category-specific Recalculations**

Recalculations occurred for FY2019, due to updates of the shipped amount of laughing gas. See Chapter 10 for impact on trend.

- e) **Category-specific Planned Improvements**

No improvements are planned.

#### 4.8.3.2. Other (2.G.3.b)

##### 4.8.3.2.a. Use during Semiconductor/Liquid Crystal Manufacturing (2.G.3.b.-)

- a) **Category Description**

N<sub>2</sub>O is used as an oxidizing agent to form an insulative oxide film during semiconductor/liquid crystal manufacturing, and the remaining is considered to be released into the atmosphere.

**b) Methodological Issues****● Estimation Method**

Emissions equal all N<sub>2</sub>O shipment amounts for semiconductor/liquid crystal manufacturing.

$$E = AD$$

*E* : N<sub>2</sub>O emissions during semiconductor/liquid crystal manufacturing

*AD* : N<sub>2</sub>O shipped for semiconductor/liquid crystal manufacturing use

**● Emission Factors**

Emissions equal activity data, and therefore no emission factor has been established.

**● Activity Data**

The N<sub>2</sub>O shipment amounts for semiconductor/liquid crystal manufacturing given in the website of the Japan Industrial and Medical Gases Association is used as activity data.

**c) Uncertainties and Time-series Consistency****● Uncertainty**

Because all N<sub>2</sub>O used during semiconductor/liquid crystal manufacturing are assumed to escape into the atmosphere, no emission factor has been set. Therefore, the uncertainty for activity data is also the uncertainty for emissions. For the uncertainty of activity data, a 5% default value in the *2006 IPCC Guidelines* were used.

**● Time-series Consistency**

The shipment amounts are taken from what is reported by the Japan Industrial and Medical Gases Association in a consistent manner throughout the time series.

**d) Category-specific QA/QC and Verification**

See section 4.2.1. d).

**e) Category-specific Recalculations**

There have been no source-specific recalculations.

**f) Category-specific Planned Improvements**

There is a possibility of over-estimation, since emissions are equal to all N<sub>2</sub>O shipment amounts for semiconductor/liquid crystal manufacturing.

**4.9. Other (2.H.)**

This category covers CO<sub>2</sub> emissions from other sources. This category includes GHG emissions from the following sources: Food and beverages industry (2.H.2.), and Imported carbonated gas (2.H.3.).

Table 4-93 Emissions from 2.H. Other

Gas		Units	1990	1995	1999	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
CO <sub>2</sub>	2.H.2	Food and beverages industry	kt-CO <sub>2</sub>	64	72	89	87	90	76	76	82	80	83	79	85	80	79	71	
	2.H.3	Emissions from imported carbonated gas	kt-CO <sub>2</sub>	0.3	0.3	0.2	0.2	0.2	1	12	23	11	10	14	28	26	25	21	16
		Total	kt-CO <sub>2</sub>	65	72	90	87	90	77	88	100	94	91	97	107	111	105	100	87

#### 4.9.1. Food and Beverages Industry (2.H.2.)

The CO<sub>2</sub> recovered, estimated together with the emissions from ethylene oxide production (2.B.8.d) is reported here.

Petroleum refining plants, ammonia production plants, and iron production plants are other sources of supply CO<sub>2</sub> for the production of carbonated gas and dry ice in Japan, however those emissions occurring from petroleum refining plants are reported under the Fuel combustion category (1.A.), and those emissions occurring from ammonia production plants are reported under ammonia production (2.B.1.), and those emissions occurring from iron production plants are reported under the Fuel combustion category (1.A.).

#### 4.9.2. Emissions from Imported Carbonated Gas (2.H.3.)

##### a) *Category Description*

CO<sub>2</sub> are emitted from the use of imported carbonated gas.

##### b) *Methodological Issues*

The total amount of imported carbonated gas was used for estimating emissions.

##### ● *Estimation Method*

No emission factors were established since the activity data is directly the emissions.

##### ● *Activity Data*

The import quantities of carbon dioxide in the *Trade Statistics of Japan* (the Ministry of Finance) was used for estimating emissions.

##### c) *Uncertainties and Time-series Consistency*

##### ● *Uncertainty*

No emission factor has been set because all CO<sub>2</sub> are emitted from the use of imported carbonated gas, and are assumed to escape into the atmosphere. Therefore, the uncertainty for activity data is also the uncertainty for emissions. For the uncertainty of activity data, a 5% value, which is the uncertainty for the use of electric arc furnaces in steel production referred to in the *Trade Statistics of Japan*, was used.

##### ● *Time-series Consistency*

Emissions are estimated in a manner consistent across the time-series methodologically, and from the point of view of data source.

##### d) *Category-specific QA/QC and Verification*

See section 4.2.1. d).

##### e) *Category-specific Recalculations*

There have been no source-specific recalculations.

##### f) *Category-specific Planned Improvements*

No improvements are planned.

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## Chapter 5. Agriculture (CRF sector 3)

### 5.1. Overview of Sector

Greenhouse gas emissions from the agricultural sector are calculated in seven categories: 3.A., 3.B., 3.C., 3.D., 3.F., 3.G., and 3.H. In 3.A.: Enteric Fermentation, CH<sub>4</sub> gas generated and emitted by cattle, buffalo, sheep, goats, horses, and swine as the result of enteric fermentation is reported. In 3.B.: Manure Management, CH<sub>4</sub> and N<sub>2</sub>O generated by treatment of manure excreted by cattle, buffalo, sheep, goats, horses, swine, poultry (hen and broiler), rabbits, and mink are reported. In 3.C.: Rice Cultivation, CH<sub>4</sub> emissions from paddy fields (continuously flooded and intermittently flooded) cultivated for rice production are reported. In 3.D.: Agricultural Soils, N<sub>2</sub>O emitted directly and indirectly from agricultural soil are reported. Emissions for 3.E.: Prescribed Burning of Savannas are reported as NO, since Japan has no emission source in this category, while CH<sub>4</sub> and N<sub>2</sub>O (as well as CO and NO<sub>x</sub>, which is described in Annex 3) emissions from field burning of grains, legumes, root crops, and sugar cane during agricultural activities are reported in 3.F.: Field Burning of Agricultural Residues. 3.G.: Liming and 3.H.: Urea Application, CO<sub>2</sub> emissions by application of limestone and urea to soil are reported.

GHG emissions in the agricultural sector in FY2020 were 32,186 kt-CO<sub>2</sub> eq., comprising 2.8% of total emissions (excluding LULUCF). The value represents a 14.1% decrease from FY1990.

Tier of methodology used in Agriculture sector are showed in Table 5-1.

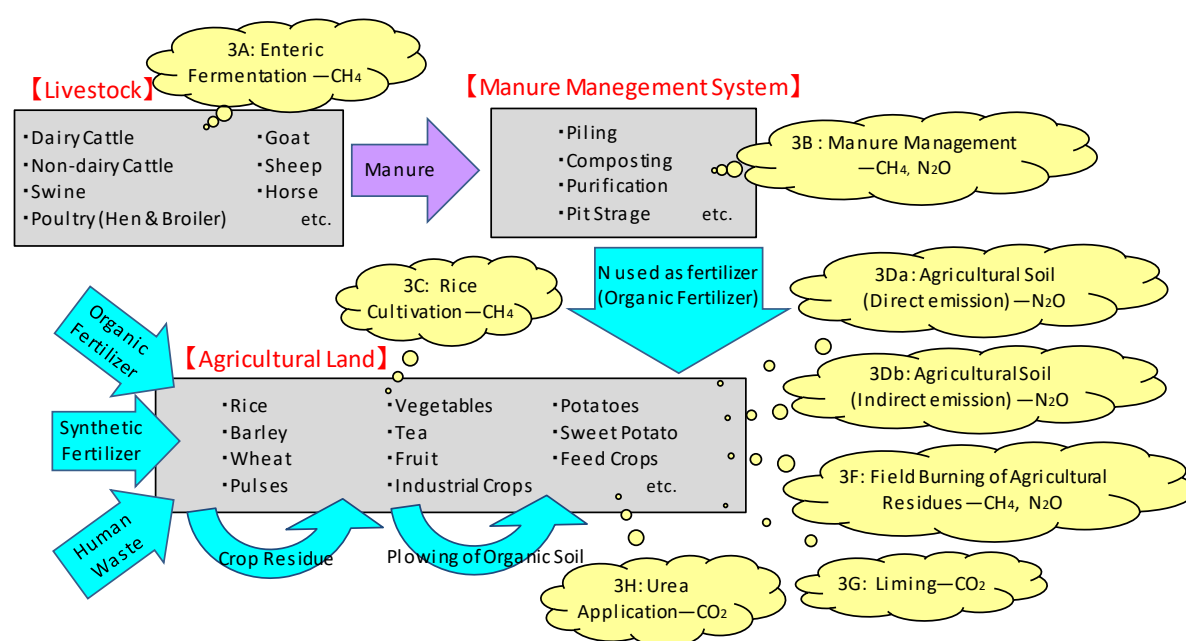


Figure 5-1 Relationships among the categories in the agricultural sector

Table 5-1 Tier of methodology used in Agriculture sector

GREENHOUSE GAS CATEGORIES	CO <sub>2</sub>		CH <sub>4</sub>		N <sub>2</sub> O	
	Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor
3.A. Enteric fermentation			CS,T1	CS,D		
3.B. Manure management			CS,T1	CS,D	CS,T1	CS,D
3.C. Rice cultivation			T3	CS		
3.D. Agricultural soils					CS,T2	CS,D
3.F. Field burning of agricultural residues			T1	D	T1	D
3.G. Liming	T1	D				
3.H. Urea application	T1	D				

Note: D: IPCC default, T1: IPCC Tier1, T2: IPCC Tier2, T3: IPCC Tier3, CS: country-specific method or emission factor

## 5.2. Enteric Fermentation (3.A.)

Ruminants such as cattle, buffalo, sheep, and goats have multi-chamber stomachs. The rumen carries out anaerobic fermentation to decompose cellulose and other substances, thereby releasing CH<sub>4</sub>. Horses and swine are not ruminants and have monogastric stomachs, but fermentations in their digestive tracts produce a small amount of CH<sub>4</sub>, which is released into the atmosphere. These CH<sub>4</sub> emissions are calculated and reported in the Enteric Fermentation (3.A.) section.

GHG emissions from enteric fermentation in FY2020 were 7,633 kt-CO<sub>2</sub> eq., comprising 0.7% of total emissions (excluding LULUCF). The value represents a decrease by 19.0% from FY1990. Main driver of the emission reduction from FY1990 is a reduction of cattle population.

Table 5-2 CH<sub>4</sub> emissions from enteric fermentation (3.A.)

Gas	Livestock species	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
CH <sub>4</sub>	3.A.1.- Dairy cattle	kt-CH <sub>4</sub>	192.1	184.4	171.2	162.9	146.3	146.2	143.4	139.7	137.0	136.4	133.5	133.5	133.4	134.9	135.5	
	3.A.1.- Non-dairy cattle		166.5	172.2	171.7	168.0	166.5	164.7	159.6	154.8	150.0	150.3	151.1	151.7	150.7	153.0	155.2	
	3.A.2. Sheep		0.167	0.115	0.097	0.071	0.159	0.160	0.129	0.138	0.140	0.140	0.143	0.158	0.162	0.170	0.160	
	3.A.3. Swine		15.9	13.9	13.7	13.5	13.7	13.6	13.6	13.4	13.2	13.0	13.1	12.9	12.8	12.9	13.0	
	3.A.4.- Buffalo		0.011	0.007	0.006	0.005	0.004	0.004	0.005	0.005	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006
	3.A.4.- Goats		0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	3.A.4.- Horses		2.1	2.1	1.9	1.6	1.3	1.4	1.3	1.3	1.2	1.3	1.3	1.3	1.4	1.4	1.4	1.3
	Total		kt-CH <sub>4</sub>	376.9	372.7	358.7	346.0	328.1	326.2	318.1	309.5	301.7	301.4	299.2	299.8	298.6	302.5	305.3
	kt-CO <sub>2</sub> eq	9,423	9,318	8,966	8,651	8,202	8,154	7,953	7,737	7,543	7,534	7,481	7,494	7,465	7,563	7,633		

### 5.2.1. Cattle (3.A.1.)

#### a) Category Description

This section provides the estimation methods for CH<sub>4</sub> emissions from enteric fermentation in Cattle.

#### b) Methodological Issues

##### ● Estimation Method

In accordance with decision tree of the *2006 IPCC Guidelines* (Volume 4, Page 10.25, Figure 10.2), calculations for dairy and non-dairy cattle should be performed using the Tier 2 method. In the Tier 2 method, emission factors are calculated by multiplying the total energy intake of livestock by the CH<sub>4</sub> conversion factor. However, estimation using amount of dry matter intake (DMI) has been practiced in Japan on livestock-related research. It is considered that applying the results of research using amount of DMI for the estimation provides more accurate results which is in accordance with the actual situation of emissions. For that reason, a technique similar to the Tier 2 method but specific to Japan was used for the calculation of CH<sub>4</sub> emissions associated with enteric fermentation by cattle. The emissions were

calculated by multiplying the cattle population (dairy and non-dairy) by the emission factors established based on their dry matter intake.

Table 5-3 Categorization and assumptions underlying calculation of CH<sub>4</sub> emissions associated with enteric fermentation in cattle

Type of cattle		Assumptions for calculation of emissions	Additional information for each animal type		
Dairy cattle	Lactating	Primipara	Population by calving time: calculated by multiplying the ratio of population by calving in <i>Record of Dairy Herd Performance Test</i> by the population in <i>Livestock Statistics</i> .	Lactating cattle. Population of 2 years old and over are written in <i>the Livestock Statistics</i> .	
		Secondipara			
		Multipara (3 and more)			
	Non-lactating		—	Cattle in non-lactating period at present.	
	Heifers	Under 2 years old and over 6 months old	Calculation excludes 6/24 of the population which was assumed to be 6 months old or younger; therefore covering 18/24 of the population under 2 years old.	Dairy cattle which are under 2 years old. Population of under 2 years old are described in <i>the Livestock Statistics</i> .	
3 to 6 months old		Comprising 4/24 of the population under 2 years old.			
Under 3 months old		Covering 2/24 of the population under 2 years old. Excluded from CH <sub>4</sub> emission estimation.			
Non-dairy cattle	Breeding cows	2 years old and over	—	Breeding cow excluding dairy breeds. Population of under 1 year old, 1 year old, 2 years old, and 3 years old and over are described in <i>the Livestock Statistics</i> .	
		Under 2 years old and over 6 months old	Calculation exclude 6/12 of the population which was assumed to be 6 months to 1 year old for under 1 year old and addition of the population under 1 year old.		
		3 to 6 months old	Comprising 4/12 of the population under 1 year old.		
		Under 3 months old	Covering 2/12 of the population under 1 year old. Excluded from CH <sub>4</sub> emission estimation.		
	Fattening cattle	Wagyu (Male)	1 year old and over	—	Cattle of native breeds in Japan called “Wagyu”, which breeds for meat only. Population of under 1 year, 1 year and 2 years old and over are described as beef cattle (Male) in <i>the Livestock Statistics</i> .
			Under 1 year old and over 6 months old	Calculation excludes 6/12 of the population which was assumed to be 6 months old or younger; therefore covering 6/12 of the population under 1 year old.	
			3 to 6 months old	Comprising 4/12 of the population under 1 year old.	
			Under 3 months old	Covering 2/12 of the population under 1 year old. Excluded from CH <sub>4</sub> emission estimation.	
		Wagyu (Female)	1 year old and over	—	Cattle of native breeds in Japan called “Wagyu”, which breeds for meat only. Population of under 1 year, 1 year and 2 years old (more than 7 categories) are described as beef cattle (Female) in <i>the Livestock Statistics</i> .
			Under 1 year old and over 6 months old	Same as same month age of Wagyu (Male)	
			3 to 6 months old	Same as same month age of Wagyu (Male)	
			Under 3 months old	Same as same month age of Wagyu (Male). Excluded from CH <sub>4</sub> emission estimation.	
Dairy breeds	Dairy breeds	Over 6 months old	Calculation excludes 6/24 of the population which was assumed to be 6 months old or younger; therefore covering 18/24 of the population under 2 years old.	Cattle of dairy breeds for meat such as Holsteins.	
		3 to 6 months old	Comprising 4/24 of the population under 2 years old.		
		Under 3 months old	Covering 2/24 of the population under 2 years old. Excluded from CH <sub>4</sub> emission estimation.		
	Hybrid	Over 6 months old	Same as same month age of Dairy breeds	F1 hybrid for beef which female dairy breeds are delivered with crossing with male beef breed cattle.	
		3 to 6 months old	Same as same month age of Dairy breeds		
		Under 3 months old	Same as same month age of Dairy breeds. Excluded from CH <sub>4</sub> emission estimation.		

$$E = \sum (EF_i \times A_i)$$

$E$	: CH <sub>4</sub> emissions from enteric fermentation for cattle [kg-CH <sub>4</sub> /yr]
$EF_i$	: CH <sub>4</sub> emission factor of enteric fermentation of cattle type $i$ [kg-CH <sub>4</sub> /head/yr]
$A_i$	: Population of each cattle type $i$ [head]
$i$	: Cattle type

As cattle begin to eat coarse feed for real at the age about three months, the calculation of the CH<sub>4</sub> emissions associated with enteric fermentation includes cattle aged three months or older (cattle under three months are excluded from estimation). To reflect the actual situation of emissions in Japan, categorization of cattle is defined as shown in the below Table 5-3, and CH<sub>4</sub> emissions are estimated by type and age.

### ● Emission Factors

The emission factor for CH<sub>4</sub> associated with enteric fermentation in cattle has been established on the basis of the result of breath testing of ruminant livestock in Japan: the measured data for volume of CH<sub>4</sub> per dry matter intake. Results of measurements have made clear that it is possible to estimate CH<sub>4</sub> from enteric fermentation in ruminant livestock using the equation given below, which uses dry matter intake as the explanatory variable (Shibata et al., 1993).

$$EF = Y / L_{CH_4} \times Mol_{CH_4} \times Day$$

$$Y = -17.766 + 42.793 \times DMI - 0.849 \times (DMI)^2$$

$EF$	: CH <sub>4</sub> emission factor associated with enteric fermentation for cattle [kg-CH <sub>4</sub> /head/yr]
$Y$	: Volume of CH <sub>4</sub> generated per head per day [l/head/day]
$L_{CH_4}$	: Volume of 1 mol CH <sub>4</sub> [l/mol] (=22.4)
$Mol_{CH_4}$	: Molecular weight of CH <sub>4</sub> [kg/mol] (=0.016)
$Day$	: Days in a year [day] (=365 or 366)
$DMI$	: Dry matter intake [kg/day]

Annual emission factors by cattle types were established by applying the DMI to the above equation. The DMI was calculated by substituting body weight, and daily weight gain by growth into the equation established for each type of cattle in *Japan Feed Standards* compiled by National Agriculture and Food Research Organization (NARO). Fat corrected milk amount (FCM) is also used for DMI calculation for dairy cattle. The equations to estimate DMI were revised in 2006 for dairy cattle (lactating and non-lactating) and in 2008 for non-dairy cattle (Wagyu(M)).

The amount of fat corrected milk was calculated by estimated milk yield from data in the *Statistics on Milk and Dairy Products* (Ministry of Agriculture, Fisheries and Forestry; MAFF) and the *Livestock Statistics* (MAFF), and from the fat content in milk data in the *Statistics of Livestock Production Costs* (MAFF). Both sets of the data are updated on a yearly basis.

The average body weights of cattle by each calving time which were firstly calculated by applying the average ages in month by calving time described in the *Record of dairy herd performance test* (Livestock Improvement Association of Japan) into the growth curve of cattle described in *Japan Feed Standard* was adopted to the body weight for lactating and non-lactating dairy cattle. Average ages in month for primipara for all years were described in the *Record of dairy herd performance test*, however, the record

of average ages in month for second calving and more has started since 2015. Therefore, the values of average ages for second calving and more for 2015 were substituted for before 2015. The regression equation expressing growth curve of dairy cattle have been revised in 1994, 1999, 2006 and each revised regression equation was applied after the revision. Data for body weight and weight gain by daily growth for heifer and non-dairy cattle were obtained from the table of weight by age in month for each type of cattle included in the *Japanese Feeding Standards*.

Table 5-4 Equation to estimate dry matter intake (DMI) by cattle

Type of cattle		Equation
Dairy cattle	Lactating	Since 2006 : $DMI = 1.3922 + 0.05839 \times W^{0.75} + 0.40497 \times FCM$ $DMI = 1.9120 + 0.07031 \times W^{0.75} + 0.34923 \times FCM$ (Primipara) $FCM = (15 \times FAT / 100 + 0.4) \times MILK$ Before 2006 : $DMI = 2.98120 + 0.00905 \times W + 0.41055 \times FCM$ $FCM = (15 \times FAT / 100 + 0.4) \times MILK$
	Non-lactating	$DMI = 0.017 \times W$
	Heifers	$DMI = 0.49137 + 0.01768 \times W + 0.91754 \times DG$
Non-dairy cattle	Breeding cows	For under 49mths old: $DMI = [0.1067 \times W^{0.75} + (0.0639 \times W^{0.75} \times DG) / (0.78 \times q + 0.006)] / (q \times 4.4)$ $q = 0.4213 + 0.1491 \times DG$ For 49mths old and over: $DMI = [0.1119 \times W^{0.75} + (0.0639 \times W^{0.75} \times DG) / (0.78 \times q + 0.006)] / 1.81$ Additional daily nutrient requirements for pregnant cows during last 2 months of pregnant: + 1.0 kg / day on calculated DMI Additional daily nutrient requirements for lactating cows during 5 months of lactation: + 0.5 kg / day to calculated DMI * Target ages are till 120 months old
	Wagyu (M)	Since 2008: $DMI = -3.481 + 2.668 \times DG + 4.548 \times 10^{-2} \times W - 7.207 \times 10^{-5} \times W^2 + 3.867 \times 10^{-8} \times W^3$ Before 2008: $DMI = [0.1124 \times W^{0.75} + (0.0546 \times W^{0.75} \times DG) / (0.78 \times q + 0.006)] / \{q \times (1.653 - 0.00123 \times W)\} / (q \times 4.4)$ $q = 0.5304 + 0.0748 \times DG$
	Wagyu (F)	$DMI = [0.1108 \times W^{0.75} + (0.0609 \times W^{0.75} \times DG) / (0.78 \times q + 0.006)] / (q \times 4.4)$ $q = 0.5018 + 0.0956 \times DG$
	Dairy breeds (over 6 months old)	$DMI = [0.1291 \times W^{0.75} + (0.0510 \times W^{0.75} \times DG) / (0.78 \times q + 0.006)] / (q \times 4.4)$ $q = (0.933 + 0.00033 \times W) \times (0.498 + 0.0642 \times DG)$
	Dairy breeds (3 to 6 months old)	$DMI = [0.1291 \times W^{0.75} + \{(1.00 + 0.030 \times W^{0.75}) \times DG\} / (0.78 \times q + 0.006)] / (q \times 4.4)$ $q = (0.859 - 0.00092 \times W) \times (0.790 + 0.0411 \times DG)$
	Hybrid	$DMI = [0.1208 \times W^{0.75} + (0.0531 \times W^{0.75} \times DG) / (0.78 \times q + 0.006)] / (q \times 4.4)$ $q = (0.933 + 0.00033 \times W) \times (0.498 + 0.0642 \times DG)$

Note:  $W$  : Weight,  $FCM$  : Fat Corrected Milk,  $FAT$  : Fat content in milk,  $MILK$  : Milk Yield,  $DG$  : Daily Gain,  $q$  : Energy metabolic rate  
 Reference: *Japan Feed Standards*

Table 5-5 Milk yield (MILK) of cattle and fat content in milk (FAT)

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Milk yield																
Multipara (3 and more)	kg/head/day	21.9	23.6	24.7	26.6	26.9	26.9	27.3	27.4	28.0	28.6	28.7	28.8	28.8	29.7	30.0
Secundipara	kg/head/day	21.4	23.1	24.2	26.0	26.4	26.3	26.8	26.9	27.3	27.9	28.0	28.1	28.1	29.0	29.2
Primipara	kg/head/day	18.5	19.9	20.9	22.4	22.7	22.7	23.0	23.1	23.5	24.0	24.2	24.5	24.3	25.2	25.2
Fat content in milk	%	3.7	3.8	3.9	4.0	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9





Table 5-9 Emission factors associated with enteric fermentation by cattle [kg-CH<sub>4</sub> head<sup>-1</sup> yr<sup>-1</sup>]

Type of cattle		1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020		
Dairy cattle	Lactating (Multipara (3 and more))	122.9	125.9	127.7	129.8	129.9	130.3	130.3	130.3	130.7	131.6	131.4	131.5	131.5	132.6	132.4		
	Lactating (Secundipara)	120.5	123.8	125.8	128.1	128.0	128.4	128.4	128.5	128.9	129.9	129.6	129.7	129.7	131.0	130.8		
	Lactating (Primipara)	112.7	116.4	118.9	121.1	122.6	123.0	123.0	123.0	123.4	124.4	124.3	124.5	124.3	125.7	125.3		
	Non-lactating	86.3	86.6	89.0	88.2	88.7	88.8	88.4	88.4	88.2	88.3	88.0	88.0	88.0	88.0	87.7		
	Heifer: under 2 yr, over 6 mth	63.4	64.7	66.9	67.8	68.0	68.1	68.0	68.0	68.0	68.1	68.0	68.0	68.0	68.1	68.0		
	Heifer: 3 to 6 mth	29.1	29.3	30.4	33.8	34.4	34.5	34.4	34.4	34.4	34.5	34.4	34.4	34.4	34.5	34.4		
Non-dairy cattle	Breeding	2 yr and over	68.3	68.5	70.7	70.7	70.7	70.9	70.7	70.7	70.9	70.7	70.7	70.7	70.9	70.7		
		Under 2 yr, over 6 mth	56.9	57.0	66.0	66.0	66.0	66.1	66.0	66.0	66.0	66.1	66.0	66.0	66.0	66.1	66.0	
		3 to 6 mth	30.3	30.3	33.7	33.7	33.7	33.8	33.7	33.7	33.7	33.8	33.7	33.7	33.7	33.8	33.7	
	Fattening cattle	Wagyu (M): 1 yr and over	under 1 yr, over 6 mth	72.1	72.3	72.1	72.1	68.5	68.7	68.5	68.5	68.5	68.5	68.5	68.5	68.5	68.7	68.5
			3 to 6 mth	58.8	59.0	58.8	58.8	61.7	61.8	61.7	61.7	61.7	61.8	61.7	61.7	61.7	61.8	61.7
			3 to 6 mth	33.0	33.1	33.0	33.0	29.4	29.4	29.4	29.4	29.4	29.4	29.4	29.4	29.4	29.4	29.4
		Wagyu (F): 1 yr and over	under 1 yr, over 6 mth	51.0	51.2	57.2	57.2	57.2	57.3	57.2	57.2	57.2	57.3	57.2	57.2	57.2	57.3	57.2
			3 to 6 mth	43.1	43.2	53.7	53.7	53.7	53.8	53.7	53.7	53.7	53.8	53.7	53.7	53.7	53.8	53.7
			3 to 6 mth	26.7	26.8	30.9	30.9	30.9	31.0	30.9	30.9	30.9	31.0	30.9	30.9	30.9	31.0	30.9
		Dairy breed: over 6 mth	3 to 6 mth	74.2	74.4	74.2	74.2	74.2	74.4	74.2	74.2	74.2	74.4	74.2	74.2	74.2	74.4	74.2
			3 to 6 mth	40.2	40.3	40.2	40.2	40.2	40.3	40.2	40.2	40.2	40.3	40.2	40.2	40.2	40.3	40.2
			Hybrid: over 6 mth	73.0	73.2	73.0	73.0	73.0	73.2	73.0	73.0	73.0	73.2	73.0	73.0	73.0	73.2	73.0
			3 to 6 mth	42.1	42.2	42.1	42.1	42.1	42.2	42.1	42.1	42.1	42.2	42.1	42.1	42.1	42.2	42.1

### ● Activity Data

For activity data of this source, the population of each type of cattle on 1<sup>st</sup> February in each year, recorded by the MAFF in its *Livestock Statistics* is used.

Table 5-10 Livestock population for cattle [1000 head]

Type of cattle		1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020		
Dairy cattle	Lactating (Multipara (3 and more))	510	467	447	391	374	364	347	334	324	317	308	309	309	296	300		
	Lactating (Secundipara)	260	250	241	229	196	197	203	202	191	194	193	194	190	186	189		
	Lactating (Primipara)	313	318	283	280	235	251	248	236	235	241	234	228	231	233	237		
	Non-lactating	332	299	249	231	195	200	194	185	184	185	179	176	171	185	184		
	Heifer: under 2 yr, over 6 mth	491	445	379	379	351	328	323	328	328	306	307	316	323	339	334		
	Heifer: 3 to 6 mth	109	99	84	84	78	73	72	73	73	68	68	70	72	75	74		
	Heifer: under 3 mth	55	49	42	42	39	36	36	36	36	34	34	35	36	38	37		
<b>Dairy cattle total</b>	<b>2,068</b>	<b>1,927</b>	<b>1,725</b>	<b>1,636</b>	<b>1,467</b>	<b>1,449</b>	<b>1,423</b>	<b>1,395</b>	<b>1,371</b>	<b>1,345</b>	<b>1,323</b>	<b>1,328</b>	<b>1,332</b>	<b>1,352</b>	<b>1,356</b>			
Non-dairy cattle	Breeding	2 yr and over	612	591	555	536	575	560	541	520	505	511	511	517	528	528	528	
		Under 2 yr, over 6 mth	84	69	68	71	78	68	64	62	61	64	69	75	79	79	79	
		3 to 6 mth	12	9	8	9	11	9	9	9	9	9	12	12	13	13	13	
		Under 3 mth	6	4	4	5	5	5	4	5	4	5	6	6	6	6	6	
	Fattening cattle	Wagyu (M): 1 yr and over	under 1 yr, over 6 mth	368	412	385	374	409	405	396	381	368	371	374	379	380	384	389
			3 to 6 mth	125	133	114	119	127	123	116	115	112	109	110	116	120	135	139
			3 to 6 mth	83	89	76	80	85	82	77	77	75	72	73	77	80	90	93
		Wagyu (F): 1 yr and over	under 3 mth	42	44	38	40	42	41	39	38	37	36	37	39	40	45	46
			under 1 yr, over 6 mth	197	265	246	290	336	343	337	328	313	293	310	312	310	306	319
			3 to 6 mth	102	105	93	89	101	98	93	91	89	86	81	84	89	103	109
		Dairy breed: over 6 mth	3 to 6 mth	68	70	62	59	67	65	62	60	59	57	54	56	60	69	72
			under 3 mth	34	35	31	30	34	33	31	30	30	29	27	28	30	34	36
			Hybrid: over 6 mth	665	541	333	351	309	294	282	276	259	249	235	221	206	201	188
			3 to 6 mth	148	120	74	78	69	65	63	61	58	55	52	49	46	45	42
Hybrid: over 6 mth	under 3 mth	74	60	37	39	34	33	31	31	29	28	26	25	23	22	21		
	3 to 6 mth	140	267	511	438	362	374	373	363	362	379	391	388	371	372	394		
	3 to 6 mth	31	59	114	97	81	83	83	81	80	84	87	86	82	83	88		
	under 3 mth	16	30	57	49	40	42	41	40	40	42	43	43	41	41	44		
<b>Non-dairy cattle total</b>	<b>2,805</b>	<b>2,901</b>	<b>2,806</b>	<b>2,755</b>	<b>2,763</b>	<b>2,723</b>	<b>2,642</b>	<b>2,567</b>	<b>2,489</b>	<b>2,479</b>	<b>2,499</b>	<b>2,514</b>	<b>2,503</b>	<b>2,555</b>	<b>2,605</b>			

### c) Uncertainties and Time-series Consistency

#### ● Uncertainties

The uncertainties for emission factors were calculated by finding the 95% confidence interval in accordance with the equation indicated in the section Emission Factors (Dairy cattle: -26% to +32%, non-dairy cattle: -40% to +49%). Populations of cattle (activity data) are decided by survey of total population in the *Livestock Statistics*, thus standard error for cattle is not described. Therefore, the uncertainties for activity data were substituted by 1% of swine in the *Livestock Statistics*. As a result, the uncertainties of the emissions were determined to be -26% to +32% for dairy cattle and -40% to

+49% for non-dairy cattle.

### ● Time-series Consistency

Emission factors were calculated consistently from FY1990 onward by the method mentioned in the section on Emission Factors. Activity data were used consistently from FY1990 onward from the data in the *Livestock Statistics*.

#### d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

It was pointed out by implementation of QA activity (QAWG) in FY2016 that ablatation of dairy cattle is at the age about three months, and CH<sub>4</sub> was actively generated from them. By taking into account it and discussions within the Committee for Greenhouse Gas Emission Estimation Methods, improvement to estimate the emission from cattle at the age three and four months was conducted in 2017 submission inventory.

Comparison between results of Japan's estimation method and IPCC Tier 2 method was conducted. For Tier2 method, equations indicated in the *2006 IPCC Guidelines* (Vol.4, Chapter 10, Equation 10.3~10.16) are used, and estimation is conducted by classification described in Table 5-3 above. If data is available, Japan's data are used (e.g. values of Table 5-4 to Table 5-8 above and values of DE calculated from data described in the *Japan Feed Standards*). If not available, default data described in the *2006 IPCC Guidelines* are used (e.g.  $Y_m$ ,  $C_f$  and  $C_{\text{pregnancy}}$ ).

As a result, for both dairy cattle and non-dairy cattle, considering the error of CH<sub>4</sub> conversion factor ( $Y_m = 6.5\% \pm 1.0\%$ ), the emissions based on Japan's method were in the range calculated by IPCC Tier 2 method. Therefore, it is considered that there were no significant differences between emissions of Japan's method and IPCC Tier 2 method.

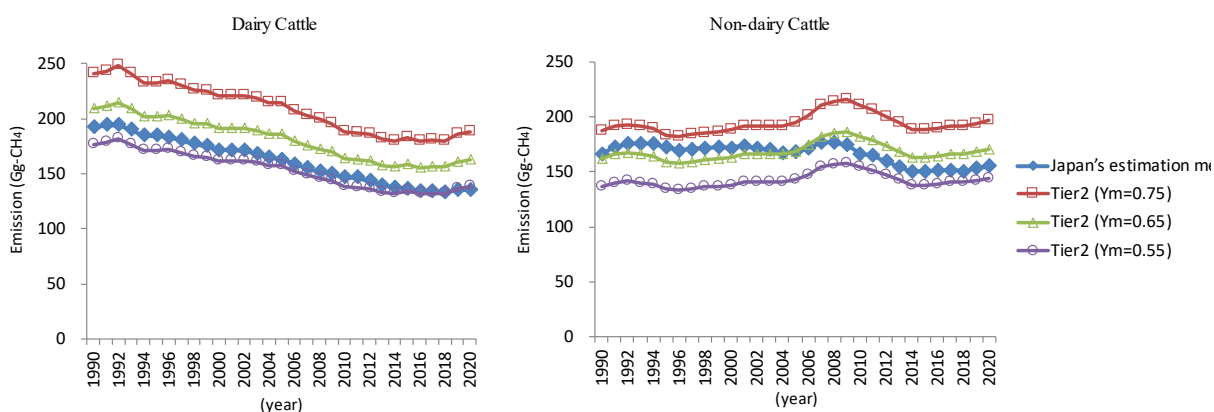


Figure 5-2 Comparison between results of Japan's estimation method and IPCC Tier 2 method

#### e) Category-specific Recalculations

Since the population of dairy cattle by calving in *Record of Dairy Herd Performance Test* was revised, the emissions from dairy cattle for FY2019 were recalculated. See Chapter 10 for impact on trend.

### f) Category-specific Planned Improvements

It is planned to discuss the development of the estimation method, which reflects the emissions reduction with technologies that suppress methane emission by controlling the rumen fermentation (such as by the addition of fatty acid calcium to feed) and by improving the feed efficiency with the total mixed ration (TMR) feeding.

## 5.2.2. Buffalo, Sheep, Goats, Horses & Swine (3.A.2., 3.A.3., 3.A.4.-)

### a) Category Description

This section provides the estimation methods for CH<sub>4</sub> emissions from enteric fermentation in buffalo, sheep, goats, horses and swine.

### b) Methodological Issues

#### ● Estimation Method

CH<sub>4</sub> emissions were calculated using the Tier 1 method in accordance with the decision tree of the 2006 IPCC Guidelines.

$$E = EF \times A$$

*E* : CH<sub>4</sub> emissions from enteric fermentation for each livestock [kg-CH<sub>4</sub>/yr]

*EF* : CH<sub>4</sub> emission factor for enteric fermentation of each livestock [kg-CH<sub>4</sub>/head/yr]

*A* : Population of each livestock [head]

#### ● Emission Factors

The emission factors for swine have been established on the basis of results of research conducted in Japan. The emission factor for sheep, goats, horses and buffalo are the default values given in the 2006 IPCC Guidelines.

Table 5-11 Emission factors for CH<sub>4</sub> associated with enteric fermentation in swine, sheep, goats, horses and buffalo

Livestock species	CH <sub>4</sub> emission factor [kg-CH <sub>4</sub> /head/yr]	Reference
Swine	1.4	Estimated from Saito (1988)
Sheep	8	2006 IPCC Guidelines
Goats	5	
Horses	18.0	
Buffalo	55.0	

#### ● Activity Data

For activity data of sheep and goats, livestock population data given in the *Statistical Document of Livestock Breeding* offered by the Japan Livestock Industry Association until FY2009 and the *Status Report regarding Health Management for Livestock Feeding* by the MAFF from FY2010 onward are used. For swine, population on 1<sup>st</sup> February in each year recorded in the *Livestock Statistics* by the MAFF are used. The data in 2004, 2009 and 2014 were interpolated. For horses, livestock population given in the *Statistical Document of Horse* offered by the MAFF until FY2009 and the *Status Report regarding Health Management for Livestock Feeding* by the MAFF from FY2010 onward are used. For buffalo, livestock population given in the *Survey Result of Feeding Livestock and Poultry* by Okinawa Prefecture are used.

Table 5-12 Livestock population for buffalo, sheep, goats, swine, and horses [1000 heads]

Livestock species	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Sheep	21	14	12	9	20	20	16	17	17	18	18	20	20	21	20
Goats	26	19	22	16	19	19	19	20	20	17	16	19	20	20	20
Swine	11,335	9,900	9,788	9,620	9,768	9,735	9,685	9,537	9,424	9,313	9,346	9,189	9,156	9,223	9,290
Horses	116	118	105	87	75	75	74	74	69	74	75	76	78	78	73
Buffalo	0.21	0.12	0.10	0.08	0.08	0.08	0.09	0.10	0.11	0.11	0.12	0.11	0.11	0.12	0.12

Note: For swine, data in 2009 and 2014 were interpolated.

### c) Uncertainties and Time-series Consistency

#### ● Uncertainties

An uncertainty assessment was conducted by each livestock category. The uncertainties for emission factors for swine were decided by the Committee of GHG Emissions Estimation Methods. The uncertainties for emission factors of livestock other than swine were applied 50% of default data given in the *2006 IPCC Guidelines*. As the uncertainty for activity data of swine, 1% of standard error for swine given in the *Livestock Statistic* was applied. For activity data of livestock other than swine, uncertainty was substituted by the value of broiler (9%) described in the *Livestock Statistics*. As a result, the uncertainties of the emissions were determined to be -72% to +157% for swine and 51% for buffalo, sheep and goats and horses.

#### ● Time-series Consistency

For emission factors, same values were used consistently. For activity data, the data given in the *Statistical Document of Livestock Breeding*, the *Livestock Statistics*, the *Statistical Document of Horse*, the *Survey Result of feeding Livestock and Poultry* by Okinawa, and the *Status Report regarding Health Management for Livestock Feeding* are used, and consistent estimation method by each livestock are used since FY1990.

### d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

### e) Category-specific Recalculations

Since the population of sheep, goats and horses for FY2018, and of swine for FY2019 was revised, the emissions for FY2018 and FY2019 were recalculated. See Chapter 10 for impact on trend.

### f) Category-specific Planned Improvements

There are no improvement plans.

## 5.2.3. Other Livestock (3.A.4.-)

Deer, alpaca, which are not reported above, but default emission factors are reported in the *2006 IPCC Guidelines*, are farmed as livestock in Japan. However, their population size is small, and the emissions from each of them are lower than 3,000t-CO<sub>2</sub> equivalent, which is the threshold to estimate in this GHG inventory decided by the Committee for GHG Emissions Estimation Methods. Therefore, it was reported as "NE" as considered insignificant (See Annex 5).

### 5.3. Manure Management (3.B.)

In livestock manure management process, CH<sub>4</sub> is generated by decomposing organic content in livestock manure with CH<sub>4</sub> fermentation. In addition, CH<sub>4</sub> generated by enteric fermentation dissolved in manure is released by aeration or agitation. In manure management, N<sub>2</sub>O is produced mainly by microorganism via nitrification and denitrification processes.

CH<sub>4</sub> and N<sub>2</sub>O emissions from manure management in FY2020 are 2,387 kt-CO<sub>2</sub> eq. and 3,843 kt-CO<sub>2</sub> eq., comprising 0.2% and 0.3% of total emissions (excluding LULUCF), respectively. The value represents a decrease by 28.3% for CH<sub>4</sub> and a decrease by 8.8% for N<sub>2</sub>O from FY1990. Main driver of the CH<sub>4</sub> emission decrease from FY1990 is a reduction of dairy cattle population, and of the N<sub>2</sub>O emission decrease from FY1990 is a reduction for indirect N<sub>2</sub>O emission by atmospheric deposition because of a reduction of livestock population.

For amount of nitrogen in excretion of swine, decrease was seen in trend since 1990. The reason is that amount of crude protein in feeds has been decreased with the decrease of proportion of soybean meal in feeds year by year.

Table 5-13 CH<sub>4</sub> and N<sub>2</sub>O emissions from livestock manure management (3.B.)

Gas	Livestock species	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
CH <sub>4</sub>	3.B.1.- Dairy cattle	kt-CH <sub>4</sub>	107.0	103.1	96.5	94.5	86.8	86.5	84.9	82.7	81.1	81.0	79.3	79.4	79.4	80.7	81.1	
	3.B.1.- Non-dairy cattle		3.7	3.8	3.9	4.3	4.9	5.1	5.1	5.2	5.3	5.5	5.8	6.1	6.3	6.3	6.3	
	3.B.2. Sheep		0.006	0.004	0.003	0.002	0.006	0.006	0.005	0.005	0.005	0.005	0.005	0.005	0.006	0.006	0.006	0.006
	3.B.3. Swine		20.5	17.9	16.3	11.4	7.8	7.6	7.4	7.1	6.9	6.6	6.5	6.5	6.4	5.8	5.8	5.8
	3.B.4.- Buffalo		0.0004	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
	3.B.4.- Goats		0.005	0.004	0.004	0.003	0.004	0.004	0.004	0.004	0.004	0.004	0.003	0.003	0.004	0.004	0.004	0.004
	3.B.4.- Horses		0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	3.B.4.- Poultry		1.6	1.5	1.5	1.7	1.9	1.9	2.0	1.9	1.9	1.9	1.9	1.9	2.0	2.0	2.0	2.0
	3.B.4.- Rabbit		0.001	0.001	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
	3.B.4.- Mink		0.1053	0.0073	0.0038	0.0004	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
	Total		kt-CH <sub>4</sub>	133.2	126.6	118.5	112.0	101.5	101.3	99.6	97.1	95.4	95.3	93.7	94.2	94.2	95.0	95.5
	kt-CO <sub>2</sub> eq.	3,329	3,164	2,961	2,801	2,537	2,532	2,490	2,428	2,385	2,382	2,343	2,355	2,356	2,375	2,387		
N <sub>2</sub> O	3.B.1.- Dairy cattle	kt-N <sub>2</sub> O	2.1	2.1	2.1	2.4	2.4	2.4	2.3	2.3	2.2	2.2	2.1	2.1	2.1	2.1	2.1	
	3.B.1.- Non-dairy cattle		2.3	2.4	2.4	2.5	2.6	2.6	2.5	2.4	2.3	2.3	2.3	2.2	2.2	2.2	2.2	
	3.B.2. Sheep		IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	
	3.B.3. Swine		3.5	3.1	3.1	3.7	4.4	4.4	4.3	4.2	4.1	4.0	4.0	4.1	4.1	4.1	4.1	
	3.B.4.- Buffalo		0.00012	0.00007	0.00006	0.00005	0.00004	0.00005	0.00005	0.00005	0.00006	0.00006	0.00007	0.00006	0.00006	0.00007	0.00007	
	3.B.4.- Goats		IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	
	3.B.4.- Horses		IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	
	3.B.4.- Poultry		1.0	0.9	0.9	0.9	1.0	1.0	0.9	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.7	
	3.B.4.- Rabbit		0.004	0.004	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	
	3.B.4.- Mink		0.0223	0.0016	0.0008	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	
	3.B.5. Indirect emissions		5.2	4.8	4.5	4.1	3.9	3.9	3.8	3.7	3.6	3.6	3.6	3.6	3.7	3.7	3.7	
Total	kt-N <sub>2</sub> O	14.1	13.3	12.9	13.6	14.3	14.2	13.9	13.3	13.0	12.9	12.8	12.9	12.8	12.8			
	kt-CO <sub>2</sub> eq.	4,214	3,965	3,849	4,056	4,273	4,235	4,133	3,970	3,869	3,833	3,806	3,853	3,807	3,820			
Total of all gases		kt-CO <sub>2</sub> eq.	7,544	7,130	6,811	6,858	6,810	6,767	6,624	6,398	6,254	6,215	6,150	6,208	6,163	6,195	6,230	

#### 5.3.1. Cattle, Swine and Poultry (Hen and Broiler) (3.B.1., 3.B.3., 3.B.4.-)

##### a) Category Description

This section provides the estimation methods for CH<sub>4</sub> and N<sub>2</sub>O emissions for manure management from cattle (dairy cattle and non-dairy cattle), swine and poultry (hen and broiler). For grazing animal, CH<sub>4</sub> emissions were reported in this category and N<sub>2</sub>O emissions were reported in “3.D.a.3. Urine and dung deposited by grazing animals”.

## b) Methodological Issues

### ● Estimation Method

CH<sub>4</sub> emissions associated with the manure management were calculated by multiplying the amount of organic matter contained in manure from each type of livestock by the emission factor for each type of management system.

$$E_{CH_4} = \sum (EF_{CH_4-n} \times A_{CH_4-n})$$

- $E_{CH_4-n}$  : CH<sub>4</sub> emissions associated with the management of manure excreted by cattle, swine and poultry [kt-CH<sub>4</sub>/yr]  
 $EF_{CH_4-n}$  : Emission factor for management system  $n$  [kg-CH<sub>4</sub>/kg-organic matter]  
 $A_{CH_4-n}$  : Amount of organic matter contained in manure managed by system  $n$  [kt-organic matter/yr]  
 $n$  : Manure management system

N<sub>2</sub>O emissions were calculated by multiplying the amount of nitrogen contained in manure of each type of animal by the emission factor for each type of management system.

$$E_{N_2O} = \sum (EF_{N_2O-n} \times A_{N_2O-n}) \times 44/28$$

- $E_{N_2O}$  : N<sub>2</sub>O emission associated with management of manure excreted by cattle, swine and poultry [kt-N<sub>2</sub>O/yr]  
 $EF_{N_2O-n}$  : Emission factor for management system  $n$  [g-N<sub>2</sub>O-N/g-N]  
 $A_{N_2O-n}$  : Amount of nitrogen contained in manure managed by system  $n$  [kt-N/yr]  
 $n$  : Manure management system

### ● Emission Factors

CH<sub>4</sub> and N<sub>2</sub>O Emission factors for each manure management system (hereafter, MMS) associated with Manure Management have been established for each treating method in Japan of for each type of livestock on the basis of the results of research by actual measurements carried out in Japan after reviewing its validity in accordance with the decision tree shown in Figure 5-3. Table 5-14 and Table 5-15 show these emission factors.

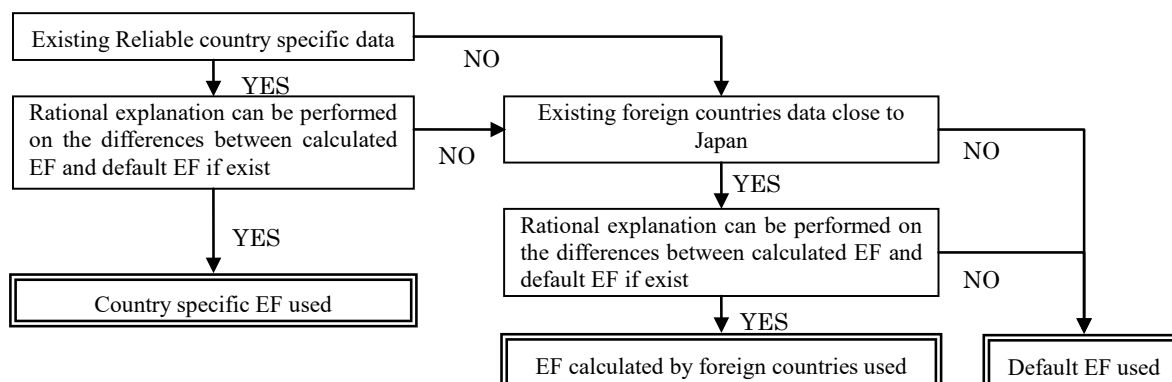


Figure 5-3 Decision tree for determination of EF

Emission factors indicated by “D (default value)” in Table 5-14 and Table 5-15 are based on the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (the 2019 Refinement). CH<sub>4</sub> emission factors among them were calculated by following equation with  $B_0$

(maximum methane producing capacity) (Dairy cattle: 0.24, Non-dairy cattle: 0.18, Swine: 0.45) and MCF (methane conversion factor, Table 5-16) in “Other Regions – High productivity systems” indicated in the *2019 Refinement*. Since MCF for composting and pit storage are described by each climate zone in the *2019 Refinement*, MCF values are calculated with regional MCF decided by the average temperature in each region, which are weighted average by regional livestock population. Average temperature by region used for development of MCF values is shown in the following Table 5-17. These temperatures were established by using the average temperatures in each municipality where livestock are mainly housed.

For country-specific emission factors, MCF values are not established because emission factors are estimated directly from results of actual measurement data.

$$EF_{CH_4-n} = Bo \times 0.67 \times MCF$$

$EF_{CH_4-n}$	: Emission factor for management system $n$ [kg-CH <sub>4</sub> /kg-organic matter]
$Bo$	: Maximum methane producing capacity [m <sup>3</sup> -CH <sub>4</sub> /kg-organic matter]
$0.67$	: Conversion factor from volume to weight [kg-CH <sub>4</sub> /m <sup>3</sup> -CH <sub>4</sub> ]
$MCF$	: Methane conversion factor [%]

For CH<sub>4</sub> emission factors of “Pit storage” and “Methane fermentation” for dairy cattle, regional emission factors of 9 regions in Japan were established by using air temperature as a parameter, and based on actual measurement data on pit storage system and methane fermentation system by using measurement technique such as floating chamber method (*The Report of Project on Survey and Investigation for Elaboration of GHG Emissions from Agriculture, Forest and Fisheries Sector, within the Project on Development for Method of Promotion for Countermeasures of Global Environment in the Agriculture, Forest and Fisheries Sector in FY2011*, 2012.). Therefore, integrated emission factors for all Japan, which are weighted averages of the regional emission factors with dairy cattle population in each region (described in the *Livestock Statistics*), are used (see Table 5-18). Emission factors in latest year are lower than 1990 because ratio of livestock population in Hokkaido region, where temperature is low and emission factor is low, has gradually increased (FY1990: 42% and FY2020: 61%).

For “Sun drying” for hen and broiler, emission factors were established on the basis of actual measurement data at poultry manure management facility with drying system (Poultry manure is dried out with agitation on conveyer belt machinery in tunnel ventilation barn) (Tsuchiya et al., 2014).

For “Composting (feces)” and “Composting (feces and urine mixed)” for swine, emission factor is referred to *Project Report of Survey on Prevention of Global Warming in the Agriculture, Forest and Fisheries Sector within the Environment and Biomass Comprehensive Strategy Promotion Project in FY2008* (Nationwide Survey) (Hereinafter called “*Report of Survey Project in FY2008* (Nationwide Survey)”).

For emission factors of Composting (feces) for hen and broiler, emission factor for swine is applied by expert judgment.

For “Piling”, the most major manure management practice in Japan, Osada et al. (2005) measured actual CH<sub>4</sub> and N<sub>2</sub>O emissions by using chamber system covering compost heap, and Japan’s emission factors for dairy cattle, non- dairy cattle and swine were set from these data.

For “Piling” of hen and broiler, emission factors were established on the basis of actual GHG

measurement data using chamber, which covers piled up manure, at piling composting management facility in three areas of Japan. Detail method is described in the report by MAFF (2014).

For “Incineration”, emission factor written in *GHGs emissions control in livestock industry Summary* (Japan Livestock Technology Association, 2002) is used.

For “Purification” for cattle, Shiraishi et al. (2017) measured actual CH<sub>4</sub> and N<sub>2</sub>O emissions for urine and the mixture of feces and urine of dairy cattle from a purification plant. Emission factors based on the result of this study were applied to the purification of urine and the mixture of feces and urine from dairy and non-dairy cattle.

For “Purification” for swine, emission factor is from *Project on Survey and Investigation for Elaboration of GHG Emissions from Agriculture, Forest and Fisheries Sector, within the Project on Development for Method of Promotion for Countermeasures of Global Environment in the Agriculture, Forest and Fisheries Sector in FY2012* (MAFF 2013) (Hereinafter called "the Report of Project (MAFF 2013)").

For “Pasture, range and paddock” of dairy cattle and non-dairy cattle, emission factors were established by actual measurement data of collected manure set in chamber in grazing area (Mori and Hojito, 2015).

Table 5-14 CH<sub>4</sub> Emission factors for each method of treating manure from cattle, swine, and poultry  
[% : kg-CH<sub>4</sub>/kg-organic matter]

Treating method	Dairy cattle		Non-dairy cattle		Swine		Hen		Broiler	
Sun drying	0.20 %	J <sup>2)</sup>	0.20 %	J <sup>2)</sup>	0.20 %	J <sup>2)</sup>	0.14 %		J <sup>10)</sup>	
Thermal drying	0 %									
Carbonization	-		-		-		0.0%		TD	
Composting (feces)					0.08 %	J <sup>7)</sup>	0.08 %		Sw	
Composting (urine)	0.113 %	D <sup>1)</sup>	0.109 %	D <sup>1)</sup>	0.302 %	D <sup>1)</sup>	-			
Composting (feces and urine mixed)					0.08 %	J <sup>7)</sup>	-			
Piling	3.8 %	J <sup>4)</sup>	0.13 %	J <sup>4)</sup>	0.16 %	J <sup>4)</sup>	0.13 %	J <sup>12)</sup>	0.02 %	J <sup>12)</sup>
Incineration	0.4 %									
Purification	0.3%		J <sup>13)</sup>		0.91 %	J <sup>11)</sup>	-			
Pit storage			3.4 %	D <sup>1)</sup>	9.2 %	D <sup>1)</sup>				
Pit storage (within a month)	Table 5-18	J <sup>8)</sup>	1.4 %	D <sup>1)</sup>	3.8 %	D <sup>1)</sup>	0.13 %	PI	0.02 %	PI
Pit storage (over a month)			4.0 %	D <sup>1)</sup>	10.6 %	D <sup>1)</sup>				
Methane fermentation (feces)	3.8%	PI	0.13%	PI	0.16%	PI	0.13 %	PI	0.02 %	PI
Methane fermentation (urine, feces and urine mixed)	Table 5-18	J <sup>8)</sup>	3.5%	DC	3.6%	DC	-			
Industrial waste treatment	Table 5-18	PS	3.4 %	PS	9.2 %	PS	0.13 %	PS	0.02 %	PS
Pasture, range and paddock	0.076%		J <sup>9)</sup>		-		0.14%		SD	
Other (feces)	3.8%	M	0.4%	M	0.4%	M	0.4%		M	
Other (urine, feces and urine mixed)	3.8%	M	4.0%	M	10.60%	M	-			

Note: See notation and sources of Table 5-15 below.



Table 5-15 N<sub>2</sub>O Emission factors for each method of treating manure from cattle, swine and poultry  
[% : kg-N<sub>2</sub>O-N/kg-N]

Treating method	Dairy cattle		Non-dairy cattle		Swine		Hen		Broiler		
Sun drying	2.0 %				D <sup>1)</sup>	0.33%				J <sup>10)</sup>	
Thermal drying	2.0 %										D <sup>1)</sup>
Carbonization	-		-		-		2.0%		TD		
Composting (feces)	0.25 %		J <sup>5)</sup>		0.16 %		J <sup>7)</sup>		0.16 %		Sw
Composting (urine)	0.6%				D <sup>1)</sup>		-				
Composting (feces and urine mixed)	0.6%		D <sup>1)</sup>		0.25%		J <sup>5)</sup>		0.16%		J <sup>7)</sup>
Piling	2.4 %		J <sup>4)</sup>		1.6 %		J <sup>4)</sup>		2.5 %		J <sup>4)</sup>
Incineration	0.1 %				0.54%		J <sup>12)</sup>		0.08%		J <sup>12)</sup>
Purification	2.88 %				J <sup>13)</sup>		2.87%		J <sup>11)</sup>		-
Pit storage	0.02%		J <sup>8)</sup>		0 %		D <sup>1)</sup>		0.54%		PI
Methane fermentation (feces)	2.4 %		PI		1.6 %		PI		2.5 %		PI
Methane fermentation (urine, feces and urine mixed)	0.15%		J <sup>8)</sup>		0.15%		DC		-		PI
Industrial waste treatment	0.02%		PS		0 %		PS		0.54%		PS
Pasture, range and paddock	0.684%				J <sup>9)</sup>		-		0.33%		SD
Other (feces)	2.4%		M		2.0%		M		2.5%		M
Other (urine, feces and urine mixed)	2.88%		M		2.88%		M		2.87%		M
	2.88%		M		2.88%		M		2.87%		M

Note:

- Manure excreted by hen and broiler was categorized as feces since it contains a very small amount of urine.
- D: Default value of the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories
- J: Established by data of Japan
- O: Established by data of other countries
- Z: No emission occurrence because of the mechanism
- PI: Application for the value of "Piling"
- SD: Application for the value of "Sun drying"
- TD: Application for the value of "Thermal draying"
- PS: Application for the value of "Pit storage"
- Sw: Application for the value of "Swine"
- DC: Estimated from regional EFs of "Dairy cattle" (N<sub>2</sub>O: Application for the value of "Dairy cattle")
- M: Application of the maximum values of the treating methods for "feces" or "feces and urine mixed"

Reference for Table 5-14 and Table 5-15:

- 1) 2019 Refinement
- 2) Ishibashi et al. (2003)
- 3) Japan Livestock Technology Association, (2002)
- 4) Osada et al. (2005)
- 5) Osada et al. (2000)
- 6) Osada (2003)
- 7) Report of Survey Project in FY2008 (Nationwide Survey), (2009)
- 8) MAFF, the Report of Project on Survey and Investigation in FY2011, (2012)
- 9) Mori and Hojito (2015)
- 10) Tsuchiya et al. (2014)
- 11) MAFF, the Report of Project on Survey and Investigation in FY2012, (2013)
- 12) MAFF, the Report of Project on Survey and Investigation in FY2013, (2014)
- 13) Shiraiishi et al. (2017)

Table 5-16 MCFs (methane conversion factor) used for calculation of default emission factors

Treating method	MCF	System classification in the 2019 Refinement
Composting (dairy cattle)	0.7%	Estimated on the basis of Composting - Intensive windrow.
Composting (non-dairy cattle)	0.9%	Estimated on the basis of Composting - Intensive windrow.
Composting (swine), (urine)	1.0%	Estimated on the basis of Composting - Intensive windrow.
Pit storage (non-dairy cattle)	28.6%	Estimated on the basis of Liquid/ Slurry
Pit storage (non-dairy cattle) (within a month)	11.6%	Estimated on the basis of Liquid/ Slurry – 1 Month
Pit storage (non-dairy cattle) (over a month)	32.9%	Estimated on the basis of Liquid/ Slurry – 3, 4, 6, 12 Month
Pit storage (swine)	30.6%	Estimated on the basis of Liquid/ Slurry
Pit storage (swine) (within a month)	12.5%	Estimated on the basis of Liquid/ Slurry – 1 Month
Pit storage (swine) (over a month)	35.1%	Estimated on the basis of Liquid/ Slurry – 3, 4, 6, 12 Month

Note: For other treating method than the above, MCF values are not established because country-specific emission factors are used.

Reference: the 2019 Refinement, Vol.4 Table10.17

Table 5-17 Average temperature by region used for development of MCF values [°C]

Region	Dairy cattle	Non-dairy cattle	Swine
Hokkaido	6.2	6.2	7.4
Tohoku	9.9	11.0	10.1
Kanto	13.0	12.1	14.4
Hokuriku	15.1	14.0	12.7
Tokai	17.1	14.3	15.0
Kinki	16.9	16.0	13.5
Chugoku	15.3	15.0	14.4
Shikoku	16.5	16.1	15.5
Kyusyu and Okinawa	16.7	16.5	16.3

Table 5-18 CH<sub>4</sub> Emission factors for “Pit storage” and “Methane fermentation” for dairy cattle  
[% : kg-CH<sub>4</sub>/kg-organic matter]

Item	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Pit storage	2.47%	2.44%	2.42%	2.40%	2.37%	2.37%	2.37%	2.37%	2.37%	2.36%	2.36%	2.36%	2.35%	2.35%	2.34%
Methane fermentation	3.22%	3.17%	3.14%	3.11%	3.06%	3.06%	3.06%	3.06%	3.05%	3.05%	3.04%	3.03%	3.03%	3.02%	3.02%

Note: These figures are weighted averages of regional emission factors from the Report of Project in FY2011, (MAFF 2012) with dairy cattle population in each region.

### ● Activity Data

The values used for the activity data are estimates of the amount of organic matter and the amount of nitrogen excreted annually by various type of livestock by management system, respectively.

$$A_{CH4-n} = P \times Ex \times Day \times Org \times Mix_n \times MS_n / 1000$$

$$A_{N2O-n} = P \times Nex \times Day \times Mix_n \times MS_n / 1000$$

$A_{CH4-n}$  : Amount of organic matter contained in manure by management system  $n$  by livestock [kt-organic matter/yr]

$A_{N2O-n}$  : Amount of nitrogen contained in manure by management system  $n$  by livestock [kt-N/yr]

$P$  : Population of each livestock [1000 heads]

$Ex$  : Amount of feces and urine excreted per head per day from each livestock [kg/head/day]

$Org$  : Organic matter content in feces and urine from each livestock [%]

$Nex$  : Nitrogen content of feces and urine excreted per head per day from each livestock [kg-N/head/day]

$Day$  : Days in a year [day]

$Mix_n$  : Proportion of separated and mixed treatment of manure by type of livestock [%]

$MS_n$  : Proportion of each manure management system by animal [%]

$n$  : Manure management system

Total amount of organic matter by livestock was calculated by multiplying the population of each type of animal by the amount of manure per head by the organic matter content in feces or urine. Total nitrogen amount was calculated by multiplying the population of each type of animal by the nitrogen

content of feces or urine excreted per head (Table 5-27, Table 5-28, Table 5-29, Table 5-30, Table 5-31). The amount of organic matter and nitrogen were allocated to each manure management system by multiplying the total amount by the proportion of separated and mixed treatment of manure and the proportion of manure management system by type of animal (Table 5-32, Table 5-33, Table 5-34).

For livestock population, same references indicated in ‘3.A. Enteric Fermentation’ for dairy cattle non-dairy cattle and swine are used.

Livestock population for hen described in the *Livestock Statistics* and *Statistics on Livestock Products Marketing* are used (see the following Table 5-19) but the data in 2004, 2009 and 2014 are interpolated. For broiler from 1990 to 2008, livestock population described in the *Statistics on Livestock Products Marketing* are used. For 2009 onwards, as livestock population are not surveyed in the statistics, livestock population are estimated by using the number of shipment of broiler in the same statistics (see the following Table 5-20). 5-year average (0.170) from FY2004 to FY2008 of “livestock population” / “annual number of shipment”, is multiplied by the number of shipment of each year in particular. In addition, days of feeding to shipment are shorter than past. Therefore, 0.919 (= 49days / 53.3days), ratio of feeding days until shipment of present (*Planning for Breeding Improvement of Poultry* (2015) and past (*Questionnaire Survey on Current Feeding Status for Broiler* (2008)) is multiplied.

Amount of feces per head per day for dairy cattle is calculated by using the multiple regression equation which is written in *Japanese Feed Standard* and has two explanatory variables, DMI and Natural Detergent Fiber of organic matter (%) (NDFom). Amount of urine excreted per head per day for dairy cattle is calculated by the multiple regression equation which is written in Otani et al. (2010) and has three explanatory variables, Nitrogen Intake (NI), potassium Intake (KI) and milk yield. DMI and milk yield are used same data described in ‘3.A. Enteric Fermentation’. NDFom was set at 35% referred to *Japanese Feed Standard*. NI was calculated by dividing Crude Protein (CP) by 6.25. CP were calculated following with formulas in *Japanese Feed Standard* with DMI, milk yield, weight, fat content in milk and daily gain which are same data in ‘3.A. Enteric Fermentation’ (Table 5-23). The preferable CP content in feed dry matter is 12% and over for the most effective digestion of feed and fermentation by microorganism in rumen, described in *Japanese Feed Standard*. Therefore, CP values are adjusted to be 12% of DMI when the calculated CP was lower than 12% of DMI. KI was set with referring to Kume et al. (2010) (Table 5-21).

Nitrogen contents in excretion per head per day for dairy cattle, for both in feces and urine, were calculated with the regression equation in Choumei et al. (2006) (Table 5-21). DMI and CP used in calculation for nitrogen contents are common to feces and urine.

For amount of excretion per head per day for non-dairy cattle, amount of feces and urine each are separately calculated by using DMI and TDN% for variables instead of GE and DE%, based on the equation 10.24 in the *2006 IPCC Guidelines* (Vol 4, page 10.42) which is for the dry-organic matter in excretion. Nitrogen contents in excretion per head per day for non-dairy cattle were calculated with the regression equation in Choumei et al. (2006) for both feces and urine (Table 5-22). Nitrogen content in feces is calculated in formula with a variable of DMI and nitrogen content in urine is calculated with formula with a variable CP. DMI is from Table 5-8 described above. CP is calculated with formula in Table 5-23. CP is adjusted to be 12% of DMI as same as in case of dairy cattle.

The amount of feces for swine was calculated by using DMI and Digestion Rate for feed (DR(%)) instead of GE and DE%, on the basis of equation 10.24 in the *2006 IPCC Guidelines*. The amount of

urine was calculated on the basis of amount of nitrogen in excretion per head per day explained in below. Categorization for calculation is for 2 types as growing-finishing pig and breeding pig.

Nitrogen contents in excretion per head per day from swine are calculated by dividing the total nitrogen in excretion per head of every class by total days of raising (Estimated on the basis of *The report of the fact-finding survey for pig farming (The result of National tabulation results)*, Japan Pork Producers Association). Nitrogen contents in excretion per head is calculated by subtracting amount of nitrogen accumulated in body from amount of nitrogen intake for each body weight class written in *Japanese feed standard*. Nitrogen intake was calculated by using the CP content in feeds and the amount of feed intake. The CP content in feeds is established as the average CP content in feed calculated by using the CP content in each feedstuff and the proportion of feedstuffs to feed (Estimated on the basis of *Feed bulletin*, MAFF). Nitrogen contents in feces and urine per day is calculated by multiplying the ratio between feces and urine to nitrogen contents in excretion per day (Table 5-24). Ratio of feces is calculated by dividing the nitrogen amount converted from the sum of the amount of undigested crude protein in feed, amount of excretion of endogenous crude protein and the amount of crude protein to be lost as fallen hair or skin by the nitrogen contents in excretion on the basis of Ogino et al. (2020). All remains are assumed to be allocated to urine, and therefore the proportion allocated to urine is estimated.

The amount of excretion of poultry was calculated from the feed intake per head per day, based on Equation 10.24 of the *2006 IPCC Guidelines*. Since the amount of feed intake at each growing stage of chicks is different, the amount of excretion per chick was calculated as the weighted average of the amount of excretion by the proportion of the number of chicks at each growing stage (Table 5-25).

The amount of nitrogen in the excretion of poultry per head per day, based on the method for calculating nitrogen excretion in Ogino et al. (2017), was calculated by subtracting the amount of nitrogen in the laid eggs and in the gaining body from the total amount of ingested nitrogen, assuming the remaining amount of nitrogen was excreted. Nitrogen intake was calculated by using the CP content in feed and the amount of feed intake, same with swine. Since broilers and chicks of layers do not lay eggs, only the amount of nitrogen in the gaining body was subtracted from the amount of ingested nitrogen, and the remaining amount of nitrogen was assumed to be excreted. Since the amount and composition of feed intake at each growing stage of chicks of layers were different, the amount of excretion for a chick was calculated as the weighted average of the amount of excretion by the proportion of the number of chicks at each growing stage.

The “Percentage of manure management by type of animal” and “Proportion of separated and mixed treatment of manure, by type of livestock” were set from percentage of treating method of manure and proportion of separated and mixed treatment of manure for 1997 in *GHGs emissions control in livestock industry Summary* (Japan Livestock Technology Association, March 2002), and percentage of treating method of manure and proportion of separated and mixed treatment of manure in the *Survey of current status for livestock manure management system 2009*, (MAFF, 2011) and in the *Survey of current status for livestock manure management system and others 2019*, (MAFF, 2021). The 1997 survey is data before enforcement of the “Act on the Appropriate Treatment and Promotion of Utilization of Livestock Manure” which has been in force since 1999 and prohibits inappropriate manure management and induced changes of percentage of manure management. Therefore, the 1997 survey results were applied until 1999, the 2009 survey results were applied for 2009 and the 2019 survey results were applied since 2019 (Table 5-32, Table 5-33 and Table 5-34). For 2000 to 2008 and 2010 to 2018, data is estimated by interpolation using the result from 1997, 2009 and 2019 survey.

Table 5-19 Livestock population for hen [1000 heads]

Livestock species	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Hen	188,786	190,634	186,202	180,697	178,546	177,607	174,784	174,806	175,270	175,733	178,900	184,350	184,917	184,145	183,373

Note: Data of non-surveyed year (in 2009 and 2014) are interpolated.

Reference: *The Livestock Statistics, The Statistics on Livestock Products Marketing*

Table 5-20 Livestock population for broiler [1000 heads]

Item	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Livestock Population in statistics (broiler)	142,740	118,123	106,311	103,687											
Number of Shipment (broiler)				606,898	633,799	617,176	649,629	653,999	661,030	666,859	677,332	685,105	700,571	712,493	725,190
Livestock Population used in this inventory (broiler)	142,740	118,123	106,311	103,687	98,913	96,319	101,384	102,066	103,163	104,073	105,707	106,920	109,334	111,195	113,176

Note: From 1990 to 2008, livestock population data in the statistics are used. In 2009 onwards, estimated data by using the number of shipment are used.

Reference: MAFF, *Statistics on Livestock Products Marketing*

Table 5-21 Equation to estimate amount of excretion and nitrogen content in excretion for dairy cattle

	Equation
Amount of feces <sup>1)</sup>	$F = -8.4753 + 1.8657 \times DMI + 0.4948 \times NDFom$ (NDFom : 35%)
Amount of urine <sup>2)</sup>	$U = -2.2870 + 0.0231 \times NI + 0.0581 \times KI - 0.3350 \times MILK$ (NI = CP / 6.25)
Potassium Intake <sup>3)</sup>	KI = : 380g/day (Primipara) : 350g/day (2nd calving and over) : 250g/day (Non-lactating) : 220g/day (Heifer: 7 to 24 months) : 100g/day (Heifer: 3 to 6 months)
Nitrogen content in feces <sup>4)</sup>	$N_f = 5.01 \times DMI^{1.2}$ (Lactating) $N_f = 4.97 \times DMI^{1.21}$ (Non-lactating and Heifer)
Nitrogen content in urine <sup>4)</sup>	$N_u = 16.57 \times (CP / 1000 / DMI) \times 100 - 138.6$ (Lactating) $N_u = 0.24 \times (CP / 6.25)^{1.14}$ (Non-lactating and Heifer)

Note: See notation and sources of Table 5-23 below.

Table 5-22 Equation to estimate amount of excretion and nitrogen content in excretion for non-dairy cattle

	Equation
Amount of feces	$F = F_{dry} / (1 - MC)$ $F_{dry} = DMI \times (1 - TDN\%)$ MC : 80% (Wagyu (M), Wagyu (F), Breeding) <sup>5)</sup> , 85% (Dairy breed, Hybrid) <sup>5)</sup>
Amount of urine	$U = VSU / OC$ $VSU = DMI \times UE \times (1 - ASH)$ OC = 2.0% <sup>5)</sup> , UE = 2.0% <sup>5)</sup> , ASH = 8.0% <sup>6)</sup>
Nitrogen content in feces <sup>4)</sup>	$N_f = 7.22 \times DMI^{1.00}$ (for dairy breeds) $N_f = 4.97 \times DMI^{1.21}$ (for other non-dairy cattle)
Nitrogen content in urine <sup>4)</sup>	$N_u = -14.96 + 0.60 \times NI$ (for dairy breeds) $N_u + N_m = 0.24 \times NI^{1.14}$ (for other non-dairy cattle) ( $N_m = 0$ , NI = CP / 6.25)

Note: See notation and sources of Table 5-23 below.

Table 5-23 Equation to estimate crude protein (CP)<sup>1)</sup>

		Equation
Dairy cattle	Lactating	$CP = (CP1 + CP2) \times CFA$ $CP1 = 2.71 \times W^{0.75} / 0.6 \times \text{Correction factor by calving}$ Correction factor by calving: primipara: 1.3, 2nd calving: 1.15, 3rd calving and more: 1 $CP2 = (26.6 + 5.3 \times \text{FAT}) \times \text{MILK} / 0.65$ $CFA = 1 + \text{MILK} / 15 \times 0.04$
	Non-lactating	$CP = 2.71 \times W^{0.75} / 0.6$
	Heifer	$CP = NP / EP$ $NP = FN \times 6.25 + UN \times 6.25 + SP + RP$ $FN = 30 \times \text{DMI} / 6.25$ $UN = 2.75 \times W^{0.5} / 6.25$ $SP = 0.2 \times W^{0.6}$ $RP = 10 \times \text{DG} \times 23.5505 \times W^{-0.0645}$ $EP = 0.51$ (for body weight 120kg and over) 0.63 (for body weight 67–119kg)
Non-dairy cattle	Before 2008	$CP = NP / EP$ $NP = FN \times 6.25 + UN \times 6.25 + SP + RP$ $FN = 4.80 \times \text{DMI}$ $UN = 0.44 \times W^{0.5}$ $SP = 0.2 \times W^{0.6}$ $RP = \text{DG} \times (235 - 0.195 \times W)$ (Dairy breeds) $RP = \text{DG} \times (235 - 0.234 \times W)$ (Hybrid and Wagyu (male)) $RP = \text{DG} \times (235 - 0.293 \times W)$ (Wagyu (female) and Breeding cows (before 49 months old)) $RP = 0$ (Breeding cows (49 months old and over)) $EP : 0.51$ (for body weight 150kg and over) : 0.56 (for body weight 101–149kg) : 0.66 (for body weight 51–100kg) (Breeding cows, additional CP for the last 2 months of pregnancy period) $CP = \text{DCPR} / 0.75$ $\text{DCPR} = \text{TP} / 38.5 \times 30.0 / 63 / 0.6 \times 1000 + FN \times 6.25$ $\text{TP} = \text{TP}(t) - \text{TP}(t - 63)$ $\text{TP}(t) = (1.486 \times 10^{-4} \times t^3 - 4.247 \times 10^{-2} \times t^2 + 3.173 \times t - 0.328) \times$ $(-0.323 \times 10^{-6} \times t^3 + 3.000 \times 10^{-4} \times t^2 - 9.430 \times 10^{-2} \times t + 11.263) \times 6.25$ $FN = 4.80 \times 3.21 / 2.7$ (Breeding cows, additional CP for 5 months of lactation period) $CP = \text{DCPR} / 0.65$ $\text{DCPR} = 53 \times \text{MILK}$
	Since 2008	$CP = (\text{MCP} / 0.85 + \text{MPu} / 0.80) / 1.15$ $\text{MCP} = 100 \times \text{TDN}$ (except Breeding cows) $\text{MCP} = 130 \times \text{TDN}$ (Breeding cows) $\text{MPu} = \text{MPR} - \text{MPd}$ $\text{MPR} = \text{MPm} + \text{MPg}$ $\text{MPd} = 0.8 \times 0.8 \times \text{MCP}$ $\text{MPm} = (FN \times 6.25 + UN \times 6.25 + SP) / 0.67$ $FN = 4.80 \times \text{DMI} - \text{Adj}$ $UN = 0.44 \times W^{0.5}$ $SP = 0.2 \times W^{0.6}$ $\text{MPg} = \text{RP} / 0.492$ $RP = \text{DG} \times (235 - 0.195 \times W)$ (Dairy breeds) $RP = \text{DG} \times (235 - 0.234 \times W)$ (Hybrid and Wagyu (male)) $RP = \text{DG} \times (235 - 0.293 \times W)$ (Wagyu (female) and Breeding cows (before 49 months old)) $RP = 0$ (Breeding cows (49 months old and over)) $\text{Adj} = (100 \times \text{TDN} \times 0.64 \times 0.25 \times 0.5) / 6.25$ (Other than breeding cows) $\text{Adj} = (130 \times \text{TDN} \times 0.64 \times 0.25 \times 0.5) / 6.25$ (Breeding cows) (Dairy breeds under 200kg of body weight) $CP = NP / EP$ $NP = FN \times 6.25 + UN \times 6.25 + SP + RP$ $FN = 4.80 \times \text{DMI}$ $UN = 0.44 \times W^{0.5}$ $SP = 0.2 \times W^{0.6}$ $RP = \text{DG} \times (235 - 0.234 \times W)$ $EP : 0.51$ (Breeding cows, additional CP for the last 2 months of pregnancy period) $\text{MPc} = \text{PP}(t) / 0.65$ $\text{PP}(t) = \text{BW} / 40 \times \text{TP}(t) \times 34.37e^{-0.00262t}$ $\text{TP}(t) = 10^{3.707 - 5.698e^{-0.0022t}}$ (Breeding cows, additional CP for 5 months of lactation period) $\text{MP}\ell = (38 \times \text{MILK}) / 0.65$

Note: for Table 5-21, Table 5-22 and Table 5-23

<i>F</i> : Feces wet weight (kg/day)	<i>DMI</i> : Dry matter intake (kg/day)	<i>NDFom</i> : Natural detergent fiber of organic matter (%)
<i>U</i> : Urine weight (kg/day)	<i>NI</i> : Nitrogen intake (kg/day)	<i>KI</i> : Potassium intake (kg/day)
<i>MILK</i> : Milk yield (kg/day)	<i>N<sub>f</sub></i> : Nitrogen content in feces (kg/day)	<i>N<sub>u</sub></i> : Nitrogen content in urine (kg/day)
<i>CP</i> : Crude protein (g)	<i>F<sub>dry</sub></i> : Feces dry weight (kg/day)	<i>MC</i> : Percentage of moisture contents in feces (%)
<i>TDN%</i> : Percentage of total digestible nutrients	<i>VSU</i> : Volatile solid excretion rate in urine (kg/day)	<i>OC</i> : Organic matter content in urine (%)
<i>UE</i> : Urinary energy (%)	<i>ASH</i> : Ash content (%)	<i>CFA</i> : Correction factor
<i>W</i> : Body weight (kg)	<i>FAT</i> : Fat content in milk (%)	<i>NP</i> : Net protein for preservation and gain for growth
<i>EP</i> : Conversion efficiency of crude protein to net protein on growth	<i>FN</i> : Metabolic fecal nitrogen for growth after ab lactation (for heifers which body weight is 66kg and over) (g/day)	<i>UN</i> : Endogenous urinary nitrogen (g/day)
<i>SP</i> : Shedding skin protein (g/day)	<i>RP</i> : Protein accumulation associate with gain (g/day)	<i>DG</i> : Daily gain (kg/day)
<i>DCPR</i> : Digestible crude protein requirement (g/day)	<i>TP(t)</i> : Total protein accumulation in pregnant uterus until (t) days after conception (g)	<i>t</i> : Days after conception (day)
<i>MCP</i> : Microbial crude protein (g/day)	<i>MP<sub>u</sub></i> : Undigestible crude protein from feed (g/day)	<i>TDN</i> : Total digestible nutrients (kg/day)
<i>MPR</i> : Metabolic protein requirement (g/day)	<i>MP<sub>d</sub></i> : Metabolic protein delivered by microbial (g/day)	<i>MP<sub>m</sub></i> : Metabolic protein requirement for maintenance (g/day)
<i>MP<sub>g</sub></i> : Metabolic protein requirement for growth (g/day)	<i>Adj</i> : Adjustment value	<i>MP<sub>c</sub></i> : Metabolic protein requirement for conception (g/day)
<i>PP(t)</i> : Protein accumulation in pregnant uterus at (t) days after conception (g/day)	<i>BW</i> : Birth weight (kg)	<i>MP<sub>l</sub></i> : Metabolic protein for lactation (g/day)

Reference:

- 1) *Japanese Feed Standard*
- 2) Otani et al. (2010)
- 3) Kume et al. (2010)
- 4) Chomei et al. (2006)
- 5) Expert judgement
- 6) *2006 IPCC Guidelines*, Vol.4

Table 5-24 Equation to estimate amount of nitrogen content in excretion for swine

	Equation
Amount of feces	$F = F_{dry} / (1 - MC)$ $MC : 72\% ^1)$ $F_{dry} = DMI \times (1 - DR\%)$
Amount of urine	$U = N_u / (OC \times 0.469)$ $OC = 1.4\% ^1)$
Nitrogen content in feces <sup>2)</sup>	$N_f = N_{out} \times f$ $f = (UDCP + ECP + CP_{loss}) / 6.25 / N_{out}$ $UDCP = UD \times F_{intake}$ $UD = 1 - \sum_n (CPFS-n \times DCP-n)$ $ECP = 14.05 \times \sum_i DMI_i$ $CP_{loss} = \sum_i 104.7 \times Day \times AVW^{0.75}$
Nitrogen content in urine	$N_u = N_{out} \times u$ $u = (1 - f)$
Nitrogen content in excretion	$N_{out} = N_{in} - N_{PR}$ $N_{out} = N_{in} - N_M$ (Lactating sow) $N_{in} = (CP \times F_{intake}) / 6.25$ $F_{intake} = F_{demand} \times Day$ $N_{PR} = (149.2 \times W^{-0.0154} \times WG) / 6.25$ (Growing-finishing pigs before 2005) $N_{PR} = (-0.121 \times W + 119.2 \times WG + 25.5) / 6.25$ (Growing-finishing pigs since 2005) $N_{PR} = ((5.78 \times NWG + 103.87) / 5.56) / 6.25$ (Pregnant sows) $N_M = \sum (CP_M \times MILK) / 6.25$ (Lactating sows)

Note:

<i>F</i> : Feces wet weight (kg/day)	<i>F<sub>dry</sub></i> : Feces dry weight (kg/day)	<i>MC</i> : Percentage of moisture contents in feces (%)
<i>DMI</i> : Dry matter intake (kg/day)	<i>DR%</i> : Digestion Rate for feed (%)	<i>U</i> : Urine weight (kg/day)

<i>N<sub>u</sub></i> : Nitrogen content in urine (kg/day)	<i>OC</i> : Organic matter content in urine (%)	<i>N<sub>f</sub></i> : Nitrogen content in feces (kg/day)
<i>N<sub>out</sub></i> : Nitrogen content in excretion (g)	<i>f</i> : Proportion of feces to excretion	<i>UDCP</i> : Undigested crude protein in feed (g)
<i>ECP</i> : Excretion of endogenous crude protein (g)	<i>CP<sub>loss</sub></i> : Amount of crude protein to be lost as fallen hair or skin (g)	<i>UD</i> : Undigestibility (%)
<i>F<sub>intake</sub></i> : Feed intake (kg)	<i>n</i> : Varieties of feedstuffs	<i>CPFS</i> : Crude protein content in feedstuffs (%)
<i>DCP</i> : Percentage of digestible crude protein in feedstuffs (%)	<i>i</i> : Body weight class for growing-finishing pigs	<i>Day</i> : Total days of raising (day)
<i>AVW</i> : Averaged body weight (kg)	<i>u</i> : Proportion of urine to excretion	<i>N<sub>in</sub></i> : Nitrogen content in feed intake (g)
<i>N<sub>PR</sub></i> : Nitrogen amount in accumulated protein in body (g)	<i>N<sub>M</sub></i> : Nitrogen amount in milk (g)	<i>CP</i> : Crude protein contents in feed intake (%)
<i>F<sub>demand</sub></i> : Daily demand of feed intake (kg/day)	<i>W</i> : Body weight (kg)	<i>WG</i> : Daily weight gain (kg/day)
<i>NWG</i> : Weight gain by pregnant sow in gestational period without conceptus (kg)	<i>CP<sub>M</sub></i> : Crude protein content in milk (%)	<i>MILK</i> : Amount of milk (g)

Reference:

- 1) *Guide for processing and using livestock manure*
- 2) Ogino et al. (2020)
- 3) *Japanese Feed Standard Swine*

Table 5-25 Equation to estimate amount of nitrogen content in excretion for poultry

	Equation <sup>1)</sup>
Amount of feces	$F_{dry} = Intake \times Dry \times (1-DR\%) \quad Dry : 87\%^{2)}$ $F_{wet} = F_{dry} / (1 - MC) \quad MC : \text{hen } 78\%, \text{ broiler } 80\%^{3)}$
Nitrogen content in excretion	$N_{out} = N_{in} - N_{egg} - N_{wg} \text{ (hen)}$ $N_{in} = F_{intake} \times W_{egg} \times CP_{feed} / 6.25$ $N_{egg} = W_{egg} \times CP_{egg} / 6.25 \quad CP_{egg} : 12\%^{2)}$ $N_{wg} = WG \times CP_{wg} / 6.25 \quad CP_{wg} : 19.2\%$ $N_{out} = N_{in} - N_{wg} \text{ (chicks of layer)}$ $N_{in} = Intake \times CP_{feed} / 6.25$ $N_{wg} = WG \times CP_{wg} / 6.25 \quad CP_{wg} : 19.2\%$ $N_{out} = N_{in} - N_{pr} \text{ (broiler)}$ $N_{in} = F_{intake} \times WG \times CP_{feed} / 6.25$ $N_{pr} = WG \times CP_{chicken} / 6.25 \quad CP_{chicken} : 19.2\%$ $WG = W / 47$

Note:

<i>F<sub>dry</sub></i> : Feces dry weight (kg/day)	<i>Intake</i> : Amount of feed intake (g/day)	<i>Dry</i> : Dry matter fraction of feed (%)
<i>DR%</i> : Digestion Rate for feed (%)	<i>F<sub>wet</sub></i> : Feces wet weight (kg/day)	<i>MC</i> : Percentage of moisture contents in feces (%)
<i>N<sub>out</sub></i> : Nitrogen content in excretion (gN/day)	<i>N<sub>in</sub></i> : Nitrogen content in feed intake (gN/day)	<i>N<sub>egg</sub></i> : Nitrogen content in egg (gN/day)
<i>N<sub>wg</sub></i> : Nitrogen content in daily weight gain (gN/day)	<i>F<sub>intake</sub></i> : Feed intake (Hen: g/ g-egg weight/day, broiler: g/g-body weight (47days old))	<i>W<sub>egg</sub></i> : Daily egg production weight (g/day)
<i>CP<sub>feed</sub></i> : Crude protein content in feed (%)	<i>CP<sub>egg</sub></i> : Crude protein content in egg (%)	<i>WG</i> : Daily weight gain (g/day)
<i>CP<sub>wg</sub></i> : Crude protein content in daily weight gain (%)	<i>N<sub>PR</sub></i> : Nitrogen amount in accumulated protein in body (g)	<i>W</i> : Body weight (47days old) (g)
<i>CP<sub>chicken</sub></i> : Crude protein content in chicken (%)		

Reference:

- 1) Ogino et al. (2017)
- 2) *Japanese Feed Standard Poultry*
- 3) Tsuiki and Harada (1997)



Table 5-26 CP content in feedstuffs (%) and proportion of feedstuffs in feed material

Name of feed material	CP content (%) <sup>1)</sup>			Proportion of feedstuffs in feed material <sup>2)</sup>								
	1995	2001	2009	Swine			Hen			Broiler		
				1995	2001	2009	1995	2001	2009	1995	2001	2009
Corn	8.8	8.0	7.6	0.471	0.503	0.541	0.589	0.606	0.581	0.485	0.444	0.427
Grain sorghum (Milo)	9.0	8.8	8.8	0.161	0.136	0.104	0.059	0.034	0.046	0.151	0.189	0.183
Wheat	12.1	12.1	12.1	0.005	0.005	0.011	0.000	0.000	0.000	0.000	0.000	0.000
Barley (Naked variety)	10.5	10.5	10.5	0.006	0.006	0.013	0.000	0.000	-	0.000	0.000	0.000
Rice	7.9	7.9	7.5	0.011	0.008	0.010	0.010	0.006	0.010	0.017	0.013	0.026
Wheat feed flour	15.5	15.5	15.5	0.010	0.008	0.008	0.000	0.000	0.001	0.001	0.001	0.003
Rye	10.9	10.4	10.0	0.029	0.024	0.004	0.000	0.000	-	0.000	0.000	0.000
Oats	9.8	9.8	9.8	0.000	0.000	0.000	-	-	-	-	-	-
Other grains	10.1	10.1	10.1	0.008	0.010	0.012	0.001	0.001	0.001	0.001	0.001	0.002
Soybean, Soybean meal	36.7	36.7	36.7	-	0.004	0.004	-	0.001	0.001	-	0.001	0.001
Other beans	25.7	25.7	25.7	-	0.000	0.000	-	0.000	-	-	0.000	-
Wheat bran / Barley bran	15.4	15.7	15.7	0.012	0.009	0.009	0.008	0.006	0.005	0.001	0.001	0.000
Rice bran	14.8	14.8	14.8	0.004	0.003	0.001	0.009	0.006	0.004	0.002	0.001	0.001
Defatted rice bran	17.7	17.5	18.6	0.006	0.007	0.007	0.009	0.008	0.008	0.001	0.001	0.001
Gluten feed	19.8	19.8	20.9	0.009	0.008	0.008	0.017	0.019	0.015	0.001	0.001	0.001
Gluten meal	51.5	51.5	51.3	0.000	0.000	0.000	0.035	0.033	0.031	0.004	0.002	0.003
Hominy feed	9.6	9.6	9.0	0.000	0.000	-	0.000	0.000	-	0.000	0.000	-
Screening pellet	12.3	12.3	12.3	0.000	0.000	-	0.000	0.000	-	-	-	-
Beat pulp	10.9	10.9	8.5	0.000	0.000	0.000	-	0.000	-	-	-	0.000
DDGS	30.8	30.8	30.8	-	-	-	-	-	-	-	-	-
Other chaff and bran	12.2	12.2	12.2	0.002	0.002	0.009	0.005	0.004	0.020	0.001	0.001	0.007
Alfalfa meal pellet cube	16.7	16.7	16.2	0.004	0.003	0.003	0.003	0.003	0.001	0.000	0.000	0.000
Soyabean meal	46.1	46.1	45.0	0.143	0.148	0.142	0.127	0.162	0.162	0.199	0.231	0.221
Rapeseed meal	37.1	37.1	37.3	0.032	0.035	0.041	0.035	0.039	0.050	0.023	0.025	0.027
Cotton seed meal	35.4	35.4	35.4	0.000	0.000	0.000	0.000	-	0.000	0.000	-	-
Other plant seed meals	32.7	32.7	32.7	0.004	0.006	0.005	0.008	0.011	0.011	0.002	0.002	0.002
Fish meal	59.8	59.8	59.6	0.014	0.010	0.008	0.023	0.014	0.010	0.021	0.011	0.009
Fish Soluble Powder	56.1	56.1	56.1	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000
Dried skim milk	35.8	35.8	34.6	0.005	0.004	0.002	0.000	-	-	0.000	0.000	0.000
Dried whey	12.0	12.0	12.0	0.003	0.004	0.004	0.000	0.000	0.000	-	-	0.000
Meat meal / Meat and bone meal	60.8	60.8	59.6	0.015	0.005	0.001	0.035	0.015	0.007	0.034	0.018	0.016
Feather meal	84.5	84.5	83.1	0.000	0.000	0.000	0.002	0.001	0.000	0.004	0.002	0.004
Other animal origin feed	43.5	43.5	43.3	0.001	0.000	0.001	0.001	0.001	0.002	0.004	0.004	0.008
Animal fat	0.0	0.0	0.0	0.013	0.013	0.011	0.018	0.024	0.027	0.042	0.046	0.048
Vegetable cooking oil	0.0	0.0	0.0	0.000	0.000	0.000	0.001	0.001	0.001	0.000	0.000	0.001
Molasses	9.4	9.4	9.4	0.005	0.004	0.004	0.000	0.000	0.000	0.000	0.000	0.000
Feed additives	0.0	0.0	0.0	0.004	0.004	0.005	0.003	0.003	0.004	0.004	0.004	0.006
Special feed	0.0	0.0	0.0	0.016	0.019	0.018	-	-	-	-	-	-
Other feed	13.1	13.1	13.0	0.005	0.009	0.013	0.001	0.002	0.004	0.001	0.001	0.003
Amino acid	100.0	100.0	100.0	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.003
Total				1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Note: Estimated based on references below. The values for 1995, 2001 and 2009 are extracted and shown.

Reference:

- 1) National Agriculture and Food Research Organization compiled, *Tables of Feed Composition in Japan*, Japan Livestock Industry Association.
- 2) Ministry of Agriculture, Forestry and Fisheries of Japan, *Feed bulletin*.

Table 5-27 Amount of excretion ( $Ex$ ) and amount of nitrogen in excretion ( $N_{ex}$ ) from dairy cattle

Item		1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020		
Dairy Cattle	Amount of excretion [kg/head/day]	Feces	Lactating (Multipara (3 and more))	41.5	43.1	44.5	46.0	46.1	46.1	46.4	46.4	46.8	47.3	47.4	47.5	47.5	48.2	48.4
			Lactating (Secundipara)	40.3	41.8	43.3	44.8	44.7	44.7	45.0	45.0	45.3	45.8	45.9	46.0	46.0	46.7	46.8
			Lactating (Primipara)	36.7	38.2	39.5	40.6	41.4	41.4	41.6	41.6	41.8	42.2	42.3	42.5	42.4	42.9	42.9
		Urine	Non-lactating	27.9	27.9	28.7	28.5	28.6	28.5	28.5	28.5	28.5	28.4	28.4	28.4	28.4	28.3	28.3
			Heifer: under 2 yr, over 6 mth	22.1	22.4	22.9	23.1	23.2	23.2	23.2	23.2	23.2	23.2	23.2	23.2	23.2	23.2	23.2
			Heifer: 3 to 6 mth	14.9	14.9	15.1	15.8	15.9	15.9	15.9	15.9	15.9	15.9	15.9	15.9	15.9	15.9	15.9
	Amount of N in excretion [g-N/head/day]	Feces	Lactating (Multipara (3 and more))	155.7	164.4	172.7	181.7	182.1	182.2	183.8	184.0	186.0	189.1	189.6	190.1	190.4	194.7	195.5
			Lactating (Secundipara)	148.5	157.4	165.5	174.3	173.9	174.0	175.6	175.7	177.6	180.5	180.8	181.3	181.3	185.5	186.3
			Lactating (Primipara)	128.6	136.7	144.1	150.2	154.7	155.0	156.0	156.1	157.4	159.5	160.1	160.9	160.3	163.6	163.7
		Urine	Non-lactating	82.7	83.0	86.8	85.6	86.4	86.1	85.9	85.9	85.7	85.5	85.4	85.4	85.3	85.0	84.9
			Heifer: under 2 yr, over 6 mth	53.3	54.5	57.2	58.3	58.5	58.5	58.5	58.5	58.5	58.5	58.5	58.5	58.5	58.5	58.5
			Heifer: 3 to 6 mth	20.6	20.7	21.6	24.3	24.9	24.9	24.9	24.9	24.9	24.9	24.9	24.9	24.9	24.9	24.9
	Amount of N in excretion [g-N/head/day]	Urine	Lactating (Multipara (3 and more))	76.1	81.0	83.2	87.9	89.5	89.4	90.5	90.8	92.1	93.5	93.9	94.2	94.2	96.4	96.9
			Lactating (Secundipara)	85.8	90.2	92.2	96.6	98.4	98.4	99.3	99.6	100.7	102.1	102.3	102.6	102.5	104.5	105.0
			Lactating (Primipara)	88.8	92.5	94.4	98.7	92.8	92.7	93.9	94.2	95.5	97.2	97.9	98.8	98.4	101.0	101.3
			Non-lactating	98.6	98.8	103.1	101.9	102.8	102.4	102.1	102.2	101.9	101.7	101.5	101.6	101.5	101.1	101.0
			Heifer: under 2 yr, over 6 mth	65.1	66.6	69.7	70.9	71.1	71.1	71.1	71.1	71.1	71.1	71.1	71.1	71.1	71.1	71.1
			Heifer: 3 to 6 mth	27.4	27.6	37.4	43.1	44.2	44.2	44.2	44.2	44.2	44.2	44.2	44.2	44.2	44.2	44.2

Table 5-28 Amount of excretion (*Ex*) and amount of nitrogen in excretion (*Nex*) from non-dairy cattle

Non-dairy cattle		Item	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020			
Amount of excretion [kg/head/day]	Feces	Breeding: 2 yr and over	17.4	17.4	18.2	18.2	18.2	18.2	18.2	18.2	18.2	18.2	18.2	18.2	18.2	18.2	18.2	18.2		
		under 2 yr, over 6 mth	12.6	12.6	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2		
		3 to 6 mth	5.9	5.9	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7		
		Wagyu (M): 1 yr and over	12.3	12.3	12.3	12.3	10.8	10.8	10.8	10.8	10.8	10.8	10.8	10.8	10.8	10.8	10.8	10.8	10.8	
		under 1 yr, over 6 mth	8.4	8.4	8.4	8.4	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	
		3 to 6 mth	5.0	5.0	5.0	5.0	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	
		Wagyu (F): 1 yr and over	10.0	10.0	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2	
		under 1 yr, over 6 mth	7.2	7.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	
		3 to 6 mth	4.5	4.5	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	
		Dairy breed: over 6 mth	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	
		3 to 6 mth	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	
		Hybrid: over 6 mth	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4	
		3 to 6 mth	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7	
		Urine	Breeding: 2 yr and over	7.1	7.1	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	
			under 2 yr, over 6 mth	5.8	5.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	
			3 to 6 mth	3.1	3.1	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	
			Wagyu (M): 1 yr and over	7.6	7.6	7.6	7.6	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	
			under 1 yr, over 6 mth	6.0	6.0	6.0	6.0	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	
	3 to 6 mth		3.3	3.3	3.3	3.3	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0		
	Wagyu (F): 1 yr and over		5.2	5.2	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8		
	under 1 yr, over 6 mth		4.3	4.3	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4		
	3 to 6 mth		2.7	2.7	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1		
	Dairy breed: over 6 mth		7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8		
	3 to 6 mth		4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0		
	Hybrid: over 6 mth		7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7		
	3 to 6 mth		4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2		
	Amount of nitrogen in excretion [g-N/head/day]		Feces	Breeding: 2 yr and over	58.9	58.9	61.8	61.8	61.8	61.8	61.8	61.8	61.8	61.8	61.8	61.8	61.8	61.8	61.8	61.8
				under 2 yr, over 6 mth	46.1	46.1	56.2	56.2	56.2	56.2	56.2	56.2	56.2	56.2	56.2	56.2	56.2	56.2	56.2	
				3 to 6 mth	21.5	21.5	24.3	24.3	24.3	24.3	24.3	24.3	24.3	24.3	24.3	24.3	24.3	24.3	24.3	
				Wagyu (M): 1 yr and over	63.5	63.5	63.5	63.5	59.1	59.1	59.1	59.1	59.1	59.1	59.1	59.1	59.1	59.1	59.1	
				under 1 yr, over 6 mth	48.1	48.1	48.1	48.1	51.3	51.3	51.3	51.3	51.3	51.3	51.3	51.3	51.3	51.3	51.3	
				3 to 6 mth	23.7	23.7	23.7	23.7	20.7	20.7	20.7	20.7	20.7	20.7	20.7	20.7	20.7	20.7	20.7	
		Wagyu (F): 1 yr and over		40.1	40.1	46.4	46.4	46.4	46.4	46.4	46.4	46.4	46.4	46.4	46.4	46.4	46.4	46.4		
		under 1 yr, over 6 mth		32.5	32.5	42.7	42.7	42.7	42.7	42.7	42.7	42.7	42.7	42.7	42.7	42.7	42.7			
		3 to 6 mth		18.7	18.7	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0				
		Dairy breed: over 6 mth		61.3	61.3	61.3	61.3	61.3	61.3	61.3	61.3	61.3	61.3	61.3	61.3	61.3				
		3 to 6 mth	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8						
		Hybrid: over 6 mth	60.2	60.2	60.2	60.2	60.2	60.2	60.2	60.2	60.2	60.2	60.2							
		3 to 6 mth	33.2	33.2	33.2	33.2	33.2	33.2	33.2	33.2	33.2	33.2								
		Urine	Breeding: 2 yr and over	73.9	73.9	76.7	76.7	74.9	74.9	74.9	74.9	74.9	74.9	74.9	74.9	74.9	74.9	74.9		
			under 2 yr, over 6 mth	57.5	57.5	69.4	69.4	70.6	70.6	70.6	70.6	70.6	70.6	70.6	70.6	70.6	70.6			
			3 to 6 mth	35.5	35.5	43.6	43.6	54.3	54.3	54.3	54.3	54.3	54.3	54.3	54.3	54.3				
			Wagyu (M): 1 yr and over	76.9	76.9	76.9	76.9	71.9	71.9	71.9	71.9	71.9	71.9	71.9	71.9	71.9				
			under 1 yr, over 6 mth	65.1	65.1	65.1	65.1	71.6	71.6	71.6	71.6	71.6	71.6	71.6	71.6					
			3 to 6 mth	41.0	41.0	41.0	41.0	48.2	48.2	48.2	48.2	48.2	48.2	48.2						
			Wagyu (F): 1 yr and over	49.8	49.8	57.2	57.2	57.2	57.2	57.2	57.2	57.2	57.2	57.2						
	under 1 yr, over 6 mth		44.8	44.8	57.5	57.5	60.4	60.4	60.4	60.4	60.4	60.4								
3 to 6 mth	33.9		33.9	42.3	42.3	51.6	51.6	51.6	51.6	51.6										
Dairy breed: over 6 mth	84.2		84.2	84.2	84.2	85.5	85.5	85.5	85.5	85.5										
3 to 6 mth	57.2	57.2	57.2	57.2	61.8	61.8	61.8	61.8												
Hybrid: over 6 mth	82.0	82.0	82.0	82.0	83.0	83.0	83.0	83.0												
3 to 6 mth	57.0	57.0	57.0	57.0	65.8	65.8	65.8	65.8												

Table 5-29 Amount of excretion (*Ex*) and amount of nitrogen in excretion (*Nex*) from swine

Swine	Item		1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
	Excretion	Feces	Growing-finishing	1.5	1.5	1.5	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.7	1.7	1.7
Breeding		kg/head/day	2.1	2.1	2.1	2.1	2.1	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
Urine	Feces	Growing-finishing	4.3	4.2	4.1	4.0	3.9	3.9	3.9	3.8	3.7	3.7	3.7	3.9	3.9	3.9	3.9
	Breeding	kg/head/day	5.5	5.5	5.5	5.2	5.1	5.1	5.1	4.9	4.8	4.8	4.8	4.8	4.8	4.7	4.7
Nitrogen	Feces	Growing-finishing	14.0	14.0	13.3	13.3	13.6	13.7	13.7	13.7	13.7	13.6	13.5	14.1	14.1	14.3	14.2
	Breeding	g-N/head/day	20.2	20.2	20.2	19.4	19.7	19.8	19.8	19.8	19.8	19.7	19.7	19.7	19.7	19.8	19.7
Urine	Feces	Growing-finishing	27.9	27.6	26.8	25.9	25.3	25.2	25.2	24.5	24.1	24.0	23.9	25.3	25.2	25.3	25.3
	Breeding	g-N/head/day	36.0	35.6	35.7	33.8	33.0	32.9	33.0	31.8	31.3	31.1	31.1	31.1	30.9	30.7	30.7

Table 5-30 Nitrogen content in feces excreted for Hen and Broiler (*N<sub>ex</sub>*)

Item		Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
Excretion	Hen	Adult	kg/head/day	0.086	0.087	0.088	0.088	0.087	0.093	0.094	0.095	0.094	0.091	0.092	0.094	0.092	0.090	0.087
		Poult	kg/head/day	0.041	0.041	0.039	0.040	0.040	0.042	0.042	0.042	0.042	0.041	0.041	0.042	0.042	0.041	0.040
	Broiler	kg/head/day	0.097	0.098	0.098	0.096	0.101	0.099	0.098	0.098	0.094	0.092	0.089	0.088	0.087	0.085	0.084	0.083
Nitrogen	Hen	Adult	g-N/head/day	2.18	2.16	2.06	1.93	1.86	1.92	1.88	1.82	1.79	1.78	1.79	1.80	1.77	1.73	1.73
		Poult	g-N/head/day	1.04	1.03	0.97	0.98	1.01	1.01	0.99	0.99	0.99	0.98	0.98	0.98	0.98	0.98	0.98
	Broiler	g-N/head/day	2.06	2.04	1.95	1.75	1.86	1.80	1.69	1.56	1.54	1.53	1.52	1.54	1.47	1.45	1.45	

Table 5-31 Organic matter content in feces and urine, by type of livestock (wet base) (*Org*)<sup>1)</sup>

Livestock species	Organic matter content	
	Feces	Urine
Dairy cattle	16%	0.5%
Non-dairy cattle	18%	2.0% <sup>2)</sup>
Swine	20%	1.4% <sup>3)</sup>
Hen	15%	—
Broiler	15%	—

- Reference: 1) Japan Livestock Technology Association, *GHGs emissions control in livestock Summary*. (2002)  
 2) Expert judgement  
 3) Estimated value based on *Guide for processing and using livestock manure*, Livestock Industry's Environmental Improvement Organization, 1998

Table 5-32 Proportion of separated and mixed treatment of manure, by type of livestock (*Mix<sub>n</sub>*)

Livestock species	Separated			Mixed		
	~1999	2009	2019	~1999	2009	2019
Dairy cattle	60.0%	45.5%	30.9%	40.0%	54.5%	69.1%
Non-dairy cattle	7.0%	4.8%	2.5%	93.0%	95.2%	97.5%
Swine	70.0%	73.9%	76.3%	30.0%	26.1%	23.7%
Hen	100.0%	100.0%	100.0%	—	—	—
Broiler	100.0%	100.0%	100.0%	—	—	—

Note: For Hen and Broiler, the proportion is reported at the mixed in the report of survey in 2019 but the proportion is reported at the separated in the NIR due to maintaining consistency in the inventory.

- Reference: Until 1999: Japan Livestock Technology Association, *GHGs emissions control in livestock Summary*. (2002)  
 At 2009: MAFF, *Survey of current status for livestock manure management system, 2009* (2011)  
 At 2019: MAFF, *Survey of current status for livestock manure management system and others, 2019* (2021)

Table 5-33 Proportion of manure management system by type of livestock (dairy cattle, non-dairy cattle and swine) (*MS<sub>n</sub>*)

State of Manure (Separated or Mixed)	Treating method	Dairy cattle			Non-dairy cattle			Swine			
		~1999	2009	2019	~1999	2009	2019	~1999	2009	2019	
Separated	Feces	Sun drying	2.8%	2.0%	2.7%	1.5%	0.9%	2.1%	7.0%	0.7%	0.8%
		Thermal drying	0%	0%	0.0% <sup>3)</sup>	0%	0%	0.0%	0.7%	0.1%	0.0%
		Carbonization			—			—			—
		Composting	9.0%	6.6%	9.0%	11.0%	8.1%	4.7%	62.0%	48.2%	57.9%
		Open Composting			7.9%			4.5%			26.3%
		Closed Composting			1.0%			0.2%			31.6%
		Piling	88.0%	90.1%	87.3%	87.0%	89.8%	92.9%	29.6%	49.3%	39.9%
		Pit storage (within a month)			0.5%			0.1%			0.1%
		Pit storage (over a month)			0.0%			0.1%			—
		Incineration	0.2%	0%	0.1%	0.5%	—	—	0.7%	0.6%	0.9%
		Methane fermentation		— <sup>2)</sup>	0.3%		—	—		0.1%	0.1%
		public sewage		0%	0.0%		—	—		—	—
		Industrial waste treatment			0.0%			0.0%			0.1%
		Pasturage		0%			—	—		—	—
Other		1.3%			1.2%			1.0%	0.01%		

State of Manure (Separated or Mixed)	Treating method	Dairy cattle			Non-dairy cattle			Swine		
		~1999	2009	2019	~1999	2009	2019	~1999	2009	2019
Urine	Sun drying		0%			0%		0%		
	Composting (urine)	1.5%	1.7%	8.6%	9.0%	1.2%	19.3%	10.0%	5.4%	7.9%
	Open Composting			6.2%			17.8%			7.1%
	Closed Composting			2.5%			1.5%			0.9%
	Purification	2.5%	5.1%	5.4%	2.0%	4.4%	7.8%	45.0%	76.3%	84.3%
	Purification - discharge			3.2%			7.2%			71.1%
	Purification - reuse			2.1%			0.5%			13.2%
	Pit storage	96.0%	89.6%	82.1%	89.0%	91.4%	68.2%	45.0%	15.3%	6.0%
	PS (within a month)			12.4%			10.3%			2.0%
	PS (over a month)			69.7%			58.0%			4.0%
	Methane fermentation		1.9%	2.7%		0%	4.5%		0.5%	1.0%
	Public sewage		0.8%	1.1%		0.6%	0.2%		0.4%	0.6%
	Industrial waste treat.			0.0%			—			0.0%
Other		0.9%	0.1%		2.4%	0.0%		2.1%	0.0%	
Mixed	Sun drying	4.4% <sup>1)</sup>	1.1%	1.9%	3.4% <sup>1)</sup>	0.7%	1.3%	6.0%	0.2%	0.2%
	Thermal drying	0%	0%	0.0%	0%	0%	—	0%	0%	—
	Carbonization			—			0.0%			—
	Composting (urine)	18.7% <sup>1)</sup>	22.9%	12.0%	21.8% <sup>1)</sup>	10.8%	14.5%	29.0%	21.3%	23.2%
	Open Composting			11.2%			13.6%			13.7%
	Closed Composting			0.7%			0.9%			9.5%
	Piling	13.1% <sup>1)</sup>	50.8%	45.1%	73.2% <sup>1)</sup>	85.7%	77.4%	20.0%	51.4%	52.1%
	Purification	0.3% <sup>1)</sup>	0.2%	0.2%	0%	0%	0.0%	22.0%	18.5%	12.9%
	Purification - discharge			0.0%			0.0%			11.7%
	Purification - reuse			0.2%			—			1.1%
	Pit storage	57.0% <sup>1)</sup>	15.4%	32.2%	0.6% <sup>1)</sup>	0.1%	5.4%	23.0%	4.0%	5.9%
	PS (within a month)			6.5%			1.8%			3.2%
	PS (over a month)			25.7%			3.6%			2.8%
	Incineration		0.1%	0.0%		0%	0.0%		0%	0.1%
	Methane fermentation		1.7%	5.9%		0%	0.1%		2.0%	4.4%
	Public sewage		0.1%	0.0%		0%	0.0%		0.7%	0.8%
	Industrial waste treat.			0.1%			0.1%			0.4%
Pasturage	6.5% <sup>1)</sup>	6.5%	2.5%	1.1% <sup>1)</sup>	1.1%	1.2%		0%	0.0%	
Other		1.2%	0.0%		1.6%	0.0%		1.9%	0.0%	

Reference: ~1999: Japan Livestock Technology Association, *GHGs emissions control in livestock Part4*. (1999)

2009: MAFF, *Survey of current status for livestock manure management system, 2009* (2011)

2019: MAFF, *Survey of current status for livestock manure management system and others, 2019* (2021)

Note:

- 1) For dairy cattle and non-dairy cattle, percentage of “Pasturage” are not indicated in Japan Livestock Association data (1999) but are indicated in the result of survey for 2009 MAFF (2011). Therefore, the percentages of “Pasturage” indicated in MAFF (2011) are applied to the years before 2009 consistently. In addition, each percentage of the mixed management of dairy cattle and non-dairy cattle is adjusted so that the sum of the percentages can be 100%.
- 2) The symbol ‘—’ is applied to for no-existing management.
- 3) ‘0.0%’ is used for the value less than a unit.
- 4) Blank is for non-listed item on the survey.

Table 5-34 Percentage of manure management system by type of livestock (hen and broiler) ( $MS_n$ )

State of Manure (Separated or Mixed)		Treating method	Hen			Broiler		
			~1999	2009	2019	~1999	2009	2019
Separated	Feces	Sun drying	30.0%	8.2%	4.1%	15.0%	2.5%	0.8%
		Thermal drying	3.0%	2.2%	0.9%	0.0%	1.1%	0.3%
		Carbonization			0.2%			0.9%
		Composting	42.0%	49.6%	52.0%	5.1%	19.3%	10.8%
		Open Composting			29.0%			9.4%
		Closed Composting			23.0%			1.4%
		Piling	23.0%	36.8%	35.3%	66.9%	36.6%	27.3%
		Pit storage (within a month)			1.1%			2.3%
		Pit storage (over a month)			1.1%			1.3%
		Incineration	2.0%	1.6%	2.9%	13.0%	30.4%	46.8%
		Methane fermentation		—	0.1%		0.1%	0.3%
		Public sewage		—	—		—	—
		Industrial waste treatment			2.0%			5.8%
		Pasturage		0%	0.0%		0.1%	—
		Other		1.6%	0.2%		9.9%	3.5%

Reference: See Table 5-33 above

#### ● *Background information for livestock manure management in Japan*

In Europe, slurry spreading (liquid system) is major manure management system. On the other hand, in Japan, composting system (“Composting” and “Piling”) are major management system. Osada et al. (2005), which investigated emission factors by actual measurement for “Piling”, described that “Proper recycling of nutritive salts from livestock compost cannot be completed only by circulation in an area where the livestock density per unit area is especially high. Thus, livestock excrement can be made more manageable through the composting process, and the resulting product can be distributed over a wide area”. Composting (“Composting” and “Piling”) is widely practiced in Japan because, among other things: (1) it is essential for Japanese livestock farmers to facilitate transportation and handling, because the lack of space required for the on-site reduction of manure makes it necessary to direct the manure for uses outside their farms; and (2) compost is in considerably higher demand as a fertilizer for various crops than slurry or liquid manure in Japan where fertilizers tend to be lost by heavy rain and the expectations of the protection of water quality, prevention of odor, and sanitary management are high.

#### ● *Reporting in Common Reporting Format (CRF)*

In the CRF, it is required to report allocation and amount of nitrogen excretion by MMS (“Anaerobic lagoons”, “Liquid systems”, “Daily spread”, “Solid storage and dry lot”, “Pasture, range and paddock”, “Composting”, “Digesters”, “Burned for fuel or as waste”, and “Other”).

For cattle, swine, and poultry, Japan’s country-specific manure treatment method and the implementation rates of the treatment method have been established for each type of animal. For details and correspondence of the Japanese manure treatment method to Manure management system (MMS) in CRF, see Table 5-35.

“Anaerobic Lagoons” have been reported as “NO”. Because there are quite small number of livestock farmers who has enough area of field to spread manure, and it is assumed that there are no livestock farmers who use anaerobic lagoons. There are cases when manure is spread to fields in Japan, but even

in these cases, stirring is conducted before the spreading. Therefore, there are no anaerobic manure management systems.

Table 5-35 Correspondence of the Japanese manure treatment method to CRF classification (Manure management system)

Classification in Japan		Classification in CRF (MMS)	Description of manure treatment method	
State of Manure	Manure treatment method			
Separated	Feces	Sun drying	Solid storage and dry lot	Dried under sunlight to facilitate handling (for storage and odor prevention).
		Thermal drying	Other	Dried by heat to facilitate handling.
		Carbonization	Other	Produced carbide by pyrolyzing organic matter under high temperature in the no oxygen or the absence of oxygen.
		Composting	Composting	Fermented for several days to several weeks with forced aeration and agitation in lidded or closed tanks.
		Open composting	Composting	Fermented for several days to several weeks with forced aeration and/or agitation in open systems as scoop type composting facilities.
		Closed composting	Composting	Fermented for several days to several weeks with forced aeration and/or agitation in closed systems as closed vertical tank type composting facilities.
		Piling	Composting	Piling system is a method of composting. Piled about 1.5-2m height on compost bed or in shed to ferment for several months with occasional turning.
		Pit storage (within a month)	Liquid system	Stored in the storage tank (Slurry store etc.) within a month and utilize in agriculture by spreading to farm field or other way after storage.
		Pit storage (over a month)	Liquid system	Stored in the storage tank (Slurry store etc.) for over a month and utilize in agriculture by spreading to farm field or other way after storage.
		Incineration	Burned for fuel or as waste	For amount reduction, disposal, or use as an energy source (e.g. chicken manure boiler).
		Methane fermentation	Digesters	Slurry livestock manure is fermented under anaerobic conditions. Generated methane gas is used as an energy source.
		Public sewage	—	Released into public sewage without purification or aeration management. Emissions are included in the Waste sector.
		Industrial waste treatment	Other	Disposed as industrial waste.
		Pasture/Range/Paddock	Pasture, range and paddock	Livestock are fed on a land with vegetation to eat. N <sub>2</sub> O Emissions are reported in the 'Urine and dung deposited by grazing animals (3.D.a.3.)'.
Other	Other	Treated with the method not mentioned above.		

Classification in Japan		Classification in CRF (MMS)	Description of manure treatment method
State of Manure	Manure treatment method		
Separated Urine	Liquid composting	Composting	Treated in an aeration storage tank.
	Open composting (aeration treatment)	Composting	Aerated in open systems.
	Closed composting (aeration treatment)	Composting	Aerated in closed systems.
	Purification	Other	Separate pollutants using aerobic microorganisms, such as activated sludge.
	Purification - discharge	Other	Discharged after removing substance causing water pollution by microorganisms in activated sludge.
	Purification - agricultural use	Other	Utilized in agriculture by spreading to farm field or other way after removing substance causing water pollution by microorganisms in activated sludge.
	Pit storage	Liquid systems	Stored in a storage tank.
	Pit storage (within a month)	Liquid system	Same as above (Pit storage (within a month) for feces)
	Pit storage (over a month)	Liquid system	Same as above (Pit storage (over a month) for feces)
	Methane fermentation	Digesters	Same as above (Methane fermentation for feces).
	Public sewage	—	Same as above (Public sewage for feces).
	Industrial waste treatment	Other	Same as above (Industrial waste treatment for feces)
	Other	Other	Treated with the method not mentioned above.
	Mixed	Sun drying	Solid storage and dry lot
Thermal drying		Other	Same as above (Thermal drying)
Carbonization		Other	Same as above (Carbonization)
Liquid composting		Composting	Treated in an aeration storage tank.
Open composting		Composting	Same as above (Open composting for feces)
Closed composting		Composting	Same as above (Closed composting for feces)
Piling		Composting	Same as above (Piling)
Purification		Other	Same as above (Purification)
Purification - discharge		Other	Same as above (Purification - discharge)
Purification - agricultural use		Other	Same as above (Purification - agricultural use)
Pit storage		Liquid systems	Stored in a storage tank (e.g. slurry storage).
Pit storage (within a month)		Liquid system	Same as above (Pit storage (within a month))
Pit storage (over a month)		Liquid system	Same as above (Pit storage (over a month))
Methane fermentation		Digesters	Same as above (Methane fermentation).
Public sewage		—	Same as above (Public sewage).
Industrial waste treatment		Other	Same as above (Industrial waste treatment)
Pasture/Range/Paddock		Pasture, range and paddock	Same as above (Pasture/Range and paddock).
Other	Other	Treated with method not mentioned above.	



### c) *Uncertainties and Time-series Consistency*

#### ● *Uncertainties*

For the uncertainties of the CH<sub>4</sub> emission factors, Tier 2 values (20%) described in the *2006 IPCC Guidelines* were applied. For N<sub>2</sub>O emission factors, uncertainty was calculated by synthesis of default uncertainties of each parameter described in the *2006 IPCC Guidelines* uncertainty.

For the uncertainties of the activity data, 1% (the standard error for swine given in the *Livestock Statistics*) was applied to swine, and 9% (the standard error for broiler given in the *Livestock Statistics*) was applied to poultry. For cattle, 1% is adopted, same as “Enteric Fermentation, Cattle”.

As a result, the uncertainties of the emissions for dairy cattle, non-dairy cattle and swine were determined to be -20% to +20% for CH<sub>4</sub> and -71% to +112% for N<sub>2</sub>O, and emissions for poultry were determined to be -22% to +22% for CH<sub>4</sub> and -72% to +112% for N<sub>2</sub>O.

#### ● *Time-series Consistency*

Emission factors were used consistently from FY1990 onward by the method. Activity data were calculated consistently from FY1990 onward from the data in the *Livestock Statistics*.

### d) *Category-specific QA/QC and Verification*

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

Country-specific emission factors are used for CH<sub>4</sub> and N<sub>2</sub>O emission factors for grazing cattle, and these values are lower than the value calculated from the default data described in the *2006 IPCC Guidelines*. It is guessed that andosol and brown forest soil, which drainage is well, are dominant for grazing land in Japan. Therefore, CH<sub>4</sub> and N<sub>2</sub>O emission factors are low in Japan.

Country-specific emission factors are used for CH<sub>4</sub> and N<sub>2</sub>O emission factors by pit storage for dairy cattle, and these values are lower than the value calculated from the default data described in *2006 IPCC Guidelines*. For CH<sub>4</sub>, the reasons are assumed that pit storage period of slurry in Japan is comparatively shorter than other countries and the short period stored slurry is spread to agriculture and grazed meadow soil before further activation of CH<sub>4</sub> emissions. For N<sub>2</sub>O, the inferred reason of lower value of the emission factor is the same as CH<sub>4</sub>, the Japanese shorter period pit storage doesn't reach to occurrence of scum which is guessed as N<sub>2</sub>O source.

In the inventory review, the ERT pointed out that Japan's IEFs for dairy cattle are very higher than other Annex I Parties. This reason is that “Piling” is major manure management system in Japan, and EF for “Piling” is very high. Moisture for dairy cattle feces is high, and they easily make anaerobic condition. It is considered to be the reason for high CH<sub>4</sub> emission factor of piling.

For emission factors by piling for poultry, hen's EF is higher than broiler's one. For CH<sub>4</sub>, the reason is guessed to be that moisture content of manure for hen is higher than for broiler. Country-specific emission factors of N<sub>2</sub>O by piling for poultry is lower than the default emission factors. The reason is guessed to be that the default emission factors include not only poultry but also other animals (such as cattle and swine) (Nitrification is less likely to occur in poultry manure than cattle or swine manure).

Country-specific emission factors of N<sub>2</sub>O for sun drying of poultry is lower than the default emission

factors. The reason is guessed to be that the default emission factors include not only poultry but also other animals, which are the same reason for emission factors by piling for poultry.

#### **e) Category-specific Recalculations**

Since the population of dairy cattle and swine for FY2019 was revised, the emissions from dairy cattle and swine for FY2019 were recalculated. Since the Bo and MCF for composting and Liquid system calculating for CH<sub>4</sub> emission factors were revised to the *2019 Refinement*, CH<sub>4</sub> emissions for the whole time-series were recalculated. Since the calculation methods for amount of excretion for poultry, and nitrogen content in excretion for poultry have been revised, the emissions from hen and broiler for the whole time-series were recalculated. See Chapter 10 for impact on trend.

#### **f) Category-specific Planned Improvements**

As research on actual emissions and information collection for emission reduction method has been continuously conducted by the organizations and agencies concerned, a review of emission factors and parameters will be implemented when the new data are obtained.

### **5.3.2. Buffalo, Sheep, Goats, Horses, Rabbits and Mink (3.B.2., 3.B.4.-)**

#### **a) Category Description**

This section provides the estimation methods for CH<sub>4</sub> and N<sub>2</sub>O emissions for manure management from buffalo, sheep, goats, horses, rabbits and mink.

#### **b) Methodological Issues**

##### ● **Estimation Method**

CH<sub>4</sub> and N<sub>2</sub>O emissions were calculated by using the Tier 1 method in accordance with the decision tree of the *2006 IPCC Guidelines* (Vol. 4, Page 10.36, Fig 10.3 and Page 10.55, Fig. 10.4).

$$E_{CH_4} = EF_{CH_4} \times P$$

$$E_{N_2O} = \sum (EF_{N_2O-n} \times P \times Nex \times MS_n)$$

$E_{CH_4}$  : CH<sub>4</sub> emissions associated with manure management [kg-CH<sub>4</sub>/yr]

$E_{N_2O}$  : N<sub>2</sub>O emissions associated with manure management [kg-N<sub>2</sub>O/yr]

$EF_{CH_4}$  : CH<sub>4</sub> emission factor [kg-CH<sub>4</sub>/head/yr]

$EF_{N_2O-n}$  : N<sub>2</sub>O emission factor of manure management  $n$  [kg-N<sub>2</sub>O/kg-N]

$P$  : Population of each livestock [head]

$Nex$  : Nitrogen content in manure [kg-N/head/yr]

$MS_n$  : Percentage of manure management system  $n$  [%]

##### ● **Emission Factors**

For the emission factors for CH<sub>4</sub>, the default values for temperate zones in industrialized nations, given in the *2006 IPCC Guidelines* were used. For buffalo, the default value given for the temperate zone in Asia was used (Table 5-36).

For the emission factors for N<sub>2</sub>O, the default values given in the *2006 IPCC Guidelines* were used (Table 5-37).

Table 5-36 CH<sub>4</sub> emission factors for sheep, goats, horses, rabbits and mink

Livestock species	CH <sub>4</sub> Emission factors [kg-CH <sub>4</sub> /head/yr]	Reference
Sheep	0.28	2006 IPCC Guidelines, Vol. 4, p. 10.40, Table 10.15
Goats	0.20	
Horses	2.34	
Buffalo	2	2006 IPCC Guidelines, Vol. 4, p. 10.39, Table 10.14
Rabbits	0.08	2006 IPCC Guidelines, Vol. 4, p. 10.41, Table 10.16
Mink	0.68	

Table 5-37 N<sub>2</sub>O Emission factors for buffalo, sheep, goats, horses, rabbits and mink

Manure management system	N <sub>2</sub> O Emission factors [% : kg-N <sub>2</sub> O-N/kg-N]
Dry lot	2.0%
Pasture/Range/Paddock (buffalo)	2.0%
Pasture/Range/Paddock (sheep, goats, horses)	1.0%
Daily spread	0%
Burned for fuel	0%

Reference: Dry lot, Daily Spread: 2006 IPCC Guidelines Vol.4, page 10.62, Table 10.21,  
Pasture Range and Paddock: 2006 IPCC Guidelines Vol.4, page 11.11, Table 11.1

### ● Activity Data

For livestock population for sheep, goats, horses and buffalo, same data described in ‘3.A. Enteric Fermentation’ are used (See Table 5-12). For rabbits and mink, population data in the *Statistical Document for small animals and laboratory animals* by MAFF are used (See Table 5-38 below).

For N<sub>2</sub>O, in order to determine the total nitrogen amount for each livestock, first, it was calculated by multiplying the population of each type of animal by the nitrogen content of manure per head of animal (or by the nitrogen amount in manure per weight and livestock weight). Then, the amount of nitrogen per manure management category was calculated by multiplying the total nitrogen by the percentage of each manure management system (Table 5-39). For the percentage of manure management system for buffalo, the default values given in the 2006 IPCC Guidelines were used (classification is “Asia”) (Table 5-40).

For rabbits and mink, percentage of manure management system usage ( $MS_n$ ) is considered by expert judgment that all manure are managed by “Dry lot” because default values are not described in the 2006 IPCC Guidelines. For the percentage of manure management system usage ( $MS_n$ ) for sheep, goats and horses, the 2006 IPCC Guidelines (Vol.4, p.10.61) described that “Manure from other animal categories is typically managed in pasture and grazing operations”. Therefore, it is assumed that their livestock manures are managed by grazing system.

Table 5-38 Livestock population for rabbits and mink [1000 heads]

Livestock Species	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Rabbit	15	16	21	19	18	18	18	18	18	18	18	18	18	18	18
Mink	155	11	6	1	1	1	1	1	1	1	1	1	1	1	1

Reference: *Statistical Document for small animals and laboratory animals* (MAFF)

Table 5-39 Body weight and N excretion rate for buffalo, sheep, goats, horses, rabbits and mink ( $N_{ex}$ )

Livestock species	Body weight [kg]	N excretion rate per weight [kg-N/1000kg-body weight/day]	N excretion rate [kg-N/head/yr]
Buffalo	380	0.32	(44.4)
Sheep	48.5	1.17	(20.7)
Goats	38.5	1.37	(19.3)
Horses	377	0.46	(63.3)
Rabbits	-	-	8.10
Mink	-	-	4.59

Note: Values in parentheses are calculated values.

Reference: 2006 IPCC Guidelines Vol.4, page 10.79, Table 10A-6, page 10.82, Table 10A-9, page 10.59, Table 10.19

Table 5-40 Percentage of manure management system for buffalo ( $MS_n$ )

Manure management system	Percentage
Lagoons	0%
Liquid /Slurry	0%
Solid storage	0%
Dry lot	41%
Pasture/Range/Paddock	50%
Daily spread	4%
Digester	0%
Burned for fuel	5%
Other	0%

Reference: 2006 IPCC Guidelines, Vol.4, page 10.79, Table 10A-6

### c) *Uncertainties and Time-series Consistency*

#### ● *Uncertainties*

An uncertainty assessment was conducted for individual livestock categories. With respect to the uncertainties for emission factors for CH<sub>4</sub>, Tier 1 default value (30%) described in the 2006 IPCC Guidelines was applied. For N<sub>2</sub>O, the uncertainty was calculated by synthesis of default values of each parameter described in the 2006 IPCC Guidelines. For the activity data, uncertainty was substituted by the value of broiler (9%) described in the *Livestock Statistics*. As a result, the uncertainties of the emissions were determined to be -31% to +31% for CH<sub>4</sub>, and -72% to +112% for N<sub>2</sub>O for each livestock.

#### ● *Time-series Consistency*

For emission factors, same values were used consistently for all the years. For Activity data were calculated consistently for all the years from the data in the *Statistical Document of Livestock Breeding*, the *Statistical Document of Horse*, the *Survey Result of Feeding Livestock and Poultry* by Okinawa and the *Status Report regarding Health Management for Livestock Feeding*.

### d) *Category-specific QA/QC and Verification*

General inventory QC procedures have been conducted in accordance with the 2006 IPCC Guidelines. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

### e) *Category-specific Recalculations*

Since the population of sheep, goats and horses for FY2018 were revised, the emissions for FY2018 were recalculated. See Chapter 10 for impact on trend.

### f) *Category-specific Planned Improvements*

There are no improvement plans.

### 5.3.3. Other Livestock (3.B.4.-)

Deer, reindeer, fox, and other poultries (duck, turkey, etc.), which are other livestock than those listed above, are reported in the *Statistical Document for Small Animals and Laboratory Animals* (MAFF). However, their population size is small, and each emission was lower than 3000t-CO<sub>2</sub> equivalent, which is the threshold to estimate in this GHG inventory decided by the Committee for GHG Emissions Estimation Methods. Therefore, it was not reported (See Annex 5).

### 5.3.4. Indirect N<sub>2</sub>O emissions (3.B.5.)

#### 5.3.4.1. Atmospheric Deposition (3.B.5.-)

##### a) Category Description

This section provides the estimation methods for N<sub>2</sub>O indirect emissions caused by atmospheric deposition of nitrogen volatilized as NH<sub>3</sub> and NO<sub>x</sub> from livestock manure management.

##### b) Methodological Issues

###### ● Estimation Method

N<sub>2</sub>O emissions have been calculated by Tier 2 method in accordance with decision tree of the 2019 Refinement (Vol.4, Page 10.79, Fig. 10.4).

$$E = N_{\text{Volatilization-MMS}} \times EF \times 44 / 28$$

$E$	: N <sub>2</sub> O emissions by atmospheric deposition in the process of livestock manure management [kg-N <sub>2</sub> O/yr]
$N_{\text{Volatilization-MMS}}$	: Nitrogen amount volatilized as NH <sub>3</sub> and NO <sub>x</sub> in the process of livestock manure management [kg (NH <sub>3</sub> -N+NO <sub>x</sub> -N) /yr]
$EF$	: Emission factor [kg-N <sub>2</sub> O-N/kg (NH <sub>3</sub> -N+NO <sub>x</sub> -N)]

###### ● Emission Factors

0.014 [kg-N<sub>2</sub>O-N/kg-NH<sub>3</sub>-N & NO<sub>x</sub>-N deposited] (default value, the 2019 Refinement, Vol.4, Page 11.26, Table 11.3, Wet climate).

###### ● Activity Data

For cattle, swine, and poultry (hen and broiler), as described in the following equation, amount of nitrogen that volatilized as ammonia and nitrogen oxides from livestock manure management ( $N_{\text{Volatilization-MMS}}$ ) is calculated using the nitrogen amount included in each treatment method ( $A_{N2O-i}$ ) which calculated in the above 5.3.1., and volatilization rate as NH<sub>3</sub> and NO<sub>x</sub> from manure in each livestock barn ( $Frac_{GASM1i}$ ) and in each process of treatment ( $Frac_{GASM2i}$ ). The volatilization rate as NH<sub>3</sub> and NO<sub>x</sub> from manure are estimated from data described in Hojito et al. (2003) (See Table 5-41). For “Purification”, it is considered that there are not volatilized in treatment process. Indirect N<sub>2</sub>O emissions from grazing animal are reported in 3.D.b.1.

$$N_{\text{Volatilization-MMS}} = \sum \{ A_{N2O-i} \times Frac_{GASM1i} + (A_{N2O-i} - A_{N2O-i} \times Frac_{GASM1i}) \times Frac_{GASM2i} \}$$

$N_{\text{Volatilization-MMS}}$	: Nitrogen amount volatilized as NH <sub>3</sub> and NO <sub>x</sub> in the process of livestock manure management [kg (NH <sub>3</sub> -N+NO <sub>x</sub> -N)/yr]
$A_{N2O-i}$	: Nitrogen amount in livestock manure by treatment method $i$ [kg-N]
$Frac_{GASM1i}$	: Volatilization rate as NH <sub>3</sub> and NO <sub>x</sub> in livestock barn by treatment method $i$ [kg-NH <sub>3</sub> -N + NO <sub>x</sub> -N/kg-N]
$Frac_{GASM2i}$	: Volatilization rate as NH <sub>3</sub> and NO <sub>x</sub> in process of treatment by treatment method $i$ [kg-NH <sub>3</sub> -N + NO <sub>x</sub> -N/kg-N]

Table 5-41 Volatilization rate as NH<sub>3</sub> and NO<sub>x</sub> from manure (in livestock barn and in process of treatment)

Livestock species	Treatment method		Volatilization rate in livestock barn	Volatilization rate in process of treatment
			( <i>FracGASM1</i> )	( <i>FracGASM2</i> )
Dairy cattle	Feces	Other than Composting	10.3%	13.7%
		Composting	10.3%	1.9%
	Urine	Other than Purification	10.3%	11.0%
		Purification	10.3%	0%
	Mixed	Other than Purification, Pit storage, Methane fermentation	4.5%	13.7%
		Purification	10.3%	0%
Pit storage, Methane fermentation		10.3%	10.8%	
Non-dairy cattle	Feces	Other than Composting	6.38%	13.7%
		Composting	6.38%	1.9%
	Urine	Other than Purification	6.38%	11%
		Purification	6.38%	0%
	Mixed	Other than Purification, Pit storage, Methane fermentation	6.38%	13.7%
		Purification	6.38%	0%
Pit storage, Methane fermentation		6.38%	10.8%	
Swine	Feces	All management	14.7%	19.7%
		Other than Purification	14.7%	27.0%
	Urine	Purification	14.7%	0%
		Other than Purification, Pit storage, Methane fermentation	15.8%	24.2%
	Mixed	Purification	14.7%	0%
		Pit storage, Methane fermentation	14.7%	25.0%
All management		8.4%	51.5%	
Hen and Broiler	Feces	All management	8.4%	51.5%

Reference: Hojito et al. (2003)

For buffalo, rabbits, and mink, nitrogen amount volatilized as NH<sub>3</sub> and NO<sub>x</sub> from manure were estimated by multiplying total nitrogen amount of manure of each livestock by default volatilization rate described in the 2006 IPCC Guidelines (Vol.4, Page10.65, Table10.22, Other-Solid storage: 12%).

$$N_{\text{Volatilization-MMS}} = (P \times N_{\text{ex}} \times MS_n) \times \text{FracGASM}$$

$N_{\text{Volatilization-MMS}}$  : Nitrogen amount volatilized as NH<sub>3</sub> and NO<sub>x</sub> in the process of livestock manure management [kg (NH<sub>3</sub>-N+NO<sub>x</sub>-N)/yr]

$P$  : Population of each livestock [head]

$N_{\text{ex}}$  : Nitrogen content in manure per head [kg-N/head/yr]

$MS_n$  : Percentage of manure management  $n$  [%]

$\text{FracGASM}$  : Volatilization rate as NH<sub>3</sub> and NO<sub>x</sub> in process of treatment for management system [%]

Table 5-42 Nitrogen amount volatilized as NH<sub>3</sub> and NO<sub>x</sub> in the process of livestock manure management [kt (NH<sub>3</sub>-N+NO<sub>x</sub>-N)/yr]

Livestock Species	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Dairy cattle	26.6	26.1	24.6	23.4	20.5	20.5	20.2	19.7	19.5	19.6	19.2	19.3	19.3	19.7	19.8
Non-dairy cattle	22.3	23.0	23.0	22.5	22.5	22.2	21.5	20.8	20.2	20.2	20.3	20.4	20.2	20.5	20.8
Swine	53.1	46.1	43.5	39.2	37.3	37.2	36.9	35.6	34.8	34.1	33.9	34.6	34.4	34.8	34.9
Poultry (Hen, Broiler)	134.0	124.4	111.5	99.7	98.1	97.5	94.4	90.4	89.4	89.7	91.0	93.6	92.5	91.3	91.7
Other livestock (Buffalo, Mink, Rabbit)	0.10	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Total	236.1	219.5	202.7	184.8	178.4	177.4	173.0	166.5	163.8	163.6	164.4	167.9	166.4	166.4	167.2

### c) *Uncertainties and Time-series Consistency*

#### ● *Uncertainties*

Uncertainty (-106% to +447%) described in “Agricultural Soils (Atmospheric Deposition)” below was applied.

#### ● *Time-series Consistency*

For emission factors, consistent values (default values) were used in all time-series. For activity data, constant value for volatilized factor and constant estimation method for manure amount calculated in 5.3.1. were used.

### d) *Category-specific QA/QC and Verification*

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

### e) *Category-specific Recalculations*

Since the population of dairy cattle and swine for FY2019 was revised, the emissions from dairy cattle and swine for FY2019 were recalculated. Since the calculation methods of nitrogen content in excretion for poultry have been revised, the emissions from hen and broiler for the whole time-series were recalculated. Since the emission factor for atmospheric deposition was revised, the emissions for the whole time-series were recalculated. See Chapter 10 for impact on trend.

### f) *Category-specific Planned Improvements*

Refer to the section” 5.3.1. Cattle, Swine and Poultry (Hen and Broiler)”.

## 5.3.4.2. Nitrogen Leaching and Run-off (3.B.5.-)

In Japan, under the "Act on the Appropriate Treatment and Promotion of Utilization of Livestock Manure", taking some measures to prevent flowing wastewater out of manure management, such as introducing concrete-clad floor, or using waterproof sheet, is required; so, the possibility of nitrogen leaching and run-off to subsurface water is very low. Therefore, this source is reported as “NO”.

## 5.4. Rice Cultivation (3.C.)

CH<sub>4</sub> is generated under anaerobic conditions by microbes’ activity. Therefore, paddy fields provide favorable conditions for CH<sub>4</sub> generation. In Japan, all paddy fields are irrigated, and intermittently and continuously flooded paddy fields are targeted in this category. In Japan, rice cultivation is practiced mainly on intermittently flooded paddy field.

CH<sub>4</sub> emissions from rice cultivation in FY2020 are 12,004 kt-CO<sub>2</sub> eq., comprising 1.0% of total emissions (excluding LULUCF). The value represents a decrease by 1.0% from FY1990.

Table 5-43 CH<sub>4</sub> emissions from rice cultivation (3.C.)

Gas	Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
CH <sub>4</sub>	3.C.1.- Continuously flooded	kt-CH <sub>4</sub>	68.5	74.9	69.1	67.6	68.3	66.1	65.0	67.6	67.8	67.0	67.6	67.0	66.7	66.1	66.2
	3.C.1.- Intermittently flooded		416.6	448.8	418.0	421.1	419.1	399.4	395.5	415.5	416.3	411.4	418.4	416.7	414.9	412.7	414.0
	Total	kt-CH <sub>4</sub>	485.2	523.7	487.0	488.6	487.4	465.4	460.4	483.1	484.1	478.4	486.0	483.7	481.6	478.8	480.2
		kt-CO <sub>2</sub> eq.	12,129	13,092	12,175	12,216	12,186	11,635	11,511	12,078	12,101	11,961	12,149	12,093	12,039	11,970	12,004

### 5.4.1. Irrigated (Intermittently Flooded (Single Aeration) and Continuously Flooded) (3.C.1.)

#### a) Category Description

This section provides the estimation methods for CH<sub>4</sub> emissions from intermittently flooded and continuously flooded rice cultivation.

#### ● Water management regime in Japanese paddy fields

The general practice of mid-season drainage and subsequent intermittent flooding by paddy farmers in Japan is different in nature from the intermittently flooded paddy field (multi aeration) concept in the 2006 IPCC Guidelines. Therefore, Japan reports its practice as “Intermittent flooding (Single aeration)” in the CRF. The diagram below presents the outline.

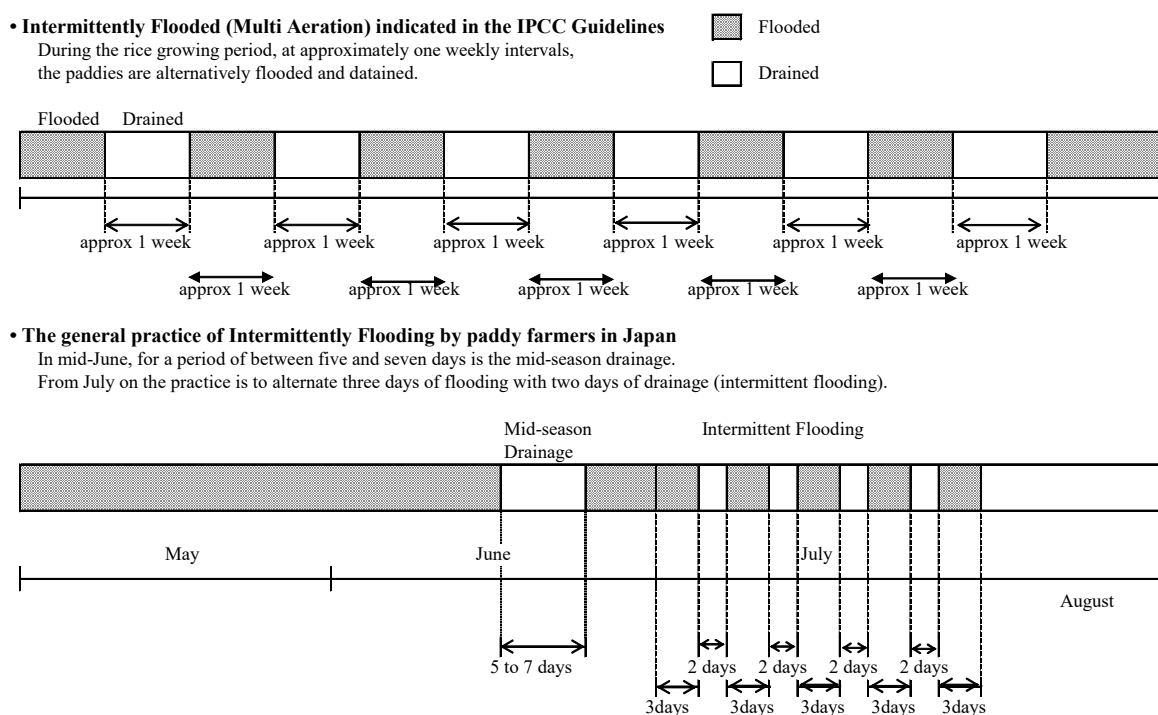


Figure 5-4 Comparison of water management regime in Japan and intermittent flooding (multi aeration) indicated in the 2006 IPCC Guidelines

#### b) Methodological Issues

#### ● Estimation Method

Based on the calculation method in the 2006 IPCC Guidelines, the emissions were estimated using emission factors calculated by the regression formula of CH<sub>4</sub> emission flux estimated by DeNitrification-DeComposition-Rice model (DNDC-Rice model, Fumoto et al. (2010)), which is the mathematical model to estimate change of CH<sub>4</sub> emissions with methods of organic matter application and/or water regime on paddy field, and the following formula established on the basis of the model. The DNDC-Rice model, the improved model, is based on the DNDC model and has developed in Japan so as to estimate CH<sub>4</sub> emissions from paddy field in Japan. Figure 5-5 is a conceptual scheme of the DNDC-Rice model.



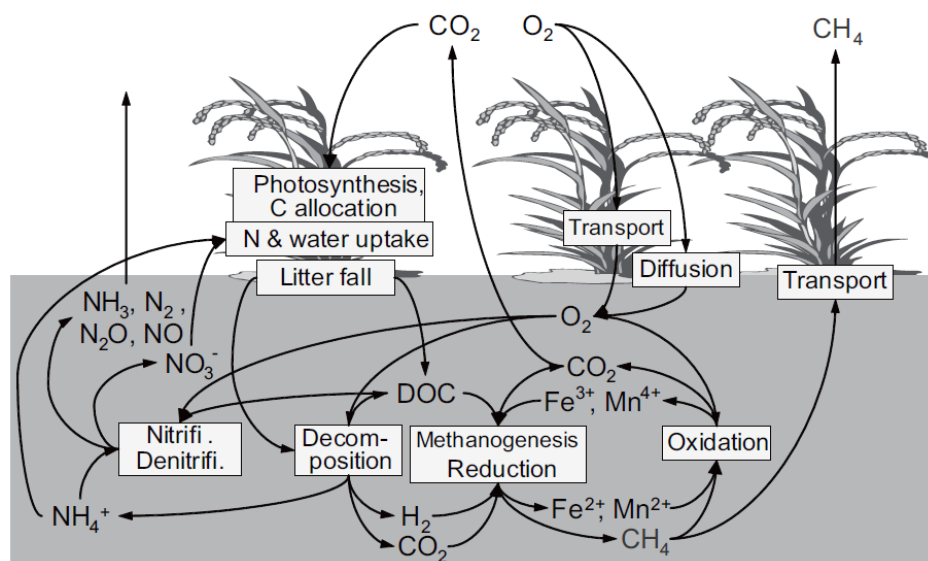


Figure 5-5 Conceptual scheme of the DNDC-Rice model

Reference: Fumoto et al. (2010)

Tier3 method (DNDC-Rice model) was used to establish emission factor, and modified Tier2 method was used to estimate emissions.

Estimation method used in this section was developed through discussion in the Committee for Greenhouse Gas Emissions Estimation Methods on the basis of a paper of Katayanagi et al. (2016), Katayanagi et al. (2017) and relevant paper.

$$E = \sum_{i,j,k,l} \{ (A_i \times f_{Dij} \times f_{W_{i,k}} \times f_{Ol}) \times EF_{i,j,k,l} \} \times 16 / 12$$

$$EF = aX + b$$

- $E$  : CH<sub>4</sub> emissions from paddy field [kgCH<sub>4</sub>/yr]  
 $i$  : Region (7 regions in Japan)  
 $j$  : Type of drainage (Poorly drained, one day drained, 4 hours drained)  
 $k$  : Type of water regime (Intermittently flooded, continuously flooded)  
 $l$  : Type of organic matter application (rice straw, compost, non-amendment)  
 $A$  : Crop area of rice paddy field by region [ha]  
 $f_D$  : Proportion of drainage  
 $f_W$  : Proportion of water regime  
 $f_O$  : Proportion of organic matter application  
 $EF$  : EFs by region, drainage, water regime, organic matter application [kgCH<sub>4</sub>-C/ha/yr]  
 $X$  : Amount of organic matter [t-C/ha/yr]  
 $a$  : Slope (from the regression formula for CH<sub>4</sub> emissions calculated by the DNDC-Rice model and amount of organic matter)  
 $b$  : Intercept (from the regression formula for CH<sub>4</sub> emissions calculated by the DNDC-Rice model and amount of organic matter)

### ● Emission Factors

The DNDC-Rice model was used to calculate the emission factor.

EFs were established on the basis of the information on nationwide 986 points of paddy field. The input data are soil (soil organic carbon content, pH, clay content, dry density, etc.), field drainage (maximum

drainage rate), meteorological data (temperature, precipitation), and field management information (the day of transplantation, harvest date, plowing date, tillage method, fertilization date, fertilizer amount, organic matter application date, amount of organic matter application, organic C/N ratio, flooded date, drained date). The following are input data and references.

- Soil physical and chemical properties: data in 986 points described in the *Basic Survey of Soil Environment* (MAFF), which includes all data needed to be input in the DNDC-Rice model
- Field drainage: Maximum drainage rate of survey sites were set as 15 mm day<sup>-1</sup>, 10 mm day<sup>-1</sup> and 5 mm day<sup>-1</sup> based on the data provided in “Flooded Situation” (4 hours drained, one day drained, poor drainage) in the *Fourth Basic Survey on Infrastructure Development of Land Use* (MAFF)
- Meteorological data: Daily lowest temperature, daily highest temperature, and precipitation of the nearest AMeDAS point from each survey site were used.
- Field management information: data set created by Hayano et al. (2013) which were divided the whole Japan to 136 regions in accordance to the primary subdivision area by Japan Meteorological Agency and included cultivated history on the basis of the data published by Japan Agricultural Cooperatives or similar organization in each region were used.
- Amount of organic matter application: By using the method described by Yagasaki and Shirato (2014), application amount of compost and rice straw plowed into soil by each prefecture in 1981 to 2019 were estimated. In other words, the amount of rice straw plowed into soil were estimated by multiplying rice straw yield estimated from the yield of paddy rice in normal years by the percentage plowed into the soil, then, by dividing the value by the rice cropping area. For amount of compost application, the average application amount per 10a in Production Cost of Rice in the *Statistics on Farm Management* (MAFF) is used.

Using the DNDC-Rice model and the above input data, CH<sub>4</sub> flux of each 986 points from 1981 to 2010 (30 years) were estimated by total 8 scenarios (water management 2 scenarios (intermittently flooded and continuously flooded) and organic matter applied 4 scenarios (straw and compost<sup>1</sup>, rice straw only, compost only, non-organic matter). Taking into account statistical significant difference of their results, CH<sub>4</sub> flux were sorted out by seven regions, drainage (3 levels), water regime, and organic matter application, and estimated averages of each year by each classification. In addition, the regression equation (linear function) to predict CH<sub>4</sub> flux (mean values for each year of each category) were determined by amount of organic matter application. Intercept “b” of the regression equation were fixed to the CH<sub>4</sub> emissions flux estimated non-organic application scenario.

Total amount of organic matter application by prefecture which was estimated by the method described in Yagasaki and Shirato (2014) were aggregated to region level. In addition, to induce amount of organic matter application by region and application type ( $X$ ) which are used in estimation for the inventory, their data of total amount of organic matter by region and proportion of organic matter management (Table 5-49) were used. The proportion of organic matter management is based on the survey result of *Basic Survey of Soil Environment, Survey of Greenhouse Gas Emissions from Soils and Soil Carbon*

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1 The application scenario “straw and compost” was constructed in the model. However, since proportion of organic matter management to input both straw and compost in Japan ( $f_o$ ) is not available, its scenario is not used for inventory emission estimation.

Sequestration, The Project of Basic Survey on Greenhouse Gas Emission Estimation from Agricultural Land Soil, and The Project of Basic Survey for Carbon Stock on Agricultural Land Soil. Amount of organic matter application in each input segment by region and the emission factor of each segment calculated these input, and they are shown in Table 5-44, and Table 5-45 below, respectively.

Table 5-44 Amount of organic matter application by region and type (X) [t-C/ha/yr]

Item		1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Rice straw	Hokkaido	1.73	1.74	1.92	2.03	2.12	2.11	1.95	1.96	1.98	2.06	2.09	2.09	2.10	2.07	2.10
	Tohoku	1.49	1.73	2.02	2.11	2.07	2.01	1.88	1.95	1.96	2.05	2.11	2.12	2.13	2.10	2.14
	Hokuriku	2.69	2.62	2.74	2.82	2.75	2.69	2.46	2.45	2.43	2.49	2.53	2.54	2.54	2.51	2.54
	Kanto	1.32	1.49	1.77	1.96	1.96	1.90	1.76	1.80	1.79	1.85	1.88	1.89	1.89	1.87	1.89
	Tokai and Kinki	2.01	1.98	2.22	2.33	2.23	2.14	1.96	2.01	2.04	2.13	2.23	2.24	2.24	2.22	2.24
	Chugoku and Shikoku	1.74	1.83	2.10	2.13	2.15	2.09	1.92	1.93	1.91	1.98	2.01	2.02	2.02	2.00	2.02
	Kyusyu and Okinawa	1.17	1.14	1.26	1.36	1.40	1.29	1.18	1.24	1.25	1.30	1.32	1.32	1.32	1.31	1.32
Compost	Hokkaido	1.69	1.86	2.10	2.05	2.18	1.90	1.96	1.87	1.98	1.88	2.00	1.93	1.85	2.07	1.91
	Tohoku	1.69	1.86	2.10	2.05	2.18	1.90	1.96	1.87	1.98	1.88	2.00	1.93	1.85	2.07	1.91
	Hokuriku	1.69	1.86	2.10	2.05	2.18	1.90	1.96	1.87	1.98	1.88	2.00	1.93	1.85	2.07	1.91
	Kanto	1.69	1.86	2.10	2.05	2.18	1.90	1.96	1.87	1.98	1.88	2.00	1.93	1.85	2.07	1.91
	Tokai and Kinki	1.69	1.86	2.10	2.05	2.18	1.90	1.96	1.87	1.98	1.88	2.00	1.93	1.85	2.07	1.91
	Chugoku and Shikoku	1.69	1.86	2.10	2.05	2.18	1.90	1.96	1.87	1.98	1.88	2.00	1.93	1.85	2.07	1.91
	Kyusyu and Okinawa	1.69	1.86	2.10	2.05	2.18	1.90	1.96	1.87	1.98	1.88	2.00	1.93	1.85	2.07	1.91

Table 5-45 CH<sub>4</sub> emission factors in each segment [kg-CH<sub>4</sub>-C/ha/yr]

Item		1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
Continuously flooded	Rice straw	Hokkaido	585	588	636	665	690	687	646	647	652	676	682	682	684	677	686
		Tohoku	573	636	714	739	727	713	678	696	699	722	739	742	743	737	747
		Hokuriku	741	725	753	772	754	740	687	684	679	694	702	705	705	699	706
		Kanto	181	202	237	260	259	252	235	240	238	246	250	251	251	248	251
		Tokai and Kinki	436	429	477	499	478	462	426	435	441	459	479	482	482	477	482
		Chugoku and Shikoku	422	439	491	499	501	490	455	458	455	468	474	476	476	472	477
		Kyusyu and Okinawa	158	155	169	181	186	172	159	167	168	174	176	177	177	175	177
	Compost	Hokkaido	574	621	686	670	708	631	646	621	654	624	657	638	618	678	634
		Tohoku	627	673	736	721	758	683	698	673	705	676	708	689	670	729	686
		Hokuriku	507	548	603	590	622	556	569	548	576	550	579	562	545	596	559
		Kanto	226	248	277	270	287	252	259	248	263	249	264	255	246	273	254
		Tokai and Kinki	372	406	454	443	470	414	425	407	430	409	433	419	404	448	416
		Chugoku and Shikoku	411	445	492	481	508	453	464	446	469	448	471	457	443	486	455
		Kyusyu and Okinawa	221	242	271	264	281	247	254	243	257	244	258	250	241	268	248
Intermittently flooded	Rice straw	Hokkaido	585	588	636	665	690	687	646	647	652	676	682	682	684	677	686
		Tohoku	547	610	687	711	700	685	651	669	672	694	711	715	716	710	720
		Hokuriku	552	539	562	578	563	551	507	505	501	513	520	522	522	517	524
		Kanto	164	182	213	234	233	227	212	216	215	221	226	226	226	224	227
		Tokai and Kinki	352	346	386	405	388	374	344	352	357	371	388	391	391	386	391
		Chugoku and Shikoku	377	393	441	448	450	440	408	411	407	419	426	427	427	423	428
		Kyusyu and Okinawa	139	136	148	159	162	151	139	146	147	152	154	154	154	153	154
	Compost	Hokkaido	574	621	686	670	708	631	646	621	654	624	657	638	618	678	634
		Tohoku	600	646	709	694	730	656	670	646	678	649	681	662	643	701	659
		Hokuriku	359	392	438	427	454	399	410	393	416	395	418	404	390	433	402
		Kanto	204	223	250	243	259	227	234	223	237	225	238	230	222	246	229
		Tokai and Kinki	300	328	367	358	381	334	343	328	348	330	350	338	326	362	336
		Chugoku and Shikoku	367	399	442	432	457	405	416	399	421	401	423	410	397	437	408
		Kyusyu and Okinawa	192	210	235	229	243	214	220	210	223	211	224	216	209	232	215
No-amendment	Hokkaido	114	114	114	114	114	114	114	114	114	114	114	114	114	114	114	
	Tohoku	175	175	175	175	175	175	175	175	175	175	175	175	175	175	175	
	Hokuriku	113	113	113	113	113	113	113	113	113	113	113	113	113	113	113	
	Kanto	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	
	Tokai and Kinki	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	
	Chugoku and Shikoku	77	77	77	77	77	77	77	77	77	77	77	77	77	77	77	
	Kyusyu and Okinawa	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	

Table 5-45 CH<sub>4</sub> emission factors in each segment [kgCH<sub>4</sub>-C/ha/yr] (Continued)

Item		1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020			
One day drained field, Continuously flooded	Rice straw	Hokkaido	342	344	375	394	410	408	381	382	385	400	405	405	406	401	407		
		Tohoku	423	471	530	549	540	529	503	516	519	536	549	552	552	548	555		
		Hokuriku	556	543	566	581	566	555	512	510	506	517	525	526	526	521	528		
		Kanto	122	135	157	172	171	167	156	159	158	163	166	166	166	165	167		
		Tokai and Kinki	198	194	217	228	218	210	193	197	200	209	218	220	220	217	220		
		Chugoku and Shikoku	166	174	196	199	201	196	181	182	180	186	189	190	190	188	190		
		Kyusyu and Okinawa	131	129	141	151	155	144	132	139	140	145	147	147	147	146	147		
		Hokkaido	335	365	407	397	421	372	381	366	386	367	389	376	364	402	374		
		Tohoku	463	499	547	536	564	506	517	499	523	501	526	511	497	541	509		
		Hokuriku	366	399	444	433	459	406	416	399	422	401	424	411	397	438	408		
	Kanto	151	164	183	179	189	167	171	164	174	165	175	169	163	181	168			
	Tokai and Kinki	167	184	206	201	214	187	192	184	195	185	196	189	183	203	188			
	Chugoku and Shikoku	162	176	197	192	204	180	184	176	187	177	188	182	176	194	181			
	Kyusyu and Okinawa	185	202	227	221	235	206	212	203	215	204	216	209	202	224	208			
	Compost	Hokkaido	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39		
		Tohoku	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119		
		Hokuriku	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46		
		Kanto	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17		
		Tokai and Kinki	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6		
		Chugoku and Shikoku	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17		
		Kyusyu and Okinawa	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12		
		One day drained field, Intermittently flooded	Rice straw	Hokkaido	236	237	259	272	284	282	263	264	266	277	280	280	281	278	282
				Tohoku	297	333	378	392	385	377	357	367	369	382	392	394	394	391	396
				Hokuriku	403	393	410	421	410	402	371	369	366	375	380	381	381	378	382
	Kanto			90	100	116	127	126	123	115	117	117	120	122	123	123	121	123	
	Tokai and Kinki			89	87	98	103	98	95	87	89	90	94	98	99	99	98	99	
Chugoku and Shikoku	88			92	105	107	107	105	96	97	96	99	101	101	101	100	102		
Kyusyu and Okinawa	75			73	80	86	88	82	75	79	80	82	84	84	84	83	84		
Hokkaido	231			252	281	275	292	257	264	252	267	254	269	260	251	278	258		
Compost	Tohoku		328	354	390	382	403	360	368	354	372	356	374	363	353	386	362		
	Hokuriku		264	288	321	313	332	293	301	289	305	290	307	297	287	317	295		
	Kanto		111	121	135	131	139	123	126	121	128	122	129	125	120	133	124		
	Tokai and Kinki		75	83	93	90	96	84	87	83	88	83	88	85	82	92	85		
	Chugoku and Shikoku		86	94	105	103	109	96	98	94	100	95	100	97	94	104	96		
	Kyusyu and Okinawa		105	115	129	126	134	118	121	116	123	116	123	119	115	128	118		
	No-amendment		Hokkaido	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	
			Tohoku	71	71	71	71	71	71	71	71	71	71	71	71	71	71	71	
Hokuriku		31	31	31	31	31	31	31	31	31	31	31	31	31	31	31			
Kanto		15	15	15	15	15	15	15	15	15	15	15	15	15	15	15			
Tokai and Kinki		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2			
Chugoku and Shikoku		5	5	5	5	5	5	5	5	5	5	5	5	5	5	5			
Kyusyu and Okinawa		7	7	7	7	7	7	7	7	7	7	7	7	7	7	7			
4 hour drained field, Continuously flooded		Rice straw	Hokkaido	308	310	338	355	369	368	343	344	347	361	365	365	366	362	367	
	Tohoku		385	431	488	506	497	487	462	475	477	493	506	508	509	504	512		
	Hokuriku		529	516	538	553	539	528	487	485	481	492	499	501	501	496	502		
	Kanto		163	180	209	228	228	222	207	211	210	216	220	221	221	219	221		
	Tokai and Kinki		212	208	232	243	233	225	207	212	215	224	233	235	235	232	235		
	Chugoku and Shikoku		225	235	266	270	271	265	245	247	245	252	256	257	257	254	257		
	Kyusyu and Okinawa		157	154	169	181	185	172	158	166	167	173	176	176	176	174	176		
	Hokkaido		302	329	367	358	380	335	344	329	348	331	350	339	328	362	337		
	Tohoku		424	458	504	493	520	465	476	458	481	460	484	470	456	498	467		
	Hokuriku		348	379	422	412	437	386	396	380	401	382	403	390	378	417	388		
	Compost	Kanto	201	218	243	237	251	222	228	218	231	219	232	225	217	240	223		
		Tokai and Kinki	180	197	221	215	229	201	207	198	209	199	211	203	196	218	202		
		Chugoku and Shikoku	220	239	266	260	275	243	250	239	253	240	254	246	238	263	245		
		Kyusyu and Okinawa	222	243	272	265	282	247	254	243	258	244	259	250	242	269	249		
		No-amendment	Hokkaido	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	
			Tohoku	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97	
			Hokuriku	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	
			Kanto	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	
			Tokai and Kinki	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	
			Chugoku and Shikoku	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	
	Kyusyu and Okinawa		13	13	13	13	13	13	13	13	13	13	13	13	13	13	13		

Table 5-45 CH<sub>4</sub> emission factors in each segment [kgCH<sub>4</sub>-C/ha/yr] (Continued)

Item		1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
4 hour drained field, Intermittently flooded	Rice straw																
	Hokkaido	171	172	188	198	206	205	191	192	193	201	203	203	204	202	205	
	Tohoku	268	301	342	355	349	341	323	333	334	346	355	357	357	354	359	
	Hokuriku	356	347	362	372	362	355	327	326	323	331	335	336	336	333	337	
	Kanto	111	123	144	157	157	153	142	145	145	149	151	152	152	151	152	
	Tokai and Kinki	119	117	130	137	131	126	116	119	120	125	131	132	132	130	132	
	Chugoku and Shikoku	156	163	184	187	188	183	169	170	169	174	177	178	178	176	178	
	Kyusyu and Okinawa	93	91	100	107	109	101	93	98	99	102	104	104	104	103	104	
	Compost																
	Hokkaido	167	183	205	200	212	186	191	183	194	184	195	189	182	202	188	
	Tohoku	296	320	354	346	365	326	333	321	337	322	339	329	319	350	327	
	Hokuriku	232	253	282	276	293	258	264	253	268	255	269	261	252	279	259	
Kanto	138	150	167	163	173	153	157	150	159	151	160	154	149	165	154		
Tokai and Kinki	101	111	124	121	129	113	116	111	117	111	118	114	110	122	113		
Chugoku and Shikoku	152	165	184	180	191	168	173	165	175	166	176	170	164	182	169		
Kyusyu and Okinawa	131	144	161	157	167	147	151	144	153	145	154	148	143	159	147		
No-amendment																	
Hokkaido	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14		
Tohoku	59	59	59	59	59	59	59	59	59	59	59	59	59	59	59		
Hokuriku	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22		
Kanto	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16		
Tokai and Kinki	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6		
Chugoku and Shikoku	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17		
Kyusyu and Okinawa	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7		

### ● Activity Data

For area of paddy rice field by region (*A*), data described in the “Statistics of Cultivated and Planted Area” by MAFF were used. For drainage (*f<sub>D</sub>*), proportion of water regime (*f<sub>w</sub>*), proportion of organic matter (*f<sub>o</sub>*), survey data by MAFF etc. described in Table 5-46 to Table 5-49 were used respectively.

Table 5-46 Area of paddy fields by region (*A*) [kha]

Region	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Hokkaido	146	163	135	119	115	114	113	113	112	111	108	107	106	106	105
Tohoku	525	539	456	444	429	406	414	419	419	415	414	413	412	412	412
Hokuriku	258	260	221	218	213	213	213	215	216	214	213	212	213	213	212
Kanto	386	390	336	331	322	323	324	324	322	322	321	318	316	315	313
Tokai	117	116	95	91	88	88	88	87	86	85	85	84	84	83	83
Kinki	145	148	122	117	111	111	111	111	110	108	107	106	106	105	104
Chugoku and Shikoku	236	232	187	182	178	176	175	175	173	170	167	165	162	159	157
Kyusyu and Okinawa	246	251	207	206	202	202	203	203	201	199	196	195	193	192	190
Total	2,058	2,098	1,758	1,708	1,657	1,632	1,641	1,647	1,639	1,623	1,611	1,600	1,592	1,584	1,575

Note: Upon the estimation, Tokai and Kinki regions are aggregated as one region

Reference: Statistics of Cultivated and Planted Area (MAFF)

Table 5-47 Proportion of drainage (*f<sub>D</sub>*)

Region	4 hours drained	One day drained	Poorly drained
Hokkaido	51%	42%	7%
Tohoku	63%	31%	6%
Hokuriku	69%	26%	4%
Kanto	59%	32%	9%
Tokai and Kinki	69%	23%	8%
Chugoku and Shikoku	65%	27%	8%
Kyusyu and Okinawa	74%	21%	5%

Reference: Forth basic survey on infrastructure development of land use

Table 5-48 Proportion of water regime (*f<sub>w</sub>*)

Region	Continuously flooded	Intermittently flooded
Hokkaido	48%	52%
Tohoku	5%	95%
Hokuriku	4%	96%
Kanto	14%	86%
Tokai and Kinki	11%	89%
Chugoku and Shikoku	8%	92%
Kyusyu and Okinawa	7%	93%

Reference: Survey of Greenhouse Gas Emissions from Soils and Soil Carbon Sequestration

Table 5-49 Proportion of organic matter management in Japan (fo)

Item	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Straw amendment	63%	70%	71%	72%	74%	75%	82%	84%	85%	83%	82%	82%	82%	83%	82%
Various compost amendment	17%	10%	9%	8%	9%	9%	6%	7%	6%	5%	6%	6%	6%	5%	6%
No-amendment	20%	20%	20%	20%	17%	16%	12%	9%	9%	12%	12%	12%	12%	12%	12%

Reference: 1990-2007: *Basic Survey of Soil Environment*

2008-2012: *Survey of Greenhouse Gas Emissions from Soils and Soil Carbon Sequestration*

2013-2014: *The Project of Basic Survey on Greenhouse Gas Emissions from Agricultural Land Soils*

Since 2015: *The Project of Basic Survey for Carbon Stock on Agricultural Land Soil*

### c) Uncertainties and Time-series Consistency

#### ● Uncertainties

For the emission factors, uncertainty (6%) was calculated by the DNDC-Rice model. For the uncertainty of the activity data, 1% for area of paddy fields given in the *Statistics of Cultivated and Planted Area* was applied. As a result, the uncertainties of the emissions were determined to be 6%.

#### ● Time-series Consistency

Emissions are estimated by using consistent estimation methods and data sources.

### d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

Comparison of CH<sub>4</sub> emissions calculated by the DNDC-Rice model and emissions of actually measured data in the field was discussed and reported in the paper by Minamikawa et al. (2014), Fumoto et al. (2010), and Katayanagi et al. (2016). Figure 5-6 is comparison of annual methane emission between values observed and values simulated by the DNDC-Rice model described in Katayanagi et al. (2016). The Paper reports that simulated CH<sub>4</sub> emission was strongly and significantly correlated with the observations ( $r=0.861$ ), reflecting the variations caused by differences among the sites and the treatments.

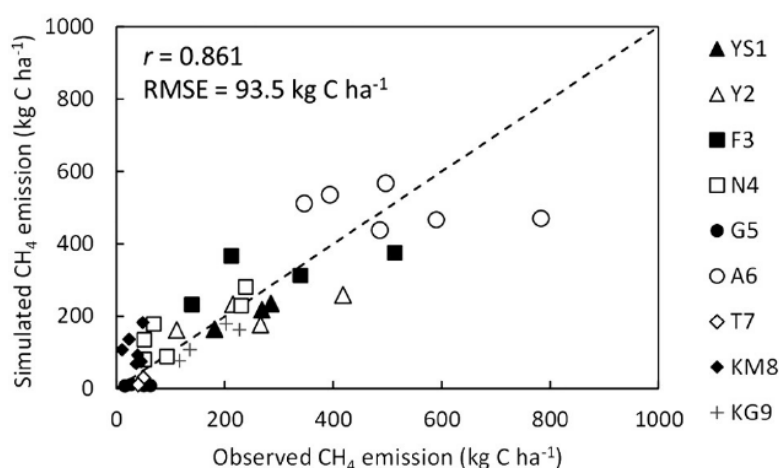


Figure 5-6 Comparison of annual methane emission between values observed and values simulated by the DNDC-Rice model

Reference: Quoted from Figure 3 in Katayanagi et al. (2016)

In addition, validation of application of the emission factors calculated by the DNDC-Rice model, into Japan's inventory has been conducted in Katayanagi et al. (2016) and also discussed in the Agriculture Breakout Group on the Committee of GHG Emission Estimation Methods.

#### ***e) Category-specific Recalculations***

Since the amount of organic matter application for DNDC-Rice model were revised since FY2017, emissions since FY2017 were recalculated. See Chapter 10 for impact on trend.

#### ***f) Category-specific Planned Improvements***

In the future, if the research on the DNDC-Rice model progress and the model are improved and updated, application of the improved version will be considered.

### **5.4.2. Rainfed, Deep Water and Other (3.C.2., 3.C.3., 3.C.4.)**

As indicated in the *World Rice Statistics 1993–94*, International Rice Research Institute (IRRI) (1995), rainfed and deep water paddy fields do not exist in Japan. Therefore, this category has been reported as “NO”.

Just as indicated in IRRI (1995), a possible source of emissions for other rice cultivation system is upland rice, but since upland rice field are not flooded, the soil condition is aerobic. The bacteria that generate CH<sub>4</sub> are obligatory anaerobic bacterium, and unless the soil is maintained in an anaerobic state, CH<sub>4</sub> will not be emitted. As generation of CH<sub>4</sub> is not feasible, this category was reported as “NA”.

### **5.5. Agricultural Soils (3.D.)**

This section provides the estimation methods for N<sub>2</sub>O direct emissions from soils (by applied inorganic N fertilizers, organic fertilizers, grazing livestock manure, crop residue, mineralization by soil carbon loss, and plowing of organic soil), and for N<sub>2</sub>O indirect emissions (by atmospheric deposition, and nitrogen leaching and run-off).

N<sub>2</sub>O emissions from agricultural soils in FY2020 are 5,809 kt-CO<sub>2</sub> eq., comprising 0.5% of total emissions (excluding LULUCF). The value represents a decrease by 23.7% from FY1990. Main drivers of the emission reduction from FY1990 are decreases of nitrogen amount applied to soil of inorganic fertilizer and organic fertilizer from livestock manure. The main reasons of their decrease of fertilizer are that the area of cropping has been decreasing (Table 5-56) and reducing the usage of fertilizer has been recommended to mitigate nitrogen pollution in groundwater in some areas.

Table 5-50 N<sub>2</sub>O emissions from agricultural soils (3.D.)

Cas	Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020		
N <sub>2</sub> O	3.D.a. Direct emission	1. Inorganic N fertilizers 2. Organic N fertilizers 3. Manure by grazing animal 4. Crop residues 5. Mineralization 6. Cultivation of organic soil	kt-N <sub>2</sub> O	6.2	5.3	5.0	4.8	4.2	4.0	4.1	4.2	4.1	3.9	3.9	3.9	3.8	3.8		
				5.0	4.7	4.5	4.0	4.2	4.2	4.1	4.1	4.1	4.4	4.4	4.5	4.5	4.3	4.3	
				0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
				2.4	2.3	2.5	2.3	2.0	2.0	2.0	2.0	2.0	1.9	1.9	1.8	1.8	1.9	1.8	
				1.5	1.5	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.3	1.3	1.3	1.3
				0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	3.D.b. Indirect emission	1. Atmospheric deposition 2. N leaching and run-off	kt-N <sub>2</sub> O	3.6	3.4	3.2	3.0	2.9	2.9	2.9	2.9	2.9	3.0	3.0	3.0	3.0	2.9	2.9	
				6.4	6.0	5.7	5.4	5.1	5.0	5.0	5.0	5.0	5.0	4.9	5.0	5.0	4.9	4.9	
	Total		kt-N <sub>2</sub> O	25.5	23.6	22.7	21.4	20.2	19.8	19.8	20.0	19.8	19.9	19.8	20.0	19.9	19.6	19.5	
			kt-CO <sub>2</sub> eq.	7,608	7,032	6,779	6,371	6,021	5,913	5,911	5,961	5,891	5,941	5,896	5,950	5,916	5,827	5,809	

### 5.5.1. Direct N<sub>2</sub>O Emissions from Managed Soils (3.D.a.)

Application of inorganic fertilizers and organic fertilizers, and grazing livestock manure, or plowing of crop residues into soil generates ammonium ions in the soil. The soil emits N<sub>2</sub>O in the process of oxidizing the ammonium ions into nitrate-nitrogen under aerobic conditions. N<sub>2</sub>O is also emitted via denitrification of nitrate. In addition, N<sub>2</sub>O is generated by decomposition of organic matter in mineral soil and plowing of organic soil because of nitrification and denitrification of nitrogen.

#### 5.5.1.1. Inorganic N Fertilizers (3.D.a.1.)

##### a) Category Description

This section provides the estimation methods for N<sub>2</sub>O emissions by the application of inorganic N fertilizers (synthetic fertilizers).

##### b) Methodological Issues

##### ● Methodology for Estimating Emissions / Removals of GHGs

N<sub>2</sub>O emissions were calculated by Tier2 method, using country-specific emission factors in accordance with decision tree of the 2006 IPCC Guidelines (Vol. 4, p.11.9, Fig.11.2).

In addition, estimation method for N<sub>2</sub>O emission reduction from agricultural soil using synthetic N fertilizer with nitrification inhibitor is also established.

$$E = \sum_{ij} (F_{SNij} \times EF_{1ij}) \times 44/28$$

- E* : N<sub>2</sub>O emissions associated with the application of synthetic fertilizer in agricultural soil (crop field) [kg-N<sub>2</sub>O/yr]  
*F<sub>SNij</sub>* : Nitrogen amount of synthetic fertilizer *j* applied to agricultural soil for crop type *i* [kg-N/yr]  
*EF<sub>1ij</sub>* : N<sub>2</sub>O emission factor of synthetic fertilizer *j* for crop type *i* [kg-N<sub>2</sub>O-N/kg-N]  
*i* : Crop type  
*j* : Fertilizer type (with or without nitrification inhibitor)

##### ● Emission Factors

Emission factors were established by analyzing measured data in Japan, based on the amount of application of synthetic fertilizer and N<sub>2</sub>O emissions. Emission factors of the application of synthetic fertilizer with nitrification inhibitor were established by multiplying their country-specific emission factor by N<sub>2</sub>O reduction rate.

Comparing emission factors among various crops, it was identified that emission factor of tea was



significantly higher and emission factor of rice was significantly lower than those of other crops. As there were not significant differences among the other crops, emission factors associated with the application of synthetic fertilizer in agricultural soil were defined three categories for rice, tea and other crops. Emission factor of Japan is lower than that of default value in the *2006 IPCC Guidelines*. It is the reason that the volcanic ash soil that is well-drained soil and widely distributed in Japan releases little N<sub>2</sub>O emissions. The emission factor of rice is adopted as a default value within the *2006 IPCC Guidelines* and its validity has been internationally confirmed.

N<sub>2</sub>O emission reduction rate using synthetic fertilizer with nitrification inhibitor was decided as 26%, the lower limit of N<sub>2</sub>O reduction rate using fertilizer with dicyandiamide (26-36%) described in Akiyama et al. (2010). Although dicyandiamide is dominantly added as nitrification inhibitor in Japan, other chemical materials as inhibitor are used in a few products. Therefore, the lower limit of the rate of dicyandiamide was used to avoid overestimation of emission reduction. In addition, since nitrification seldom occur on flooded situation for paddy rice, synthetic fertilizer with nitrification inhibitor is never used. Therefore, EF with nitrification inhibitor for paddy rice was not developed.

Table 5-51 N<sub>2</sub>O emission factor for synthetic fertilizer to agricultural soil

Crop type	Emission Factor without nitrogen inhibitor [% : kg-N <sub>2</sub> O-N/kg-N]	Emission Factor with nitrogen inhibitor [% : kg-N <sub>2</sub> O-N/kg-N]
Paddy rice	0.31 %	-
Tea	2.9 %	2.1 % [=2.9%×(1-0.26)]
Other crops	0.62 %	0.46 % [=0.62%×(1-0.26)]

Reference: Akiyama et al. (2006 a)  
Akiyama et al. (2006 b)  
Akiyama et al. (2010)

### ● Activity Data

For total nitrogen amount of synthetic fertilizer, demand for nitrogenous fertilizer described in *Yearbook of Fertilizer Statistics (Pocket Edition)* by Association of Agriculture and Forestry Statistics are used for estimation. To estimate amount of synthetic fertilizer applied to the agricultural soil, amount of synthetic fertilizer applied to forest are subtracted from this total amount (Table 5-52).

In addition, to estimate the amount of synthetic fertilizer applied by crop type, values corresponding to the amounts of nitrogen applied for each crop type are calculated by multiplying area of each crop field (Table 5-56) by the amounts of synthetic fertilizers applied per unit area for each crop type based on the results of studies (Tsuruta 2001) in Japan. Total synthetic fertilizer is apportioned to each crop type in accordance with the corresponding application amount for each crop type.

$$F_{SNI} = (F_T - F_{FRST}) \times \frac{(RA_i \times RF_i \times 10)}{\sum(RA_n \times RF_n \times 10)}$$

$F_{SNI}$	: Nitrogen amount of synthetic fertilizer applied to agricultural soil for crop type $i$ [t-N/yr]
$F_T$	: Total nitrogen amount of synthetic fertilizer [t-N/yr]
$F_{FRST}$	: Nitrogen amount of synthetic fertilizer applied to forest [t-N/yr]
$RA_i$	: Area planted of crop type $i$ [ha]
$RF_i$	: Nitrogen amount of synthetic fertilizer per area planted of crop type $i$ [kg-N/10a]
$RA_n$	: Area planted by each crop type [ha]
$RF_n$	: Nitrogen amount of synthetic fertilizer per area planted by each crop type [kg-N/10a]

The amounts of fertilizer applied by crop type are known because the amounts of synthetic and organic fertilizers applied for each crop type were determined by a farming study conducted in 2000 (Tsuruta

2001). Based on expert judgement, there is likely little year-on-year change in application amounts to crops except for paddy rice and tea, data on the amounts of synthetic fertilizer applied per unit area according to Tsuruta (2001) were applied uniformly for these crops in all the years (Table 5-54).

Fertilizer application amounts for tea change from year to year because of the influence of the transition of recommended rate of fertilizer application by local governments and other factors. The amounts of nitrogen applied to tea fields (the total amount of nitrogen from synthetic and organic fertilizer) in 1993, 1998, and 2002 investigated and summarized by Nonaka (2005) and the ratio of synthetic fertilizer and organic fertilizer applied to tea according to Tsuruta (2001) were used to estimate the amounts of synthetic and organic fertilizer applied in 1993, 1998 and 2002. Time-series data were prepared by interpolating calculated values by estimated fertilizer amount data of three years into from 1993 to 2002 and deferring the 1993 data for previous years and the 2002 data for subsequent years (see Table 5-55).

For paddy rice, the data of synthetic fertilizer application amount for unit area for each year in *Yearbook of Fertilizer Statistics* was used. The values of paddy rice were substituted for upland rice.

Shipping amount of synthetic fertilizer with nitrification inhibitor which is included in "N amount of synthetic fertilizer applied (agricultural soil)" is from surveyed data by MAFF since 1996, and 13% which is an average nitrogen content in production from major manufacturers was applied for emission estimation. In addition, since synthetic fertilizer with nitrification inhibitor was not used for paddy rice nor feed crops, they were excluded from estimation.

Table 5-52 Nitrogen amount of synthetic fertilizer applied to soil [t-N/yr]

Item	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Total N amount in synthetic fertilizer	611,955	527,517	487,406	471,190	409,590	387,201	396,783	409,918	394,629	372,339	374,879	374,879	374,879	374,879	374,879
N amount in synthetic fertilizer applied (forest soil)	288	248	229	222	193	182	187	193	186	175	176	176	176	176	176
N amount in synthetic fertilizer applied (agricultural soil)	611,667	527,269	487,177	470,968	409,397	387,019	396,596	409,725	394,443	372,164	374,703	374,703	374,703	374,703	374,703

Note: This amount includes synthetic fertilizer with nitrification inhibitor.

Reference: Total N amount: *Yearbook of Fertilizer Statistics (Pocket Edition)*

N amount to forest soil: Estimated on the basis of Forestry Agency Survey

Table 5-53 Nitrogen amount of synthetic fertilizer with nitrification inhibitor [t-N/yr]

Item	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
N amount in synthetic fertilizer with nitrification inhibitor	NE	NE	4,030	4,290	4,940	5,850	5,070	7,800	4,550	5,070	5,330	5,070	5,590	6,045	5,798

Note: The value is estimated based on the assumption that products have 13% of nitrogen contents.

Reference: Survey by MAFF

Table 5-54 Amount of synthetic fertilizers application per area by each crop type (other than rice and tea)

Crop type	Amount of application [kg-N/10a]
Vegetables	21.27
Fruit	14.70
Potatoes	12.70
Pulse	3.10
Feed crops	10.00
Sweet potato	6.20
Wheat	10.00
Coarse cereal (including Buckwheat)	4.12
Mulberries	16.20
Industrial crops	22.90
Tobacco	15.40

Reference: Tsuruta (2001)

Table 5-55 Amount of synthetic fertilizers application per area (rice and tea) [kg-N/10a]

Item	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
N amount in synthetic fertilizers application per area (rice)	9.65	8.71	7.34	6.62	5.95	5.93	6.04	6.10	5.97	5.85	5.85	5.85	5.85	5.85	5.85
N amount in synthetic fertilizers application per area (tea)	57.23	54.88	48.06	44.76	44.76	44.76	44.76	44.76	44.76	44.76	44.76	44.76	44.76	44.76	44.76

Reference: Rice: *Yearbook of Fertilizer Statistics (Pocket Edition)*, Tea: Nonaka (2005) and Tsuruta (2001)

Table 5-56 Planted area by each crop type [kha]

Crop type	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Vegetables	620.1	564.4	524.9	476.3	465.4	460.4	457.9	453.4	452.1	448.9	444.1	441.7	437.3	432.5	424.9
Paddy rice (for grain)	2,055.0	2,106.0	1,763.0	1,702.0	1,625.0	1,574.0	1,579.0	1,597.0	1,573.0	1,505.0	1,478.0	1,465.0	1,470.0	1,469.0	1,462.0
Fruit	346.3	314.9	286.2	265.4	246.9	243.5	240.3	237.0	233.8	230.2	226.7	222.7	218.5	215.1	211.3
Tea	58.5	53.7	50.4	48.7	46.8	46.2	45.9	45.4	44.8	44.0	43.1	42.4	41.5	40.6	39.1
Potatoes	115.8	104.4	94.6	86.9	82.5	81.0	81.2	79.7	78.3	77.4	77.2	77.2	76.5	74.4	71.9
Pulse	256.6	155.5	191.8	193.9	189.0	186.2	180.2	178.5	181.0	187.6	187.7	187.9	185.4	183.6	183.3
Feed crops	1,096.0	1,013.0	1,026.0	1,030.0	1,012.0	1,030.0	1,029.0	1,012.0	1,019.0	1,072.0	1,082.0	1,084.9	1,068.6	1,059.1	1,052.6
Sweet potato	60.6	49.4	43.4	40.8	39.7	38.9	38.8	38.6	38.0	36.6	36.0	35.6	35.7	34.3	33.1
Wheat	366.4	210.2	236.6	268.3	265.7	271.7	269.5	269.5	272.7	274.4	275.9	273.7	272.9	273.0	276.2
Coarse cereal (incl. buckwheat)	29.6	23.4	38.4	45.9	49.7	58.1	62.6	62.9	61.4	59.7	62.2	64.5	65.5	67.1	68.3
Mulberries	59.5	26.3	5.9	3.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Industrial crops	142.9	124.5	116.3	110.3	104.8	101.9	100.2	98.5	97.8	98.8	99.3	100.3	98.2	97.3	97.9
Tobacco	30.0	26.4	24.0	19.1	15.0	13.0	9.0	8.9	8.6	8.3	8.0	7.6	7.1	6.5	6.1
Upland rice	18.9	11.6	7.1	4.5	2.9	2.4	2.1	1.7	1.4	1.2	0.9	0.8	0.8	0.7	0.6
Total	5,256.2	4,783.7	4,408.5	4,295.1	4,147.4	4,109.3	4,097.7	4,085.0	4,063.9	4,046.1	4,023.2	4,006.3	3,980.0	3,955.1	3,929.2

Reference: Potatoes: *Vegetable Production and Shipment Statistics*, Tobacco: Survey of Japan Tobacco Inc., Mulberries: MAFF Survey, Other crops: *Statistics of Cultivated and Planted Area* (Note: "Industrial crops" is subtracted the area of "Tobacco" from estimated value from total area of tea, rape, sugar beet and sugarcane. The values of "Vegetable" before 2017 excluded the value of "Potatoes". The values of "Vegetable", "Fruit", "Pulse", "Feed crops" and "Coarse cereal" in 2017 are estimated by using the last five years average proportion of sum of planted areas for object crops in each crop group to the statistic because of the abolition of statistical survey for planted area of these crop groups.)

### c) Uncertainties and Time-series Consistency

#### ● Uncertainties

For the emission factors, uncertainty (31%) described in the reference of EFs, Akiyama et al. (2006), was applied. For activity data, 1% for area of paddy fields given in the *Statistics of Cultivated and Planted Area* was applied as substitution. As a result, the uncertainties of the emissions were determined to be 31%.

#### ● Time-series Consistency

Emissions are estimated by using consistent estimation methods and data sources.

### d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1. Comparison with Japan's EF and the default EF in the IPCC Guidelines is described in the section 'Emission factors' above.

### e) Category-specific Recalculations

Data calculation method for demand for nitrogenous fertilizer since FY2017 was revised. Therefore, emissions since FY2017 were recalculated. See Chapter 10 for impact on trend.

### f) Category-specific Planned Improvements

There are no improvement plans.

#### 5.5.1.2. Organic N Fertilizers (3.D.a.2.)

##### a) Category Description

This section provides the estimation methods for N<sub>2</sub>O emissions by application of organic fertilizer (manure from livestock and other, and compost).

##### b) Methodological Issues

###### ● Estimation Method

Emissions of N<sub>2</sub>O have been calculated by Tier2 method in accordance with decision tree of the 2006 IPCC Guidelines (Vol.4, p.11.9, Fig.11.2).

$$E = \sum_i (F_{ONi} \times EF_{1i}) \times 44/28$$

$E$	: N <sub>2</sub> O emissions from the organic fertilizers applied to agricultural soils [kg-N <sub>2</sub> O/yr]
$F_{ONi}$	: Nitrogen amount of organic fertilizer applied to agricultural soil for crop type $i$ [kg-N/yr]
$EF_{1i}$	: N <sub>2</sub> O emission factor of organic fertilizer for crop type $i$ [kg-N <sub>2</sub> O-N/kg-N]
$i$	: Crop types

###### ● Emission Factors

Emission factors for N<sub>2</sub>O associated with the application of synthetic fertilizers without nitrification inhibitor and organic fertilizers were defined as the same value, because there was no significant difference between emission factors of synthetic fertilizers and organic fertilizers.

###### ● Activity Data

For activity data (total amount of nitrogen contained in the organic fertilizers), the following nitrogen was calculated on the basis of formula described in the 2006 IPCC Guidelines (Vol.4, p11.12, Equation 11.3).

$$F_{ON} = F_{AM} + F_{SEW} + F_{FU} + F_{COMPsub} + F_{OOA}$$

$F_{ON}$	: Nitrogen amount in organic fertilizers applied to soil [kg-N/yr]
$F_{AM}$	: Nitrogen amount in livestock manure applied to soil [kg-N/yr]
$F_{SEW}$	: Nitrogen amount in sewage sludge applied to soil [kg-N/yr]
$F_{FU}$	: Nitrogen amount in human waste applied to soil [kg-N/yr]
$F_{COMPsub}$	: Nitrogen amount in composting sub-material applied to soil (rice straw, rice husk, wheat straw) [kg-N/yr]
$F_{OOA}$	: Nitrogen amount in other organic fertilizers applied to soil (fish residue, soybean oil residue, canola oil residue, etc.) [kg-N/yr]

###### ➤ Nitrogen amount in livestock manure applied to soil ( $F_{AM}$ )

Amount of nitrogen in livestock manure applied to agricultural soil ( $F_{AM}$ ) was calculated by subtracting the amount of nitrogen included in grazing livestock excretion ( $F_{PRP}$ ), nitrogen discharged into public sewage ( $F_{PSW}$ ) nitrogen in livestock manure volatilized as N<sub>2</sub>O (excluding grazing livestock) ( $F_{N2O}$ ), nitrogen in manure volatilized as NH<sub>3</sub> and NO<sub>x</sub> (excluding grazing livestock) ( $F_{NH3+NOx}$ ), nitrogen not

applied to soil due to disposal as industrial waste, discharge to river after purification and other reasons ( $F_{disposal}$ ) from the total nitrogen in livestock manure ( $F_{Total-AW}$ ).

$$F_{AM} = F_{Total-AW} - F_{PRP} - F_{PSW} - F_{N_2O} - F_{NH_3+NOx} - F_{disposal}$$

$F_{AM}$	: Nitrogen amount in livestock manure applied to soil [kg-N/yr]
$F_{Total-AW}$	: Total amount of nitrogen excreted by livestock [kg-N/yr]
$F_{PRP}$	: Amount of nitrogen included in grazing livestock excretion [kg-N/yr]
$F_{PSW}$	: Amount of nitrogen discharged into public sewage [kg-N/yr]
$F_{N_2O}$	: Nitrogen in livestock manure volatilized as $N_2O$ (excluding N from grazing livestock) [kg-N/yr]
$F_{NH_3+NOx}$	: Nitrogen in manure volatilized as $NH_3$ and $NO_x$ (excluding N from grazing) [kg- $NH_3$ -N + $NO_x$ -N/yr]
$F_{disposal}$	: Nitrogen not applied to farm field due to disposal as industrial waste, discharge to river after purification and other reasons [kg-N/yr]

For the amount of nitrogen included in grazing livestock excretion ( $F_{PRP}$ ) amount of nitrogen discharged into public sewage ( $F_{PSW}$ ) and nitrogen in livestock manure volatilized as  $N_2O$  (excluding N from grazing livestock excretion) ( $F_{N_2O}$ ), the amount calculated in 3.B. Manure management were used.

Nitrogen not to applied to farm field ( $F_{disposal}$ ) was calculated by using the percentage of non-agricultural utilization in the *survey of current status for livestock manure management system and others 2019* (MAFF, 2021).

Table 5-57 Nitrogen amount in livestock manure applied to agricultural soil ( $F_{AM}$ ) [t-N/yr]

Item	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Total nitrogen amount in animal waste ( $F_{Total-AW}$ )	683,190	642,484	604,830	569,646	554,199	551,774	540,003	521,676	511,887	511,179	511,532	520,651	517,390	521,113	524,052
Nitrogen amount in excretion from grazing livestock and for public swedge ( $F_{PRP} + F_{PRP}$ )	12,987	12,836	12,024	11,653	11,365	11,244	10,881	10,592	10,025	10,118	9,907	9,890	9,851	9,693	9,428
Amount of $N_2O$ -N released from manure (excluding excretion from grazing livestock and for public swedge) ( $F_{N_2O}$ )	5,695	5,394	5,383	6,075	6,628	6,559	6,404	6,148	5,969	5,894	5,826	5,878	5,800	5,829	5,866
Amount of $NH_3$ -N and $NO_x$ -N released from manure (excluding excretion from grazing livestock and for public swedge) ( $F_{NH_3} + F_{NOx}$ )	236,054	219,528	202,664	184,778	178,364	177,421	173,008	166,498	163,830	163,571	164,382	167,874	166,418	166,375	167,239
Nitrogen amount not to applied to farm field ( $F_{disposal}$ )	40,698	35,271	36,112	46,106	55,675	55,246	54,876	52,428	51,253	50,666	50,658	52,275	51,904	52,532	52,784
Nitrogen amount in livestock manure applied to agricultural soil ( $F_{AM}$ )	387,756	369,454	348,647	321,033	302,167	301,303	294,834	286,010	280,810	280,929	280,759	284,733	283,417	286,684	288,736

#### ➤ Nitrogen amount in sewage sludge applied to soil ( $F_{SEW}$ )

Nitrogen amount in sewage sludge applied to soil ( $F_{SEW}$ ) was calculated by multiplying amount of sludge described in the *Yearbook of Fertilizer Statistics (Pocket Edition)* by nitrogen contents established using data provided by Japan Sewage Works Association.

#### ➤ Nitrogen amount in human wastes applied to soil ( $F_{FU}$ )

Nitrogen amount of human waste ( $F_{FU}$ ) was calculated from the amount of human waste-derived nitrogen calculated with the data of *Waste Treatment in Japan*.

#### ➤ Nitrogen amount in composting sub-material applied to soil ( $F_{COMPsub}$ )

For composting sub-material, data of "composting" and "barn bedding" of rice straw, rice chaff and wheat straw calculated from each prefecture data were used. For nitrogen content rate of rice straw, rice chaff and wheat straw, values described in 5.5.1.4. "Crop Residue" below were used (Table 5-65).

➤ **Nitrogen amount in other organic fertilizers applied to soil ( $F_{OOA}$ )**

Nitrogen amount in other organic fertilizers (fish residue, soybean oil residue, canola oil residue, etc.) applied to soil ( $F_{OOA}$ ) was calculated by multiplying amount of other organic fertilizer described in the *Yearbook of Fertilizer Statistics (Pocket Edition)* by nitrogen contents established using data provided in the *Yearbook of Fertilizer Statistics (Pocket Edition)*.

Table 5-58 Amount of sludge and other organic fertilizer [kt/yr]

Item	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Animal derived Fertilizers	384.1	389.4	341.0	262.7	268.3	259.8	302.6	298.3	268.2	300.6	310.0	285.4	287.5	277.2	268.2
Fish residue	111.5	88.6	89.0	73.9	62.2	52.1	55.4	60.0	51.7	52.9	54.7	53.3	61.8	53.2	51.4
Bone meal	113.1	134.2	112.8	11.4	16.7	17.6	19.4	16.2	18.5	20.0	22.3	20.0	18.4	22.5	15.5
Other animal derived	159.5	166.6	139.2	177.5	189.4	190.1	227.7	222.1	198.1	227.7	233.0	212.1	207.4	201.6	201.3
Plant derived fertilizers	635.9	725.7	982.4	494.8	1,064.3	1,190.9	1,079.2	1,203.7	1,455.4	1,852.7	1,810.9	2,012.0	1,981.9	1,569.6	1,634.6
Soybean oil residue	3.5	4.7	28.9	1.1	209.5	138.5	134.4	167.7	265.0	477.0	494.5	491.3	484.8	494.6	488.4
Canola oil residue	451.0	437.2	620.7	241.0	221.4	396.3	347.9	288.4	399.5	474.8	486.8	449.3	420.1	414.6	403.4
Other plant derived	181.4	283.8	332.8	252.7	633.5	656.1	596.9	747.6	790.9	900.9	829.6	1,071.4	1,077.0	660.4	742.7
Sludge	787.3	935.2	817.7	1,287.4	1,395.6	1,361.5	1,329.3	1,355.5	1,292.9	1,395.7	1,351.7	1,377.8	1,358.0	1,345.9	1,261.5

Reference: *Yearbook of Fertilizer Statistics (Pocket Edition)*

Table 5-59 Nitrogen content rate of each organic fertilizer

Organic fertilizer	Nitrogen content
Fish residue	8.0%
Bone meal	4.1%
Other animal matters	7.5%
Soybean oil residue	7.5%
Canola oil residue	5.1%
Other vegetable matter	4.6%
Sludge	2.7%

Reference: Other than sludge: *Yearbook of Fertilizer Statistics (Pocket Edition)*

Sludge: Established from Japan Sewage Works Association data

Table 5-60 Nitrogen amount in organic fertilizers applied to agricultural soil [t-N/yr]

Item	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
From livestock manure ( $F_{AM}$ )	387,756	369,454	348,647	321,033	302,167	301,303	294,834	286,010	280,810	280,929	280,759	284,733	283,417	286,684	288,736
From sewage sludge ( $F_{SEW}$ )	21,257	25,250	22,078	34,760	37,682	36,759	35,892	36,599	34,907	37,685	36,497	37,202	36,666	36,339	34,059
From human waste ( $F_{FU}$ )	10,394	4,747	2,116	874	427	369	351	286	273	231	204	223	260	234	197
From composting sub-material ( $F_{COMP-sub}$ )	18,316	15,514	11,485	11,217	8,864	8,443	8,803	8,879	7,700	6,816	6,774	6,480	6,578	6,471	6,483
From other organic fertilizers ( $F_{OOA}$ )	57,128	60,790	71,314	43,685	76,006	79,927	77,593	83,796	96,378	123,560	122,844	130,034	128,575	108,916	111,215
Total (Nitrogen amount applied to agricultural soil as organic N fertilizer) ( $F_{ON}$ )	494,851	475,754	455,640	411,570	425,146	426,801	417,473	415,570	420,068	449,221	447,077	458,672	455,496	438,643	440,690

➤ **Estimation for nitrogen amount of organic fertilizer applied to agricultural soil for crop type  $i$**

Nitrogen amount of organic fertilizer applied to agricultural soil for crop type  $i$  ( $F_{ONi}$ ) is calculated by multiplying the total nitrogen amount in organic fertilizers applied to agricultural soil above ( $F_{ON}$ ) by the proportion of nitrogen amount to be applied to crop type  $i$  for the total nitrogen ( $F_{ON}$ ) (proportion of fertilizer application). The proportion of fertilizer application was calculated by dividing the product of nitrogen amount of organic fertilizer application per unit area of crop field for crop type  $i$  and the cultivation area for crop type  $i$  by the grand total of all products for all crop types.

$$F_{ONi} = F_{ON} \times \frac{(RA_i \times RF_i / 10)}{\sum (RA_n \times RF_n / 10)}$$

$F_{ONi}$  : Nitrogen amount of organic fertilizer applied to agricultural soil for crop type  $i$  [t-N/yr]

$F_{ON}$  : Total nitrogen amount in organic fertilizers applied to agricultural soil [t-N/yr]

$RA_i$  : Area planted of crop type  $i$  [ha]

$RF_i$  : Nitrogen amount of organic fertilizer per area of crop field for crop type  $i$  [kg-N/10a]

$RA_n$  : Area planted by each crop type [ha]

$RF_n$  : Nitrogen amount of organic fertilizer per area of crop field by each crop type [kg-N/10a]

For nitrogen amount in organic fertilizer applied per unit area for tea, as same as the synthetic fertilizers, the amounts of nitrogen applied to tea fields (the total of synthetic and organic) in 1993, 1998, and 2002 investigated and summarized by Nonaka (2005) and the ratio of synthetic fertilizer and organic fertilizer applied to tea according to Tsuruta (2001) were used to estimate the amounts of organic fertilizer applied and time-series data were prepared (see Table 5-55). Organic fertilizer application amount per unit area by each crop type except tea is based on the data on the survey in 2000 as same as synthetic fertilizer. The value of upland rice was substituted by the value of paddy rice. Cultivated area by each crop type is same as synthetic fertilizers.

Table 5-61 Amount of nitrogen applied as organic fertilizers per area for tea [kg-N/10a]

Item	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
N amount in organic fertilizers application per area (tea)	20.77	19.92	17.44	16.24	16.24	16.24	16.24	16.24	16.24	16.24	16.24	16.24	16.24	16.24	16.24

Reference: Nonaka (2005), Tsuruta (2001)

Table 5-62 Amount of nitrogen applied as organic fertilizers per area by each crop type (except tea)

Crop type	Amount of application [kg-N/10a]
Vegetables	23.62
Paddy rice	3.2
Fruit	10.90
Potatoes	7.94
Pulse	6.24
Feed crops	10.00
Sweet potato	8.85
Wheat	5.70
Coarse cereal (including Buckwheat)	1.81
Mulberries	0.00
Industrial crops	3.96
Tobacco	11.41

Reference: Tsuruta (2001)

### c) *Uncertainties and Time-series Consistency*

#### ● *Uncertainties*

For the emission factors, uncertainty (31%) described in the reference of EFs, Akiyama et al. (2006), was applied. For activity data for livestock manure, 9% for population of broiler given in the *Livestock Statistics* was applied as substitution. For activity data for others, 1% for area of paddy fields given in the *Statistics of Cultivated and Planted Area* was applied as substitution. As a result, the uncertainties of the emissions were determined to be 23%.

#### ● *Time-series Consistency*

Emissions are estimated by using consistent estimation methods and data sources.

### d) *Category-specific QA/QC and Verification*

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

### e) *Category-specific Recalculations*

Since the population of dairy cattle and swine for FY2019 was revised, the emissions from animal waste for FY2019 were recalculated. The calculation method of nitrogen content in excretion for poultry have

been revised. Therefore, the emissions for the whole time-series were recalculated. Since amount of sludge and other organic fertilizer for FY2019 was revised, the emissions from sludge and other organic fertilizer for FY2019 were recalculated. See Chapter 10 for impact on trend.

#### **f) Category-specific Planned Improvements**

The same emission factor has been used for synthetic and organic fertilizers. Thus, the possibility to establish separate emission factors for these two types of fertilizer is under consideration.

### **5.5.1.3. Urine and Dung Deposited by Grazing Animals (3.D.a.3.)**

#### **a) Category Description**

This section provides the estimation methods for N<sub>2</sub>O emissions from urine and dung deposited by grazing animals.

#### **b) Methodological Issues**

The method for calculating CH<sub>4</sub> and N<sub>2</sub>O emissions from urine and dung deposited by grazing animals is described in 5.3.1 “Livestock Waste Management: Cattle, Swine and Poultry (Hen and Broiler) (3.B.1., 3.B.3., 3.B.4.)” and 5.3.2. “Buffalo, Sheep, Goats, Horses, Rabbits and Mink (3.B.2., 3.B.4.)”.

### **5.5.1.4. Crop Residues (3.D.a.4.)**

#### **a) Category Description**

This section provides the estimation methods for N<sub>2</sub>O emissions by crop residue plowed into soil.

#### **b) Methodological Issues**

##### ● **Estimation Method**

Basically, the N<sub>2</sub>O emissions were calculated by using the *2006 IPCC Guidelines*. For Emission factors, default EF described in the *2006 IPCC Guidelines* were used. However, activity data for some crops (rice, tea, vegetables, sugarcane and sugar beet) were estimated by country-specific method which is considered to be capable for estimating emissions more accurately than the method provided in the *2006 IPCC Guidelines*.

$$E = EF \times A \times 44 / 28$$

<i>E</i>	: N <sub>2</sub> O emissions from crop residue [kg-N <sub>2</sub> O/yr]
<i>EF</i>	: N <sub>2</sub> O emission factor for crop residue [kg-N <sub>2</sub> O-N/kg-N]
<i>A</i>	: Nitrogen amount in crop residue plowed into soils [kg-N/yr]

##### ● **Emission Factors**

0.01 [kg-N<sub>2</sub>O-N/kg-N] (Default, *2006 IPCC Guidelines*)

##### ● **Activity Data**

##### ➤ **Rice**

For the amount of rice crop residue of above-ground biomass plowed into soil, the data for rice straw and rice chaff plowed into soil calculated from each prefecture data was used. The nitrogen content of



rice was calculated by multiplying the aforementioned data by nitrogen content in crop residue (kg-N/t) calculated from Date (1988). In addition, below-ground was calculated from yield, dry matter fraction of harvested crop, ratio of below-ground residues to yield, N content of below-ground residues. For the ratio of below-ground residues to yield ( $Frac_{BGR-Y}$ ), 27% indicated by Ogawa et al. (1988) was used. For dry matter fraction of harvested product ( $DRY$ ), 0.89 of default value indicated in the 2006 IPCC Guidelines was used.

$$A_{Rice} = Residue \times N_{AG} + Y \times DRY \times Frac_{BGR-Y} \times N_{BG}$$

$A_{Rice}$	: Nitrogen amount in crop residue plowed into soils [t-N] (Rice)
$Residue$	: Amount of crop residue plowed into soils (rice straw and chaff) [t]
$N_{AG}$	: N contents of above-ground residues (rice straw and chaff) [% : kg-N/kg]
$Y$	: Yield of rice [t]
$DRY$	: Dry matter fraction of harvested product
$Frac_{BGR-Y}$	: Ratio of below-ground residues to yield of crop T [%]
$N_{BG}$	: N contents of below-ground residues [% : kg-N/kg]

### ➤ Tea

For tea, "Leaf fall" and "Autumn pruning" were targeted as the residues which return into soils annually. In addition, as residues return into soil once in several years, "Medium pruning", which prunes the part of 30-50 cm from the ground and carried out once in about five years, was targeted. For the "Medium pruning", it assumed that it carried out by one fifth in every year in all area of tea field, and all of tea field will be renewal in five years. The residues' nitrogen contents were calculated by multiplying by nitrogen contents per unit area of "Leaf fall", "Autumn pruning" and "Medium pruning" by crop field areas. The crop field areas used for this were the data indicated in the *Statistics of Cultivated and Planted Area* by MAFF.

$$A_{Tea} = (A_{AP} + A_{LF} + A_{MP}/5) \times 10 \times Area$$

$A_{Tea}$	: Nitrogen amount in crop residue plowed into soils [kg-N] (Tea)
$A_{AP}$	: Nitrogen amount included in residue by autumn pruning [kg-N/10a]
$A_{LF}$	: Nitrogen amount included in residue by leaf fall [kg-N/10a]
$A_{MP}$	: Nitrogen amount included in the residue by medium pruning [kg-N/10a]
$Area$	: Area planted of tea [ha]

Table 5-63 Amount of nitrogen content included in tea residue of branch pruning

Kind of branch pruning		Amount of Nitrogen content [kg-N/10a]	Reference
Autumn pruning	Annual	7.7	Hoshina et al.(1982), Kinoshita et al. (2005), Tachibana et al. (1996)
Medium pruning	Once in five years	19.4	Ohta et al. (1996)
Leaf fall	Annual	11.5	Hoshina et al.(1982)

### ➤ Vegetables, sugarcane and sugar beet

The amount of nitrogen in each crop residue plowed into soil were calculated by multiplying nitrogen content in residue per crop yield calculated from Matsumoto (2000) by annual crop yield (by *Statistics of Cultivated and Planted Area* or *Vegetable Production and Shipment Statistics*) by the fraction of above-ground residue removed and fraction burnt on field (after consideration of Combustion Factor).

For the amount of nitrogen in crop residue plowed into soil, the data of the *Document of Kagoshima prefectural Institute for Agricultural Development* was used for sugarcane, and the data of *Hokkaido*

*Fertiliser Recommendations 2010* was used for sugar beets, potato, Japanese radish and onion, and the data of Owa (1996) was used for Chinese cabbage and lettuce.

When any crop has no available data with respect to nitrogen content included in crop residue per crop yield, the value for a similar type of crop was used. The same values were adopted for all fiscal years.

$$A_{Vegetable} = Y \times (1 - Frac_{Remove} - Frac_{burnt} \times CF) \times N_R$$

$A_{Vegetable}$	: Nitrogen amount in crop residue plowed into soils (Vegetables, Sugarcane, Sugarbeet) [t-N]
$Y$	: Yield [t]
$Frac_{Remove}$	: Fraction of above-ground residue removed [%]
$Frac_{burnt}$	: Fraction burnt on field [%]
$CF$	: Combustion factor
$N_R$	: Nitrogen contents in crop residue [% : kg-N/kg]

Table 5-64 Fraction of above-ground residue removed ( $Frac_{Remove}$ ), Fraction burnt on field ( $Frac_{burnt}$ ), Combustion factor ( $CF$ ), and Ratio of below-ground residues to above-ground biomass ( $R_{BG-BIO}$ ) for main crops

Crop type	Fraction of above-ground residue removed ( $Frac_{Remove}$ )	Fraction burnt on field ( $Frac_{burnt}$ )	Combustion factor ( $CF$ )	Ratio of above-ground residues ( $R_{BG-BIO}$ )
Vegetables	47%	7%	0.80 <sup>4)</sup>	-
Sugarbeet	47% <sup>1)</sup>	7% <sup>1)</sup>	0.80 <sup>4)</sup>	-
Sugarcane	47% <sup>1)</sup>	7% <sup>1)</sup>	0.80 <sup>4)</sup>	-
Green manure crops	0% <sup>2)</sup>	0% <sup>2)</sup>	-	Non-legume hay:0.80 Sorghum: 0.24 <sup>9)</sup>
Feed crops	100% <sup>3)</sup>	0% <sup>3)</sup>	-	
Wheat, barley, rye and oats	See Table 5-66	See Table 5-66	0.90 <sup>5)</sup>	Wheat: 0.24 Barley: 0.22 Rye: 0.25 <sup>10)</sup> Oats: 0.25
Pulse	13%	12%	0.80 <sup>4)</sup>	0.19 <sup>6)</sup>
Maize, tubers and roots, other crops	47% <sup>1)</sup>	7% <sup>1)</sup>	0.80 <sup>4)</sup>	Maize: 0.22 Tubers and roots: 0.20 <sup>7)</sup> Other crops: 0.22 <sup>8)</sup>

Reference:

$Frac_{Remove}$ ,  $Frac_{burnt}$ : *Survey of Greenhouse Gas Emissions from Soils and Soil Carbon Sequestration*  
 $CF$ ,  $R_{BG-BIO}$ : *2006 IPCC Guidelines*

Note:

1): Value of vegetables, 2): all residue are plowed into soil, 3): all above-ground biomass removed as for feed, 4): Value of maize and/or sugarcane, 5): Value of wheat, 6): Value of Soybean, 7): Value of potato, 8): Value of grains, 9): Average value between maize and oats, 10): Substituted by oats

Table 5-65 N contents of above- and below-ground residues ( $N_{AG}$ ,  $N_{BG}$ ) for main crops

Crop type	N contents of above-ground residues ( $N_{AG}$ )	N contents of below-ground residues ( $N_{BG}$ )	Note
Rice (above ground)	Straw: 0.541% <sup>a)</sup> Chaff: 0.423% <sup>a)</sup>	-	Wet weight
Rice (below ground)	-	0.9% <sup>z), 3)</sup>	Dry weight
Vegetables	Japanese radish: 0.093% <sup>b), c)</sup> Chinese cabbage: 0.071% <sup>e)</sup> Cabbage: 0.183% <sup>e)</sup> Lettuce: 0.164% <sup>e)</sup> Onion: 0.019% <sup>b), c)</sup>		Wet weight
Sugar beet		0.095% <sup>b), c)</sup>	
Sugarcane		0.548% <sup>d)</sup>	
Green manure crops and Feed crops	Non-legume hay: 1.5% <sup>z)</sup> Sorghum: 0.7% <sup>z)</sup>	Non-legume hay: 1.2% <sup>z)</sup> Sorghum: 0.6% <sup>z)</sup>	
Wheat	0.43% <sup>e)</sup>	0.9% <sup>z)</sup>	
Barley	Two-row: 2.14% <sup>e)</sup> Six-row: 0.31% <sup>e)</sup>	1.4% <sup>z)</sup>	Dry weight
Rye	0.50% <sup>z)</sup>	1.1% <sup>z)</sup>	
Oats	0.70% <sup>z)</sup>	0.8% <sup>z)</sup>	
Maize	1.64% <sup>e)</sup>	0.7% <sup>z)</sup>	
Soybean	0.65% <sup>e)</sup>	0.8% <sup>z)</sup>	
Adzuki beans	0.84% <sup>e)</sup>	1.0% <sup>z), 1)</sup>	
Potatoes	2.42% <sup>e)</sup>	1.4% <sup>z), 2)</sup>	

Reference:

- a): Date (1988)
- b): Hokkaido Government, Department of Agriculture (2010)
- c): Owa (1996)
- d): Document of Kagoshima prefectural Institute for Agricultural Development
- e): Matsumoto (2000)
- z): 2006 IPCC Guidelines

Note:

- 1): Substituted by dry bean
- 2): Substituted by potato
- 3): Substituted by wheat

➤ **Feed and green manure crops, wheat, barley, orzo, rye, maize, pulse, tubers and roots (e.g. potato, sweet potato), and other crops (e.g. buckwheat, tobacco)**

Activity data were calculated by the method shown in the following equation in accordance with the 2006 IPCC Guidelines. For parameters, values in Table 5-64 and Table 5-65 were used. The proportion removed from field and burned in field for wheat, barley, rye and oats were determined on the basis of data of crop area by treating method for wheat straw surveyed by MAFF as shown in the Table 5-66. Since the survey data are not available in and before FY2006, the values for FY2007 were applied to these years. Fraction renewed of field ( $Frac_{Renew}$ ) was determined for feed crops as 3% by expert judgment, taking into account variable survey results. For other crops, it was calculated as 100% renewed.

$$A = \sum_T \left\{ \left[ \left( Area_{(T)} - Area_{burnt(T)} \times CF \right) \times Frac_{Renew(T)} \times \left[ AG_{DM(T)} \times N_{AG(T)} \times (1 - Frac_{Remove(T)}) + (AG_{DM(T)} \times 1000 + Crop_{(T)}) \times R_{BG-BIO(T)} \times N_{BG(T)} \right] \right] \right\}$$

$$Area_{burnt(T)} = Area_{(T)} \times Frac_{burnt(T)}$$

- $A$  : Nitrogen amount in crop residue plowed into soils [t-N]
- $Area_{(T)}$  : Area planted of crop T [ha]
- $Area_{burnt(T)}$  : Area burnt of crop T [ha]
- $CF$  : Combustion factor
- $Frac_{Renew(T)}$  : Fraction renewed of field of crop T [%]
- $AG_{DM(T)}$  : Dry matter of above-ground residues of crop T [Mg/ha]

$N_{AG(T)}$	: N contents of above-ground residues of crop T [%]
$Frac_{Remove(T)}$	: Fraction removed from field of crop T [%]
$Crop(T)$	: Dry matter in yield of crop T [kg/ha]
$R_{BG-BIO(T)}$	: Ratio of below-ground residues to above-ground biomass of crop T
$N_{BG(T)}$	: N contents of below-ground residues of crop T [%]
$Frac_{burnt(T)}$	: Fraction burnt on field of crop T [%]

Table 5-66 Proportion removed from field and burned in field for wheat, barley, rye and oats [%]

Item	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Proportion removed from field	32.1	32.1	32.1	32.1	37.8	39.8	40.2	41.0	41.0	37.9	40.2	38.5	39.5	37.2	37.2
Proportion burned in field	13.5	13.5	13.5	13.5	10.6	9.5	9.2	8.8	8.3	8.0	7.7	7.7	6.9	7.5	7.6

Note: Calculated from each prefecture data

### c) *Uncertainties and Time-series Consistency*

#### ● *Uncertainties*

For uncertainty of the emission factor, default values (-70% to +200%) described in the *2006 IPCC Guidelines* were applied. For activity data, 1% for area of paddy fields given in the *Statistics of Cultivated and Planted Area* was applied as substitution. As a result, the uncertainties of the emissions were determined to be -70% to +200%.

#### ● *Time-series Consistency*

Emissions are estimated by using consistent estimation methods and data sources.

### d) *Category-specific QA/QC and Verification*

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

At the Break Out Group on Agriculture of the Committee for GHG Emissions Estimation Method in 2012, nitrogen content for rice were checked in detail. As a result, the group decided to use data by Date (1988), which were separated into rice straw and chaff and were considered as the most appropriate to represent Japan's actual circumstances because the data are intermediate among the various regional data in Japan.

### e) *Category-specific Recalculations*

Since proportion removed from field and burned in field for wheat, barley, rye and oats were revised, the emissions for FY2019 were recalculated. See Chapter 10 for impact on trend.

### f) *Category-specific Planned Improvements*

Discussion whether it will be possible to establish country-specific emission factors for Japan has been conducted.

## 5.5.1.5. Mineralization/Immobilization Associated with Loss/Gain of Soil Organic Matter (3.D.a.5.)

### a) *Category Description*

This section estimates N<sub>2</sub>O emissions by nitrogen mineralization in loss of carbon oxidized by organic

matter in mineral soil.

## b) Methodological Issues

### ● Estimation Method

Based on Equation 11.1 and Equation 11.8 described in section 11.2.1. in Vol.4 of the 2006 IPCC Guidelines, N<sub>2</sub>O emission factor per unit area ( $EF_{N_2O-N_{i,j}}$ ) [kg-N<sub>2</sub>O-N] is set for calculation. The N<sub>2</sub>O emission factors are country-specific values by region by soil type. Activity data are the area of cropland remaining cropland in mineral soil.

$$N_2O-N_{direct-N_{Mineral_{i,j}}} = F_{SOM_i} \times EF_i \quad (\text{eq.11.1, the 2006 IPCC Guidelines})$$

$$F_{SOM_i} = \sum_k \left( \Delta C_{Mineral_{i,k}} \times \frac{1}{R_{i,k}} \right) \quad (\text{eq.11.8, the 2006 IPCC Guidelines})$$

$$N_2O-N_{direct-N_{Mineral_{i,j}}} = EF_{N_2O-N_{i,j}} \times A_{i,j}$$

$N_2O-N_{direct-N_{Mineral}}$	: Direct N <sub>2</sub> O emissions from N mineralization as a result of loss of organic matter in mineral soil [kg-N <sub>2</sub> O-N]
$EF$	: N <sub>2</sub> O emission factor per amount of N mineralization [kg-N <sub>2</sub> O-N/kg-N]
$A$	: Mineral soil area with soil carbon loss as a result of loss of soil organic matter [ha]
$i$	: Land use/type of land (paddy fields, upland fields, orchard and tea plantations)
$j$	: Regions (Hokkaido, Tohoku, Kanto, Hokuiku, Tokai/Kinki, Chugoku/Shikoku, Kyushu/Okinawa)
$k$	: Soil type (soil type based on the classification of Yagasaki and Shirato (2014))

### ● Emission Factors

The emission factor is established by Shirato et al. (2021). The detail of the estimation are shown in LULUCF sector (6.14.b)).

Table 5-67 N<sub>2</sub>O emission factor by mineralization for paddy field and upland field by each region [kg N<sub>2</sub>O-N/ha/yr]

Region	Paddy field	Upland field
Hokkaido	0.244	0.210
Tohoku	0.269	0.189
Kanto	0.291	0.166
Hokuriku	0.265	0.167
Tokai and Kinki	0.284	0.172
Chugoku and Shikoku	0.307	0.200
Kyushu and Okinawa	0.310	0.197

Reference: Shirato et al. (2021)

### ● Activity Data

The area of plowed mineral soil was established by subtracting the area of organic soils (peat soil and muck soil) in paddy fields and common upland fields by region in Japan from the cultivated areas of paddy fields and common upland fields, obtained from the *Statistics of Cultivated and Planted Area* (MAFF). Lands of mineral soil converted to paddy field and upland field are estimated in LULUCF sector. For detail, see estimation method described in LULUCF sector (6.6.1 b) 2) “Activity Data” below).

Table 5-68 Intended areas of mineral soil in Agriculture sector [kha]

Item	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Intended paddy field	2,640	2,579	2,500	2,418	2,359	2,338	2,330	2,323	2,314	2,302	2,287	2,271	2,254	2,240	2,225
Hokkaido	191	191	187	181	179	178	178	178	178	178	178	177	177	177	176
Tohoku	578	582	578	564	557	543	542	541	539	536	533	529	526	524	521
Kanto	488	478	465	445	429	426	424	422	420	418	415	412	409	406	403
Hokuriku	318	305	296	288	282	281	280	280	279	278	277	276	275	274	273
Tokai and Kinki	366	352	337	325	313	312	311	309	307	305	303	301	298	295	293
Chugoku and Shikoku	338	323	303	291	282	280	279	277	276	274	272	270	267	266	262
Kyusyu and Okinawa	361	349	335	325	318	317	316	315	315	313	309	305	302	299	296
Intended upland field	1,166	1,122	1,101	1,121	1,139	1,137	1,137	1,135	1,131	1,126	1,124	1,116	1,110	1,104	1,098
Hokkaido	384	363	363	381	395	397	398	398	398	400	401	401	402	402	403
Tohoku	134	131	127	129	132	130	130	130	130	129	128	127	126	126	125
Kanto	294	289	289	289	286	284	284	282	280	277	275	272	269	266	263
Hokuriku	24	23	23	24	25	25	25	25	25	25	25	25	25	25	25
Tokai and Kinki	59	58	58	61	61	62	62	62	62	62	61	61	60	60	60
Chugoku and Shikoku	61	58	52	52	55	55	55	54	54	53	53	52	52	51	50
Kyusyu and Okinawa	210	200	188	185	184	184	184	183	182	181	180	178	176	174	173

### c) Uncertainties and Time-series Consistency

#### ● Uncertainties

For the emission factors, uncertainty (paddy field 2.4%, upland field 2.9%) was estimated from standard deviation described in the reference of EFs, Shirato et al.(2021) was applied. For activity data, 1% for area of paddy fields given in the *Statistics of Cultivated and Planted Area* was applied as substitution. As a result, the uncertainties of the emissions were determined to be 2.4%.

#### ● Time-series Consistency

Emissions are estimated by using consistent estimation methods and data sources.

### d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

### e) Category-specific Recalculations

The N<sub>2</sub>O emission factor for mineralization/immobilization associated with loss/gain of soil organic matter was revised, the emissions for whole time-series were recalculated. See Chapter 10 for impact on trend.

### f) Category-specific Planned Improvements

There are no improvement plans.

## 5.5.1.6. Plowing of Organic Soils (3.D.a.6.)

### a) Category Description

In Japan, organic soil mainly occurs in Hokkaido. In Japanese GHG inventory, two categories of soil type, “muck soil” and “peat soil”, are treated as organic soils. In Japan, the creation of farmland on organic soils was mostly completed by the 1970s, and in general farmers till land that has had soil dressing.

## b) Methodological Issues

### ● Estimation Method

Emissions of N<sub>2</sub>O from the plowing of organic soil were calculated by multiplying the area of the plowed organic soil of paddy field, upland field, and grassland by the emission factor in accordance with the 2006 IPCC Guidelines.

$$E = EF \times A \times 44 / 28$$

<i>E</i>	: N <sub>2</sub> O emission associated with the plowing of organic soils [kg-N <sub>2</sub> O/yr]
<i>EF</i>	: N <sub>2</sub> O emission factor for plowing of organic soils [kg-N <sub>2</sub> O-N/ha/yr]
<i>A</i>	: Area of plowed organic soils [ha]

### ● Emission Factors

For paddy field cultivation in organic soils, it is known that N<sub>2</sub>O emission in paddy field is lower than the one in upland field. In Japan, Nagata and Sameshima (2006) observed N<sub>2</sub>O emissions for paddy field of organic soil in Hokkaido, but the observations included emissions from applied nitrogen. Therefore, country-specific emission factor is determined to be 0.30 [kg-N<sub>2</sub>O-N/ha/year] by deducting emission for applied fertilizer (estimated from country-specific emission factor of fertilizers (0.31% [% : kg-N<sub>2</sub>O-N/kg-N]) indicated in Table 5-51 above). For the upland field of organic soil, some observation results exist (Nagata and Sameshima, 2006, Nagata et al., 2009), but there is not much difference from the default of temperate region (8 [kg-N<sub>2</sub>O-N/ha/year]) indicated in 2006 IPCC Guidelines. Therefore, default value is used for upland field. For grassland, same default value (8 [kg-N<sub>2</sub>O-N/ha/year]) is used.

### ● Activity Data

The area of organic soil was obtained from the value calculated in LULUCF sector. For 1992, 2001 and 2010 when area data by soil type is available, the proportion of soil categorized in organic soil was estimated from area data by soil types, land categories and prefectures, and the proportion was multiplied by area by land categories and prefectures to obtain organic soil area. For other years, organic soil area was estimated by adjusting constant rate of converted land area to the area in 1992, 2001 and 2010.

Plowed area of organic soil includes all areas of organic soil for rice field and upland field and the renewed pasture lands, while organic soils for orchard, grazed meadow and wild land are not included. This is because orchard, grazed meadow and wild land are not plowed. (see 6.7.1. Grassland remaining Grassland)

The renewal of grassland is the maintenance work with re-sowing and re-plowing which is done once in several years. Annual plowed grassland area of organic soil is calculated by multiplying the annual renewal ratios by organic soil areas of grassland. For annual renewal ratio of grassland, a report of a study result by Hatano (2017) was utilized. The result by Hatano mentioned annual renewal ratios of grassland for categorized two areas, “Hokkaido” and “other areas” from 2006 to 2015. Averaged annual renewal ratios from 2006 to 2010 for each area (Hokkaido : 3.0%, other area : 1.3% ) were substituted for the ratios before 2006 and since 2016.

Table 5-69 Annual renewal ratio of grassland

	Before 2006	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Since 2016
Hokkaido	3.0%	2.5%	2.8%	3.0%	3.7%	2.9%	3.5%	3.6%	3.3%	3.9%	4.1%	3.0%
Other area	1.3%	1.0%	1.2%	1.0%	1.4%	2.1%	3.8%	15.7%	9.6%	5.2%	3.5%	1.3%

Reference: Hatano (2017)

Table 5-70 Intended areas of organic soil in the agriculture sector [kha]

Item	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Intended paddy field	131.5	129.8	129.1	127.3	125.3	124.7	124.8	125.0	125.0	124.9	124.7	124.8	124.9	124.9	124.9
Intended upland field	16.7	16.7	17.0	16.9	16.8	16.6	16.5	16.4	16.3	16.2	16.1	16.1	16.1	16.1	16.2
Intended grassland (Hokkaido)	1.2	1.2	1.2	1.2	1.1	1.4	1.4	1.3	1.5	1.6	1.2	1.2	1.2	1.2	1.2
Intended grassland (other area)	0.005	0.004	0.003	0.003	0.004	0.007	0.029	0.018	0.010	0.006	0.002	0.002	0.002	0.002	0.002

### c) Uncertainties and Time-series Consistency

#### ● Uncertainties

For uncertainty of the emission factor, default values (-75% to +200%) described in the *2006 IPCC Guidelines* were applied. For activity data, 1% for area of paddy fields given in the *Statistics of Cultivated and Planted Area* was applied as substitution. As a result, the uncertainties of the emissions were determined to be -75% to +200%.

#### ● Time-series Consistency

Emissions are estimated by using consistent estimation methods and data sources.

### d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

The country-specific emission factor, 0.30 [kg-N<sub>2</sub>O-N/ha/yr], from paddy fields with organic soil is set based on the actual measurement values of N<sub>2</sub>O emissions from the paddy fields with peat soil in Hokkaido (Nagata and Sameshima, 2006). N<sub>2</sub>O emissions from the paddy fields with peat soil were measured on 8 observation points and the range of emission measurement values were -0.28 to 1.27 [kgN<sub>2</sub>O-N/ha/yr]. For setting the CSEF, emissions from fertilization were deducted because fertilizers were applied on those observation points. Emission estimation values of N<sub>2</sub>O from fertilization to the paddy fields were in the range between 0.11 to 0.29 [kgN<sub>2</sub>O-N/ha/yr]. The N<sub>2</sub>O emission factor from the paddy fields with peat soil, therefore, is calculated as 0.30 [kg-N<sub>2</sub>O-N/ha/yr].

Moreover, Nagata conducted measurements for N<sub>2</sub>O emissions at upland fields with peat soil. Measurement from upland fields was conducted on 9 observation points and the emission measurement values were in the range between 2.87 to 13.60 [kg-N<sub>2</sub>O-N/ha/yr]. N<sub>2</sub>O emissions from fertilization to the upland fields were in the range between 0.17 to 2.38 [kg-N<sub>2</sub>O-N/ha/yr]. The emission factor from the upland field with peat soil was 7.42 [kg-N<sub>2</sub>O-N/ha/yr] after subtracting estimated emission by fertilization from measurement emission value. This value is close to the default emission factor 8 [kg-N<sub>2</sub>O-N/ha/yr] (*2006 IPCC Guideline*, Vol.4, page 11.11, Table 11.1). The result by Nagata and Sameshima (2006) disclosed N<sub>2</sub>O emissions were clearly different between the irrigated paddy field and the upland field on organic soil.

### e) Category-specific Recalculations

Since the organic soil area associated with land use conversion in LULUCF sector was changed, the emissions of FY1990, FY1991, and from FY2011 to FY2019 were recalculated. See Chapter 10 for impact on trend.



### f) Category-specific Planned Improvements

No improvement plans.

## 5.5.2. Indirect N<sub>2</sub>O Emissions from Managed Soils (3.D.b.)

Nitrogen compounds such as ammonia, that volatilize and are released into the atmosphere from synthetic fertilizers applied to agricultural soils, organic fertilizers applied to agricultural soils and the grazing livestock manure applied to soil are deposited on soil as the results of various actions, including turbulent diffusion, molecular diffusion, effect of electrostatic forces, chemical reactions, plant respiration, and being washed out of the air by rain. In this section, the amount of N<sub>2</sub>O generated by microbe activity on the deposited nitrogen compounds was calculated.

N<sub>2</sub>O is generated by the action of microbes on nitrogen that leaches or runs off as nitrate from synthetic fertilizers, organic fertilizers, etc.

### 5.5.2.1. Atmospheric Deposition (3.D.b.1.)

#### a) Category Description

This section provides the estimation methods for N<sub>2</sub>O indirect emissions caused by atmospheric deposition of nitrogen compounds volatilized as NH<sub>3</sub> and NO<sub>x</sub> from synthetic fertilizers applied to soil, organic fertilizers applied to soil, and the grazing livestock manure applied to soil.

#### b) Methodological Issues

##### ● Estimation Method

N<sub>2</sub>O emissions have been calculated in accordance with decision tree of the *2019 Refinement* (Vol. 4, Page 11.23, Fig11.3).

$$E = EF \times A \times 44 / 28$$

$E$	: N <sub>2</sub> O emissions from atmospheric deposition [kg-N <sub>2</sub> O/yr]
$EF$	: N <sub>2</sub> O emission factor for atmospheric deposition [kg-N <sub>2</sub> O-N/ kg-NH <sub>3</sub> -N+NO <sub>x</sub> -N volatilized]
$A$	: Total nitrogen amount volatilized as NH <sub>3</sub> and NO <sub>x</sub> from synthetic fertilizers, organic fertilizers, and deposition by grazing livestock [kg-NH <sub>3</sub> -N+NO <sub>x</sub> -N/yr]

##### ● Emission Factors

0.014 [kg-N<sub>2</sub>O-N/kg-NH<sub>3</sub>-N & NO<sub>x</sub>-N volatilized] (default value, *2019 Refinement*, Vol.4 Table11.3).

##### ● Activity Data

As described in the following equation, the activity data are composed of the “nitrogen amount volatilized as NH<sub>3</sub> and NO<sub>x</sub> from synthetic fertilizers applied to soil by type of fertilizer, organic fertilizers applied to soil, and the excretion deposited by grazing livestock. The “nitrogen amount volatilized NH<sub>3</sub> and NO<sub>x</sub> in process of livestock manure management” are reported in 3.B.5.

$$A = \sum_t (F_{SNt} \times Frac_{GASFt}) + [(F_{ON} + F_{PRP}) \times Frac_{GASM3}]$$

$A$	: Total N amount volatilized as NH <sub>3</sub> and NO <sub>x</sub> from synthetic fertilizers, organic fertilizers, and excretion by grazing livestock [kg-NH <sub>3</sub> -N+NO <sub>x</sub> -N]
$F_{SNt}$	: N amount for synthetic fertilizers $t$ applied to agricultural soil [kg-N/yr]

- $Frac_{GASF_i}$  : Fraction of volatilization as  $NH_3$  and  $NO_x$  from synthetic fertilizer applied to agricultural soil [(kg- $NH_3$ -N +  $NO_x$ -N)/kg-N]  
 $F_{ON}$  : N amount for organic N fertilizers applied to agricultural soil [kg-N/yr]  
 $F_{PRP}$  : N amount in urine and dung deposited by grazing livestock [kg-N/yr]  
 $Frac_{GASM3}$  : Fraction of volatilization as  $NH_3$  and  $NO_x$  from applied organic N fertilizer ( $F_{ON}$ ) and of urine and dung N deposited by grazing animals ( $F_{PRP}$ ) [(kg- $NH_3$ -N +  $NO_x$ -N)/kg-N]

➤ ***N amount volatilized as  $NH_3$  and  $NO_x$  from synthetic fertilizers applied to soil ( $F_{SN} \times Frac_{GASF}$ )***

For N amount of synthetic fertilizer applied to agricultural soil ( $F_{SN}$ ), the demand for nitrogenous fertilizer described in *Yearbook of Fertilizer Statistics (Pocket Edition)* was used for estimation. To estimate the value of synthetic fertilizer applied to agricultural soil ( $F_{SN}$ ), amount of synthetic fertilizer applied to forest were subtracted from this demand for nitrogenous fertilizer. The default values, indicated in Table 5-72, given in the *2019 Refinement* were used for the fraction of volatilization ( $Frac_{GASF_i}$ ).

Table 5-71 Amount of synthetic fertilizer applied to agricultural soil by type (excluding forest application)

Type	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Urea-based	115,620	107,917	106,712	125,170	117,267	119,590	109,403	136,391	129,924	136,622	132,424	132,424	132,424	132,424	132,424
Ammonium-based	465,738	393,888	363,180	286,181	245,364	232,845	249,294	239,123	228,585	208,505	224,393	224,393	224,393	224,393	224,393
Ammonium-nitrate-based	8,010	7,090	3,947	2,207	989	894	877	1,105	889	713	3,160	3,160	3,160	3,160	3,160
Other	22,300	18,374	13,338	57,410	45,778	33,690	37,022	33,105	35,045	26,325	14,726	14,726	14,726	14,726	14,726

Reference: *Yearbook of Fertilizer Statistics (Pocket Edition)*

Table 5-72 Fraction of nitrogen volatilized from synthetic fertilizers and organic fertilizers as ammonia or nitrogen oxides [kg- $NH_3$ -N +  $NO_x$ -N/kg-N]

	Type	Value
$Frac_{GASF}$	Urea	0.15
	Ammonium-based	0.08
	Ammonium-nitrate-based	0.05
	For other type of N fertilizer	0.11
$Frac_{GASM}$	All organic N fertilizer	0.21

Reference: *2019Refinement* Vol. 4, Table 11.3

➤ ***N amount volatilized as  $NH_3$  and  $NO_x$  from organic fertilizers applied to agricultural soil and from excretion by grazing livestock ( $(F_{ON} + F_{PRP}) \times Frac_{GASM3}$ )***

For nitrogen amount in organic N fertilizers applied to agricultural soil ( $F_{ON}$ ), the data described in the “Organic N Fertilizers (3.D.a.2.)” were used. For the nitrogen amount in excretion from grazing livestock ( $F_{PRP}$ ), the calculated data in 3.B. were used. For fraction of nitrogen volatilized as  $NH_3$  and  $NO_x$  ( $Frac_{GASM3}$ ), default value ( $Frac_{GASM} = 0.21$ ) of the *2019 Refinement* indicated in Table 5-72 above was used.

Table 5-73 Amount of nitrogen that volatilizes as ammonia and nitrogen oxides from synthetic fertilizers, livestock manure, and human waste [t ( $NH_3$ -N+ $NO_x$ -N)/yr]

Item	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
From synthetic N fertilizers applied to soil ( $F_{SN} \times Frac_{GASF}$ )	57,455	50,074	46,726	48,095	42,304	40,317	40,470	43,285	41,675	40,105	39,593	39,593	39,593	39,593	39,593
From organic N fertilizers ( $F_{ON} \times Frac_{GASM3}$ )	103,919	99,908	95,684	86,430	89,281	89,628	87,669	87,270	88,214	94,336	93,886	96,321	95,654	92,115	92,545
From excretion from grazing livestock ( $F_{PRP} \times Frac_{GASM4}$ )	2,727	2,696	2,506	2,342	2,220	2,192	2,115	2,058	1,940	1,959	1,913	1,904	1,894	1,856	1,800
Total (nitrogen amount volatilized as ammonia and nitrogen oxides (A))	164,101	152,678	144,916	136,867	133,805	132,137	130,254	132,613	131,829	136,400	135,393	137,818	137,141	133,564	133,938

**c) Uncertainties and Time-series Consistency****● Uncertainties**

For uncertainty of the emission factor, uncertainty (-106% to +447%) was calculated by synthesis of defaults of each parameter described in the *2006 IPCC Guidelines*. For activity data, 9% for population of broiler given in the *Livestock Statistics* was applied as substitution. As a result, the uncertainties of the emissions were determined to be -106% to +447%.

**● Time-series Consistency**

Emissions are estimated by using consistent estimation methods and data sources.

**d) Category-specific QA/QC and Verification**

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

**e) Category-specific Recalculations**

Data calculation method for demand for nitrogenous fertilizer since FY2017 was revised. Therefore, emissions since FY2017 were recalculated. Since the population of livestock for FY2018 and FY2019 was revised, the emissions from livestock for FY2018 and FY2019 were recalculated. Since the calculation methods for nitrogen content in excretion for poultry was revised, the emissions from hen and broiler for the whole time-series were recalculated. Since the emission factor for atmospheric deposition was revised, the emissions for the whole time-series was recalculated. See Chapter 10 for impact on trend.

**f) Category-specific Planned Improvements**

Discussion for the establishment of country-specific emission factors and the ratios of volatile nitrogen compounds has been conducted.

**5.5.2.2. Nitrogen Leaching and Run-off (3.D.b.2.)****a) Category Description**

This section provides the estimation methods for N<sub>2</sub>O emissions from Nitrogen Leaching and Run-off.

**b) Methodological Issues****● Estimation Method**

N<sub>2</sub>O emissions were calculated according to the decision tree in the *2019 Refinement* (Vol. 4, Page 11.23, Fig11.3), by multiplying default emission factors by the amount of nitrogen that leached and run-off.

$$E = EF \times A \times 44 / 28$$

*E* : N<sub>2</sub>O emissions from N leaching and run-off [kg-N<sub>2</sub>O/yr]

*EF* : N<sub>2</sub>O emission factor for N leaching and run-off [kg-N<sub>2</sub>O-N/kg-N]

*A* : Total nitrogen amount for N leaching and run-off from synthetic fertilizers, organic fertilizers, etc. [kg-N/yr]

- **Emission Factors**

0.011 [kg-N<sub>2</sub>O-N/kg-N] (default value, *2019 Refinement*, Vol. 4, Table11.3).

- **Activity Data**

As described in the formula below, activity data was composed of each nitrogen amount of leaching and run-off by synthetic fertilizers, organic fertilizers, excretion deposited by grazing livestock, crop residue, and carbon loss by mineralization. Each AD was calculated by multiplying the default value of fraction of leaching and run-off ( $Frac_{LEACH}$ , 0.24 [kg-N/kg-N]) given in the *2019 Refinement* by the amount of nitrogen calculated in 3.D.a.1. to 3.D.a.5. above.

$$A = (F_{SN} + F_{ON} + F_{PRP} + F_{CR} + F_{SOM}) \times Frac_{LEACH}$$

$A$	: Total nitrogen amount for N leaching and run-off from synthetic fertilizers, organic fertilizers, etc. [kg-N/yr]
$F_{SN}$	: Nitrogen amount in synthetic fertilizers applied to agricultural soil [kg-N/yr]
$F_{ON}$	: Nitrogen amount in organic N fertilizers applied to agricultural soil [kg-N/yr]
$F_{PRP}$	: Nitrogen amount in urine and dung deposited by grazing livestock [kg-N/yr]
$F_{CR}$	: Nitrogen amount in crop residue plowed into soil [kg-N/yr]
$F_{SOM}$	: Nitrogen amount in mineralization in loss of carbon oxidized by organic matter in mineral soil [kg-N/yr]
$Frac_{LEACH}$	: Fraction of nitrogen leaching and run-off in each activity [kg-N/kg-N]

Table 5-74 Total nitrogen amount for N leaching and run-off from synthetic fertilizers, organic fertilizers, etc. [t (NH<sub>3</sub>-N+NO<sub>x</sub>-N) /yr]

Item	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
From synthetic N fertilizers applied to soil ( $F_{SN} \times Frac_{LEACH}$ )	146,800	126,545	116,922	113,032	98,255	92,885	95,183	98,334	94,666	89,319	89,929	89,929	89,929	89,929	89,929
From organic N fertilizers ( $F_{ON} \times Frac_{LEACH}$ )	118,764	114,181	109,354	98,777	102,035	102,432	100,193	99,737	100,816	107,813	107,299	110,081	109,319	105,274	105,766
From excretion from grazing livestock ( $F_{PRP} \times Frac_{LEACH}$ )	3,117	3,081	2,864	2,676	2,537	2,505	2,417	2,351	2,217	2,239	2,187	2,175	2,165	2,121	2,057
From crop residue ( $F_{CR} \times Frac_{LEACH}$ )	36,239	35,824	38,175	35,164	30,200	30,017	30,631	30,620	29,862	29,533	28,265	28,125	27,916	28,518	27,933
From mineralization ( $F_{SOM} \times Frac_{LEACH}$ )	66,535	64,808	62,866	61,221	60,055	59,576	59,407	59,227	59,008	58,721	58,354	57,941	57,533	57,179	56,784
Total (nitrogen amount by leaching and run-off) (A)	371,455	344,438	330,181	310,870	293,083	287,415	287,832	290,269	286,569	287,625	286,033	288,252	286,862	283,021	282,468

### c) Uncertainties and Time-series Consistency

- **Uncertainties**

For uncertainty of the emission factor, uncertainty (-115% to +287%) was calculated by synthesis of defaults of each parameter described in the *2006 IPCC Guidelines*. For activity data, 9% was applied as same as “Atmospheric Deposition” above. As a result, the uncertainties of the emissions were determined to be -115% to +287%.

- **Time-series Consistency**

Emissions are estimated by using consistent estimation methods and data sources.

### d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

**e) Category-specific Recalculations**

Data calculation method for demand of nitrogenous fertilizer since FY2017 was revised. Therefore, emissions since FY2017 were recalculated. Since the population of livestock for FY2018 and FY2019 was revised, the emissions from livestock for FY2018 and FY2019 were recalculated. Since the calculation methods for nitrogen content in excretion for poultry have been revised, the emissions from hen and broiler for the whole time-series were recalculated. Since proportion removed from field and burned in field for wheat, barley, rye and oats were revised, the emissions for FY2019 were recalculated. Since the N<sub>2</sub>O emission factor for mineralization/immobilization associated with loss/gain of soil organic matter was revised, the emissions for whole time-series were recalculated. Since the emission factor for nitrogen leaching and run-off and fraction of leaching and run-off was revised, the emissions for the whole time-series were recalculated. See Chapter 10 for impact on trend.

**f) Category-specific Planned Improvements**

Discussion for the establishment of country-specific emission factors and the fraction of nitrogen leaching and run-off has been conducted.

**5.6. Prescribed Burning of Savannas (3.E.)**

This source is given in the *2006 IPCC Guidelines* as “being for the purpose of managing pastureland in sub-tropical zones”. There is no equivalent activity in Japan, and this source has been reported as “NO”.

**5.7. Field Burning of Agricultural Residues (3.F.)****a) Category Description**

Incomplete burning of crop residues in field releases CH<sub>4</sub> and N<sub>2</sub>O into the atmosphere. CH<sub>4</sub> and N<sub>2</sub>O emissions from this source are calculated and reported in this category.

CH<sub>4</sub> and N<sub>2</sub>O emissions from Field Burning of Agricultural Residues in FY2020 are 64 kt-CO<sub>2</sub> eq. and 20 kt-CO<sub>2</sub> eq., comprising 0.006% and 0.002% of total emissions (excluding LULUCF), respectively. The value represents a decrease by 49.7% and 49.7% for CH<sub>4</sub> and N<sub>2</sub>O from FY1990, respectively.

Table 5-75 CH<sub>4</sub> and N<sub>2</sub>O emissions from field burning of agriculture residues (3.F.)

Gas	Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020			
CH <sub>4</sub>	3.F.1. Cereals	Wheat	kt-CH <sub>4</sub>	0.38	0.22	0.27	0.31	0.24	0.22	0.21	0.20	0.19	0.18	0.18	0.18	0.16	0.17	0.18		
		Barley		0.15	0.09	0.08	0.08	0.07	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	
		Maize		0.08	0.07	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.05	0.04	0.04
		Rice		1.96	2.05	1.38	1.03	0.70	0.70	0.66	0.75	0.68	0.56	0.57	0.47	0.53	0.51	0.51	0.51	
		Other cereals		0.06	0.05	0.08	0.09	0.09	0.11	0.12	0.12	0.12	0.11	0.12	0.12	0.13	0.13	0.13	0.13	
	3.F.2. Pulses	Soybeans		0.47	0.22	0.40	0.43	0.45	0.44	0.42	0.42	0.43	0.46	0.49	0.49	0.47	0.46	0.46	0.46	
		Other pulses		0.35	0.27	0.22	0.19	0.16	0.16	0.15	0.16	0.16	0.14	0.12	0.12	0.12	0.12	0.13	0.13	
	3.F.3. Tubers and roots	Potatoes		0.23	0.20	0.18	0.17	0.16	0.16	0.16	0.16	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.14	
		Sugarbeet		0.14	0.14	0.14	0.13	0.12	0.12	0.12	0.11	0.11	0.11	0.12	0.11	0.11	0.11	0.11	0.11	
		Other tubers and roots		0.20	0.17	0.15	0.13	0.12	0.12	0.12	0.12	0.12	0.11	0.11	0.11	0.11	0.11	0.11	0.10	
	3.F.4. Sugarcane			0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	
	3.F.5. Vegetables			0.95	0.87	0.81	0.74	0.72	0.71	0.71	0.70	0.69	0.69	0.68	0.68	0.68	0.67	0.66	0.66	
	Other	Other crops			0.08	0.06	0.05	0.04	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	Total			kt-CH <sub>4</sub>	5.1	4.4	3.8	3.4	2.9	2.9	2.8	2.9	2.8	2.7	2.7	2.6	2.6	2.6	2.6	
				kt-CO <sub>2</sub> eq.	127	111	96	86	74	73	71	72	70	67	67	64	65	64	64	
N <sub>2</sub> O	3.F.1. Cereals	Wheat	kt-N <sub>2</sub> O	0.010	0.006	0.007	0.008	0.006	0.006	0.005	0.005	0.005	0.005	0.005	0.005	0.004	0.004	0.005		
		Barley		0.004	0.002	0.002	0.002	0.002	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001		
		Maize		0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001		
		Rice		0.051	0.053	0.036	0.027	0.018	0.018	0.017	0.019	0.018	0.015	0.015	0.012	0.014	0.013	0.013		
		Other cereals		0.002	0.001	0.002	0.002	0.002	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003		
	3.F.2. Pulses	Soybeans		0.012	0.006	0.010	0.011	0.012	0.011	0.011	0.011	0.011	0.012	0.013	0.013	0.012	0.012	0.012		
		Other pulses		0.009	0.007	0.006	0.005	0.004	0.004	0.004	0.004	0.004	0.004	0.003	0.003	0.003	0.003	0.003		
	3.F.3. Tubers and roots	Potatoes		0.006	0.005	0.005	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004		
		Sugarbeet		0.004	0.004	0.004	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003		
		Other tubers and roots		0.005	0.004	0.004	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003		
	3.F.4. Sugarcane			0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001		
	3.F.5. Vegetables			0.025	0.023	0.021	0.019	0.019	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.017	0.017		
	Other	Other crops			0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.0005	0.0004	0.0004		
	Total			kt-N <sub>2</sub> O	0.13	0.12	0.10	0.09	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07		
				kt-CO <sub>2</sub> eq.	39	34	30	26	23	22	22	22	22	21	21	20	20	20		
Total of all gases			kt-CO <sub>2</sub> eq.	166	145	126	112	96	95	93	94	92	88	88	84	85	84			

## b) Methodological Issues

### ● Estimation Method

CH<sub>4</sub> and N<sub>2</sub>O emissions were calculated by using the method indicated in the 2006 IPCC Guidelines.

$$E = A \times M_B \times C_f \times G_{ef} \times 10^{-3}$$

*E* : CH<sub>4</sub> and N<sub>2</sub>O emissions from field burning of agriculture residues [t-CH<sub>4</sub> or t-N<sub>2</sub>O]

*A* : Area burnt [ha]

*M<sub>B</sub>* : Mass of fuel available for combustion [t/ha]

*C<sub>f</sub>* : Combustion factor

*G<sub>ef</sub>* : Emission factor [g-CH<sub>4</sub>/kg or g-N<sub>2</sub>O/kg]

### ● Emission Factors

CH<sub>4</sub>: 2.7 [g-CH<sub>4</sub>/kg (dry matter)] (default value in the 2006 IPCC Guidelines, Table 2.5)

N<sub>2</sub>O: 0.07 [g-N<sub>2</sub>O/kg (dry matter)] (default value in the 2006 IPCC Guidelines, Table 2.5)

### ● Activity Data

Parameters used in estimation are indicated in the Table 5-76 below. For proportion of burned residue and combustion factor, same values in Crop Residues (3.D.a.4.) were used. For rice, since data of the amount of burning rice straw and rice chaff on crop field (Table 5-77) is available, mass of fuel available for combustion (*M<sub>B</sub>*) was not multiplied in estimation. The proportion burned in field for wheat, barley, rye and oats were the same values as shown in Table 5-66.

Table 5-76 Proportion of burned residue on agricultural field,  $M_B \times C_f$  and Combustion factor

Crop	Proportion of burned residue	$M_B \times C_f$	Combustion Factor ( $C_f$ )
Rice	---	---	0.80
Pulse	12% <sup>1)</sup>	10 <sup>3)</sup>	---
Vegetable, Sugarbeet, Maize, Tuber crops (e.g. potato), Buckwheat, Canola seed, Konjac, Rush grass, Tabaco	7% <sup>2)</sup>	10 <sup>3)</sup>	---
Sugarcane	7% <sup>2)</sup>	6.5	---
Wheat, Barley, Ray, Oats	See Table 5-66	4 <sup>4)</sup>	---

Reference: Proportion burned: *Survey of Greenhouse Gas Emissions from Soils and Soil Carbon Sequestration*  
 $M_B \times C_f$ : *2006 IPCC Guidelines*

Note: 1): value of pulse, 2): value of vegetable, 3): value of maize, 4): value of wheat

For rice, amount of rice straw and rice chaff burned on crop field is surveyed by MAFF (Table 5-77). The amounts of burning residue of other crops were estimated by area data described in the *Crop Statistics* or the *Vegetable Production and Shipment Statistics*.

Table 5-77 Amount of rice straw and rice chaff burned on crop field [kt]

Item	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Rice straw	438.2	536.9	429.1	276.6	149.3	187.0	149.4	183.4	161.7	144.2	152.8	129.3	136.1	123.3	123.3
Rice chaff	581.3	528.3	291.3	260.3	212.9	179.2	195.6	206.6	193.9	147.5	142.6	114.2	140.7	140.7	140.7
Total	1,019.5	1,065.2	720.4	536.9	362.2	366.2	345.0	390.0	355.6	291.7	295.4	243.5	276.8	264.0	264.0

Reference: Calculated from each prefecture data

### c) Uncertainties and Time-series Consistency

#### ● Uncertainties

For uncertainty of the emission factor, uncertainties (CH<sub>4</sub>: 296%, N<sub>2</sub>O: 300%) were calculated by synthesis of defaults of each parameter described in the *2006 IPCC Guidelines*. For activity data, 1% for area of paddy fields given in the *Statistics of Cultivated and Planted Area* was applied as substitution. As a result, the uncertainties of the emissions were determined to be 296% for CH<sub>4</sub> and 300% for N<sub>2</sub>O.

#### ● Time-series Consistency

Emissions are estimated by using consistent estimation methods and data sources.

### d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

### e) Category-specific Recalculations

Planted area of vegetable for FY1995 to FY1999, FY2008, and FY2019 were revised, the emissions for these years were recalculated. Since proportion removed from field and burned in field for wheat, barley, rye and oats were revised, the emissions for FY2019 were recalculated. See Chapter 10 for impact on trend.

### f) Category-specific Planned Improvements

No improvement plans.

## 5.8. Liming (3.G.)

### a) Category Description

CO<sub>2</sub> are released into the air by application of limestone (CaCO<sub>3</sub>) fertilizer and/or dolomite (CaMg(CO<sub>3</sub>)<sub>2</sub>) fertilizer via hydrogen carbonate ions (HCO<sub>3</sub><sup>-</sup>) which is released in soil water. This category deals with CO<sub>2</sub> emissions from their agricultural lime application.

CO<sub>2</sub> emissions from this category in FY2020 were 233 kt-CO<sub>2</sub>, comprising 0.02% of total emissions (excluding LULUCF). The value represents a decrease by 57.7% from FY1990.

Table 5-78 CO<sub>2</sub> emissions from agricultural lime application (3.G.)

Gas	Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
CO <sub>2</sub>	3.G.-Limestone	kt-CO <sub>2</sub>	550	303	332	231	242	246	369	379	362	258	252	293	241	241	232
	3.G.-Dolomite		0.3	0.5	0.5	0.6	1.0	1.1	0.6	1.1	1.0	0.8	0.8	0.9	0.9	0.9	0.8
	Total	kt-CO <sub>2</sub>	550	304	333	231	243	247	370	380	363	259	253	294	242	242	233

### b) Methodological Issues

#### ● Estimation Method

The Tier 1 method is used in accordance with the decision tree described in the *2006 IPCC Guidelines* (Vol.4, 11.27, Figure11.4).

$$E = (M_{Limestone} \times EF_{Limestone} + M_{Dolomite} \times EF_{Dolomite}) \times 44/12$$

$E$  : Annual CO<sub>2</sub> emissions from agricultural lime application [t-CO<sub>2</sub>/yr]

$M_{Limestone}$  : Annual amount of calcic limestone [t/yr]

$EF_{Limestone}$  : Emission factor of calcic limestone [t-C/t]

$M_{Dolomite}$  : Annual amount of dolomite [t/yr]

$EF_{Dolomite}$  : Emission factor of dolomite [t-C/t]

#### ● Emission Factors

Limestone (CaCO<sub>3</sub>): 0.12 [t-C/t] (default value, *2006 IPCC Guidelines*, Vol.4, page 11.29).

Dolomite (CaMg(CO<sub>3</sub>)<sub>2</sub>): 0.13 [t-C/t] (default value, *2006 IPCC Guidelines*, Vol.4, page 11.29).

#### ● Activity Data

##### ➤ Annual amount of limestone and dolomite applied to cropland

These data were calculated by adding up lime production and import quantities as listed in *the Yearbook of Fertilizer Statistics* published by the Association of Agriculture and Forestry Statistics. Based on expert judgment, all of the “Calcium carbonate fertilizer” and 70% of each of “Fossil seashell fertilizer”, “Crushed limestone” and “Seashell fertilizer” listed in the Yearbook were classified as calcic limestone (CaCO<sub>3</sub>), and all of the “Magnesium carbonate fertilizer” and 74% of “Mixed magnesium fertilizer” as dolomite (CaMg(CO<sub>3</sub>)<sub>2</sub>).

Table 5-79 Amount of limestone and dolomite applied to agricultural soils [kt]

Item	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Applied Limestone	1,250	689	755	524	550	558	839	860	822	586	573	665	548	549	527
Applied Dolomite	0.7	1.1	1.1	1.4	2.0	2.4	1.3	2.2	2.0	1.7	1.7	2.0	1.9	1.9	1.8

Reference: Estimated from the data described in *Yearbook of Fertilizer Statistics*

### c) Uncertainties and Time-series Consistency

#### ● Uncertainties

For uncertainty of the emission factor, default values (50%) described in the *2006 IPCC Guidelines* was



applied. For activity data, 1% for area of paddy fields given in the *Statistics of Cultivated and Planted Area* was applied as substitution. As a result, the uncertainties of the emissions were determined to be 50%.

- **Time-series Consistency**

Emissions are estimated by using consistent estimation methods and data sources.

**d) Category-specific QA/QC and Verification**

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

**e) Category-specific Recalculations**

Statistical data of limestone and dolomite in FY2019 were revised. The emissions for FY2019 were recalculated. See Chapter 10 for impact on trend.

**f) Category-specific Planned Improvements**

There are no improvement plans.

## 5.9. Urea application (3.H.)

**a) Source/Sink Category Description**

CO<sub>2</sub> are released into the air by application of urea ((NH<sub>3</sub>)<sub>2</sub>CO) fertilizer via hydrogen carbonate ions (HCO<sub>3</sub><sup>-</sup>) which is released in soil water. This category deals with estimation and reporting for this CO<sub>2</sub> emissions. Since estimation of urea production in Japan in Industrial Processes sector includes CO<sub>2</sub> emission in use phase, this category estimates CO<sub>2</sub> emissions from use phase of imported urea fertilizer.

CO<sub>2</sub> emissions from this category in FY2020 were 193 kt-CO<sub>2</sub>, comprising 0.02% of national total emissions (excluding LULUCF). The value represents an increase by 229% from FY1990.

Table 5-80 CO<sub>2</sub> emissions from urea fertilizer (3.H.)

Gas	Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
CO <sub>2</sub>	3.H. Urea fertilization	kt-CO <sub>2</sub>	59	56	110	179	160	168	150	198	189	201	193	193	193	193	193

**b) Methodological Issues**

- **Estimation Method**

The Tier 1 method is used in accordance with the decision tree described in the *2006 IPCC Guidelines* (Vol.4, p.11.33, Fig.11.5).

$$E = (M \times EF) \times 44/12$$

*E* : Annual CO<sub>2</sub> emissions from urea application [t-CO<sub>2</sub>/yr]  
*M* : Annual amount of imported urea fertilizer [t/yr]  
*EF* : Emission factor for urea application [t-C/t]

- **Emission Factors**

0.20 [t-C/t] (default value, *2006 IPCC Guidelines*, p.11.34).

- **Activity Data**

These data were calculated by deducting “amount of domestic urea production for fertilizer” from “total demand of urea fertilizer” described in *the Yearbook of Fertilizer Statistics (Pocket Edition)* published by the Association of Agriculture and Forestry Statistics.

Table 5-81 Amount of imported urea fertilizer [kt]

Item	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Amount of imported urea fertilizer	80	76	149	244	218	229	205	270	258	274	263	263	263	263	263

Reference: Estimated from the data described in *Yearbook of Fertilizer Statistics (Pocket Edition)*

- c) **Uncertainties and Time-series Consistency**

- **Uncertainties**

For uncertainty of the emission factor, default value (50%) described in the *2006 IPCC Guidelines* was applied. For activity data, 1% for area of paddy fields given in the *Statistics of Cultivated and Planted Area* was applied as substitution. As a result, the uncertainties of the emissions were determined to be 50%.

- **Time-series Consistency**

Emissions are estimated by using consistent estimation methods and data sources.

- d) **Category-specific QA/QC and Verification**

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

- e) **Category-specific Recalculations**

The data calculation method for the amount of imported urea fertilizer in the statistic from FY2017 forward was revised. Therefore, emissions of FY2017 onward were recalculated. See Chapter 10 for impact on trend.

- f) **Category-specific Planned Improvements**

There are no improvement plans.

## 5.10. Other Carbon-containing Fertilizers (3.I)

Since there are no other sources to be reported in this category, this category is reported as “NO”.

## 5.11. Other (3.J)

Since there are no other sources as “Other”, this category is reported as “NO”.

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## Chapter 6. Land Use, Land-Use Change and Forestry (CRF sector 4)

### 6.1. Overview of Sector

The land use, land-use change, and forestry (LULUCF) sector deals with greenhouse gas (GHG) emissions and removals resulting from land use such as forestry activities and its land-use change. GHG emissions and removals in this sector consist of carbon stock changes in five carbon pools (aboveground biomass, belowground biomass, dead wood, litter, and soil) in each land-use category, such as forest land (4.A.), cropland (4.B.), grassland (4.C.), wetlands (4.D.), settlements (4.E.) and other land (4.F.) which are divided in accordance with the *2006 IPCC Guidelines*' land-use classification, and carbon stock changes in harvested wood products (HWP) pool in forest land (4.G.). It also consists of direct N<sub>2</sub>O emissions from N fertilization (4.(I)), CH<sub>4</sub> and N<sub>2</sub>O emissions from drainage of organic soils (4.(II)), N<sub>2</sub>O emissions from nitrogen mineralization resulting from land-use changes in mineral soils or changes of its management (4.(III)), indirect N<sub>2</sub>O emissions from managed soils (4.(IV)), and CH<sub>4</sub> and N<sub>2</sub>O emissions, etc. from biomass burning (4.(V)) also in each category (except N<sub>2</sub>O emissions from 4.(I) and 4.(II) in cropland and grassland as well as from 4.(III) and 4.(IV) in cropland remaining cropland, which are reported in the Agriculture sector). Methodological tiers used in this sector are shown in Table 6-1. In this chapter, above- and below- ground biomass are collectively referred as “living biomass”, and dead wood and litter are also referred as “dead organic matter”.

This sector includes both sources and sinks; however, it has been continuously a net sink since FY1990 in Japan. Net removals in FY2020 were 52,010 kt-CO<sub>2</sub> eq; which accounts for 4.7% of the total national emissions (excluding LULUCF). The net removals in FY2020 also represent a decrease of 20.4% compared to FY1990 and an increase of 2.1% compared to FY2019. Net removals in Japan had been increasing from FY1990 to FY2003, but have been on a long-term decreasing trend since FY 2004. The key drivers for the rise in removals from FY1990 to FY2003 were increase of removals in forest land, decrease of the amount of carbon loss in mineral soils in cropland and decrease of emissions due to the decrease of areas of forest land-conversion. The decreasing trends in net removals after FY 2004 are mainly caused by the decrease of removals in forest land.

Table 6-1 Methodological tiers used in the LULUCF sector

GHG source and sink category	CO <sub>2</sub>		CH <sub>4</sub>		N <sub>2</sub> O	
	Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor
A. Forest land	T1,T2,T3	CS,D	T1	D	T1,T2	CS,D
B. Cropland	T1,T2,T3	CS,D	T1	D	T1,T2	CS,D
C. Grassland	T1,T2,T3	CS,D	T1	D	T1,T2	CS
D. Wetlands	T1,T2	CS,D	-	-	-	-
E. Settlements	T1,T2	CS,D	T1	CS,D	T1	CS,D
F. Other land	T2	CS,D	-	-	T1	D
G. Harvested wood products	T2,T3	CS,D				

Note: D: IPCC default, T1: IPCC Tier1, T2: IPCC Tier2, T3: IPCC Tier3, CS: country-specific method or emission factor

Japan's national land is an archipelago consisting of Hokkaido, Honshu, Shikoku, Kyushu and other islands, and lies off the east coast of the Eurasian Continent. The archipelago is formed into a crescent shape extending from northeast to southwest. Its northernmost point is located at about 45 degrees north

latitude, and its southernmost point is located at about 20 degrees north latitude. Most of Japan's national land is located in a temperate, humid climate zone. Some islands in the southern part of Japan belong to a subtropical climate zone, and the northern part of Japan is located in a cool-temperate climate zone.

## 6.2. Land-use definitions and the classification systems used and their correspondence to the land use, land-use change and forestry categories

In order to classify all lands in Japan into one of the 6 land-use categories in accordance with the 2006 IPCC Guidelines, each land is allocated in each land-use category on the basis of the criteria and definitions in existing statistics in Japan as shown in Table 6-2. Lands which are not classified into the five land-use categories (forest land, cropland, grassland, wetlands and settlements) is defined as "Other Land", of which the area is determined by deducting the total area of five land-use categories from total national land. In addition, the years for which statistics are not available are supplemented by interpolation or the substitution of the previous year's value.

Table 6-2 Criteria for IPCC land-use category allocation and data source and methods for determining land areas

IPCC Land-use category	Criteria for land-use category allocation	Data source and methods for determining land areas
Forest land	Forests under Forest Law Article 5 and 7.2.	Forests with standing trees (intensively managed forests, semi-natural forests), forests with less standing trees and bamboo in the forests which are included in the regional forests plan according to the <i>Forestry Status Survey</i> [-FY2004] and the <i>National Forest Resources Database (NFRDB)</i> [FY2005-] (Forestry Agency). <sup>1</sup>
Cropland	Rice fields, upland fields, orchards and dilapidated farmland	Rice fields, upland fields and orchard according to <i>Statistics of Cultivated and Planted Area</i> by the MAFF. Dilapidated farmland according to <i>Census of Agriculture and Forestry</i> (MAFF) and <i>Survey on the Occurrence and Resolution of Dilapidated Farmland</i> (MAFF), etc.
Grassland	Pasture land, grazed meadow land, and wild land <sup>2</sup> . (excluding pasture land and grazed meadow land)	Pasture land according to <i>Statistics of Cultivated and Planted Area</i> (MAFF), grazed meadow land (excluding when it is included in forest land) according to <i>Census of Agriculture and Forestry</i> (MAFF), and wild land according to <i>Land Use Status Survey</i> (MLIT).
Wetlands	Lands covered with water (such as dams), rivers, and waterways.	Lands covered with water, rivers, and waterways according to <i>Land Use Status Survey</i> , <i>Survey of Forestry regions</i> (MLIT). The green areas along rivers and erosion control sites allocated to settlements are subtracted from this area.
Settlements	Urban areas that do not constitute forest land, cropland, grassland or wetlands. Urban green areas are all wooded and planted areas that do not constitute forest land.	Settlements are roads, residential land, school reservations, park and green areas, road sites, environmental facility sites, golf courses, ski courses and other recreation sites identified in <i>Land Use Status Survey</i> and other surveys by the MLIT. The included figures for urban green areas are taken from the surveys on urban green facilities conducted by the MLIT. (Details are shown in Table 11-11).
Other land	Any land that does not belong to the above land-use categories.	Determined by subtracting the total area belonging to the above five land-use categories from the total area of national land according to <i>Statistical Reports on the Land Area by Prefectures and Municipalities in Japan</i> by the Geospatial Information Authority of Japan.

Note: MAFF: Ministry of Agriculture, Forestry and Fisheries; MLIT: Ministry of Land, Infrastructure, Transport and Tourism

<sup>1</sup> The *Forestry Status Survey* and the *National Forest Resources Database (NFRDB)* use the same definitions and survey methods for forests, and these two data bases have time-series consistency.

<sup>2</sup> Its present status is mainly wild grassland (including perennial pasture land, degenerated pasture land, and areas abandoned after cultivation and becoming wild). The item of "wild land" was changed to "wild land, etc" including grazed meadow land, so the areas of wild land from 2011 onward were calculated excluding grazed meadow land of the "*Census of Agriculture and Forestry*".

Japan's total land area as of FY2020 identified from the above is about 37.8 million ha. The most dominant land-use type is forest land comprising 66.1 % of the land or about 24.98 million ha, followed by cropland comprising 10.7 % of the land or about 4.06 million ha. In addition, grassland, wetlands, settlements, and other land cover about 0.95 million ha, 1.35 million ha, 3.89 million ha, and 2.57 million ha, respectively. In the estimation and reporting in LULUCF sector, only land territory is included and sea area for which the *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands* (hereafter *Wetlands Guidelines*) provides some methodologies is excluded. Our land area has had some increment by 0.06% since FY1990 because of the reclamation by drainage and landfilling of sea areas<sup>3</sup>, and this increment is included in our land territory.

In addition, our national determined country-specific subcategories are established as for forest land, cropland, grassland and settlements (forest land: forests with standing trees (intensively managed forests / semi-natural forests) / forests with less standing trees / bamboo; cropland: rice fields / upland fields / orchards / dilapidated farmland; grassland: pasture land / grazed meadow land / wild land; settlements: special greenery conservation zones / urban green facilities / other). The definition of country-specific subcategory for forest land is shown in Table 6-3.

Table 6-3 Definitions of forest subcategories

Forest subcategories	Definitions
Forest with standing trees	Forest that does not fall under "forest with less standing trees" and has a tree crown cover of standing trees 30% or higher (including young stands with the degree of stocking of 3 or higher even though the tree crown cover is less than 30%). Even if the tree crown cover of standing trees is less than 30%, forest in which the sum of the crown covers of both standing trees and bamboo is 30% or higher, while dominated by standing trees, is also included.
Intensively managed forest	Forest land that is subject to artificial regeneration such as tree planting and seeding, and in which no less than 50% of the volume (or the number) of standing trees are of tree species subject to artificial regeneration.
Semi-natural forest	Forest with standing trees which is not classified as intensively managed forests
Forest with less standing trees	Forest in which the sum of the tree crown covers of both standing trees and bamboo is less than 30 percent.
Bamboo	Forest, other than "forest with standing trees", in which a tree crown cover of bamboo (excluding bamboo grasses) is 30% or higher. Even if the tree crown cover of bamboo is less than 30%, forest in which the sum of the crown covers of both standing trees and bamboo is 30% or higher with bamboo being dominated is also included.

Reference: Forestry Agency of Japan, *Forest Status Survey* (March, 2007) (partially modified)

Note: The degree of stocking is the ratio of actual volume to the expected volume of the forest stand, multiplied by 10.

Furthermore, each land-use category is classified into "Land remaining Land" and "Land converted to Land" depending on its history of land-use conversion. To classify into these two sub-categories, a default value of 20 years is applied as the threshold to distinguish the occurrences of land-use conversion in accordance with the *2006 IPCC Guidelines*. Each land-use area is estimated based on existing statistics. Among them, areas of land conversion between other land-use categories and forest land are estimated based on data utilizing orthophotos and satellite images, in addition to existing statistics. For detailed information on the methods of determining the areas of afforestation, reforestation and deforestation using image interpretation, see section 11.4.2.3. in Chapter 11. Other estimation measures are described in the next section and each section.

<sup>3</sup> *Statistical reports on the land area by prefectures and municipalities in Japan* (the Geospatial Information Authority of Japan: GSI) <<http://www.gsi.go.jp/kokusaikoryu/kokusaikoryu-e30092.html>>

### 6.3. Approaches for estimating land areas and land-use database used for the inventory preparation

#### 6.3.1. Survey methods and due dates of major land area statistics

Table 6-4 shows the survey methods and due dates of major land area statistics.

Table 6-4 Survey methods and due dates of major land area statistics

Name of the statistics / census	Survey method	Survey due date	Frequency	Presiding ministry
Forest Status Survey	Complete count survey	March, 31 <sup>st</sup>	Approximately every 5 years	Forestry Agency
National Forest Resources Database (NFRDB)	Complete count survey	April, 1 <sup>st</sup>	Every year	Forestry Agency
Statistics of Cultivated and Planted Area (Survey of cropland area)	[Cropland area]	Ground measurement survey (sample)	Every year	MAFF
	[Expansion area and converted area of cropland]	Tabular survey (using documents from relevant agencies and aerial photographs, etc.)		
Census of Agriculture and Forestry	Complete count survey	February, 1 <sup>st</sup>	Every 5 years	MAFF
Land Use Status Survey	Complete count Survey	October, 1 <sup>st</sup>	Every year	MLIT
Statistical Reports on the Land Area by Prefectures and Municipalities in Japan	Complete count Survey	October, 1 <sup>st</sup>	Every year	GSI

Details of surveys for urban green facilities are shown in Table 11-11.

#### 6.3.2. Land area estimation methods

Some land areas cannot be directly determined from existing statistics; therefore, they are estimated using the following methods:

- Interpolation
- Allocation of areas of land conversion by means of the ratio of actual land areas for each land-use category
- Allocation of areas of land conversion by means of the ratio of converted land areas for a certain year
- Estimation of area by using the ratio of the number of conversion points to the total number of interpretation points by identifying the presence or absence of land conversion by image comparison at two different time points.

Please refer to each related section for more detailed explanations about estimation method in individual area.

#### 6.3.3. Land-use transition matrix

Land-use transition matrix to determine land use conversion has been produced annually since FY1990 until now, for six land use categories whose areas are identified in accordance with the description in section 6.2. and in the beginning part of section 6.3. Land use conversion made in FY1990 and in FY2020 are shown in the following Table 6-5 and Table 6-6, respectively. In addition, land use matrix produced by accumulating land conversion between each land use category, from the beginning of FY1990 to the end of FY2020, is shown in Table 6-7.

Table 6-5 Land-use transition matrix for Japan in FY1990 [kha]

After Conversion \ Before Conversion	Forest land	Cropland	Grassland	Wetlands	Settlements	Other land	Total
Forest Land	24,945.68	5.27	0.74	0.31	14.56	3.61	24,970.17
Cropland	2.71	4,757.60	0.90	0.02	21.35	2.16	4,784.75
Grassland	0.67	0.00	1,029.78	0.01	3.19	0.36	1,034.01
Wetlands	NO	0.34	0.12	1,308.56	IE	IE	1,309.02
Settlements	0.60	IE	NO	0.00	3,160.13	IE	3,160.74
Other land	0.60	0.21	0.01	0.09	0.76	2,513.36	2,515.03
Total	24,950.27	4,763.42	1,031.55	1,308.99	3,200.00	2,519.48	37,773.71

Table 6-6 Land-use transition matrix for Japan in FY2020 [kha]

After Conversion \ Before Conversion	Forest land	Cropland	Grassland	Wetlands	Settlements	Other land	Total
Forest Land	24,984.89	0.35	0.16	0.08	4.06	0.30	24,989.82
Cropland	NO	4,052.09	0.54	0.01	8.28	5.31	4,066.23
Grassland	0.03	0.01	943.15	0.00	1.41	0.61	945.20
Wetlands	NO	NO	NO	1,348.20	IE	IE	1,348.20
Settlements	NO	IE	NO	0.00	3,875.15	IE	3,875.15
Other land	NO	6.49	1.25	0.02	0.11	2,565.06	2,572.92
Total	24,984.91	4,058.93	945.10	1,348.31	3,889.00	2,571.27	37,797.53

Table 6-7 Land-use transition matrix of Japan for FY1990-FY2020 [kha]

2020 \ 1990	Forest land	Cropland	Grassland	Wetlands	Settlements	Other land	Total
Forest Land	24,883.16	27.95	13.65	16.40	217.07	51.72	25,209.96
Cropland	38.19	3,977.46	24.01	1.37	394.88	80.33	4,516.23
Grassland	12.93	1.09	901.08	0.28	61.15	11.23	987.76
Wetlands	0.14	1.08	0.43	1,325.65	IE	IE	1,327.29
Settlements	27.03	IE	NO	0.08	3,190.20	IE	3,217.31
Other land	23.47	51.35	5.93	4.53	25.70	2,427.99	2,538.98
Total	24,984.91	4,058.93	945.10	1,348.31	3,889.00	2,571.27	37,797.53
Net change	-225.04	-457.30	-42.66	21.02	671.69	32.30	-

Note: The areas described as "IE" are included in "Other lands remaining the same land-use category" which could be used for adjustment with total area of national land.

#### 6.4. Parameters for estimating carbon stock changes due to land-use conversions

Prior to the sections describing detailed methods for each land-use category, basic parameters used for estimating carbon stock changes due to land-use conversions are shown here (Table 6-8 to Table 6-13) to avoid the reiteration of indicating these parameters in each subsequent section. Parameters for estimations in the categories of land-use conversion from forest land are set by each year in time series. The values are shown in Table 6-13.

Table 6-8 Biomass stocks or carbon stocks in living biomass before and immediately after land-use conversion

Land use category		Biomass stocks or Carbon stocks	Methodology for setting parameters and data source used	
Before conversion	Forest land	146.4 [t-d.m./ha] (FY2020)	The values of biomass stocks in land of deforestation under Article 3.3, of the Kyoto Protocol are used for biomass loss from conversion of forest per unit area occurred in each year at the land. The values from FY1990 to FY2007 are substituted by the average value from FY2008 to FY2012 in the first commitment periods. (See Table 6-13 for the value at each year in the time series.)	
	Cropland	Cropland (Average)	1.7 [t-C/ha]	Average value of below-listed rice and upland fields from FY 1990 to FY2017 (Weighted average value of area in rice and upland fields is used for the value at each year.) The amount of dry matter of crop residues plowed into rice and upland fields is estimated by utilizing the activity data in the agriculture sector (3.D.a.4.)
		Rice field	2.0 [t-C/ha]	Average carbon content of crop residues plowed into rice fields from FY1990 to FY2017
		Upland field	1.3 [t-C/ha]	Weighted average carbon content of crop residues plowed into upland fields from FY1990 to FY2017, calculated by crop cultivation area for each type of crop.
		Orchard	-	It is not indicated since carbon stock change after conversion is calculated collectively in the calculation of the “orchard” in cropland remaining cropland. See 6.6.1.b) for the parameter of “orchard remaining orchard”.
	Grassland	13.5 [t-d.m./ha]	Default value (Table 6.4: “warm temperate wet”, Volume 4 of the 2006 IPCC Guidelines)	
	Wetlands, settlements and other land	0 [t-d.m./ha]	Assumed to be “0”.	
Immediately after conversion	All land uses	0 [t-d.m./ha]	Assumed to be “0”.	

Table 6-9 Annual increments in living biomass after land-use conversion

Land use category		Annual increments	Methodology for setting parameters and data source used	
After conversion	Forest land	3.0 [t-C./ha/yr]	To estimate the average annual growth of forests within 20 years after conversion, average growth increments per unit area for 3 years (FY2008-FY2010) including year of FY2009, which is 20 years after the start of AR activity under the Kyoto Protocol, is applied.	
	Cropland	Cropland (Average)	1.7 [t-C/ha/yr]	Assumed that carbon stock after conversion reaches the value in Table 6-8 in one year
		Rice field	2.0 [t-C/ha/yr]	Assumed that carbon stock after conversion reaches the value in Table 6-8 in one year
		Upland field	1.3 [t-C/ha/yr]	Assumed that carbon stock after conversion reaches the value in Table 6-8 in one year
		Orchard	-	It is not indicated since carbon stock change after conversion is calculated collectively in the calculation of the "orchard" in cropland remaining cropland.
	Grassland	2.7 [t-d.m./ha/yr]	Assumed that carbon stock after conversion reaches the default value (Table 6.4: 13.5 at "warm temperate wet", Volume 4 of the 2006 IPCC Guidelines) in 5 years.	
	Settlements (urban green facilities)	Green areas on roads	0.0103 [t-C/tree/yr] 0.0108 [t-C/tree/yr]	Values on the left: upper Hokkaido, lower: Other than Hokkaido See Table 6-41 for the methodology used.
		Other than green areas on roads	0.0098 [t-C/tree/yr] 0.0105 [t-C/tree/yr]	
Wetlands, Settlements (other than above) and other land		0 [t-C/ha/yr]	Assumed to be "0".	

Table 6-10 Carbon stocks in dead wood before, immediately after and after land-use conversion

Land-use Category		Carbon Stocks	Methodology for setting parameters and data source used
Before Conversion	Forest land	14.5 [t-C/ha] (FY2020)	Average carbon stocks in dead wood in all forests with standing trees in the previous year of the inventory year calculated by the CENTURY-jfos model. The values before 2004 are substituted by the value of FY2005. (See Table 6-13 for the value at each year in the time series.)
	Cropland, grassland, wetlands, settlements, other land	0 [t-C/ha]	Default value (Section 5.3.2 etc. in Volume 4 of the 2006 IPCC Guidelines, Tier 1)
Immediately after conversion	All land uses	0 [t-C/ha]	Default value (Section 5.3.2 etc. in Volume 4 of the 2006 IPCC Guidelines, Tier 1)
After conversion	Forest land	13.0 [t-C/ha]	Average carbon stocks per unit area in 20-year-old forests calculated by the CENTURY-jfos model
	Cropland, grassland, wetlands, other land	0 [t-C/ha]	Default value (Section 5.3.2 etc. in Volume 4 of the 2006 IPCC Guidelines, Tier 1)
	Settlements	0 [t-C/ha]	Default value (Section 8.3.2 in Volume 4 of the 2006 IPCC Guidelines, Tier 1) If land is converted to urban green facilities, it is not indicated since it is included in the estimation of stock changes in living biomass.

Table 6-11 Carbon stocks or annual changes in litter before, immediately after and after land-use conversion

Land-use Category		Carbon Stocks or Annual Change	Methodology for setting parameters and data source used
Before Conversion	Forest land	7.3 [t-C/ha] (FY2020)	Average carbon stocks in litter in all forests with standing trees in the previous year of the inventory year calculated by the CENTURY-jfos model. The values before FY2004 are substituted by the value of FY2005. (See Table 6-13 for the value at each year in the time series)
	Cropland, grassland, wetlands, settlements, other land	0 [t-C/ha]	Default value (Section 5.3.2 etc. in Volume 4 of the 2006 IPCC Guidelines, Tier 1)
Immediately after conversion	All land-uses	0 [t-C/ha]	Default value (Section 5.3.2 etc. in Volume 4 of the 2006 IPCC Guidelines, Tier 1)
After conversion	Forest land	5.6 [t-C/ha]	Average carbon stocks per unit area in 20-year-old forests calculated by the CENTURY-jfos model
	Cropland, grassland, wetlands, settlements (other than below) and other land	0 [t-C/ha]	Default value (Section 5.3.2 etc. in Volume 4 of the 2006 IPCC Guidelines, Tier 1)
	Settlements (urban green facilities (urban parks and green areas on roads))	0.0882 [t-C/ha/yr] 0.0594 [t-C/ha/yr]	Values on the left: upper Hokkaido, lower: Other than Hokkaido See section 6.9.2.b2) for the methodology used.

Table 6-12 Carbon stocks in mineral soils before and after land-use conversion

Land-use Category		Carbon Stocks	Methodology for setting parameters and data source used	
Before conversion	Forest land	85.5 [t-C/ha] (FY2020)	Average carbon stocks in soils in all forests with standing trees in the previous year of the inventory year calculated by the CENTURY-jfos model. The value in FY2005 is applied to the years before 2004. (See Table 6-13 for the value at each year in the time series)	
	Cropland	Rice field	71.4 [t-C/ha]	Value of soil carbon stocks at 0-30 cm depth. Data provided from Dr. Makoto Nakai, National Institute for Agro-Environmental Sciences (Unpublished) * These carbon stocks were not applied to “cropland converted to grassland” and “grassland converted to cropland”, since it is included in the calculation of the Roth C model that takes into account the history of land conversion.
		Upland field	87.0 [t-C/ha]	
		Orchard	77.5 [t-C/ha]	
		Cropland (average)	76.5 [t-C/ha]	
	Grassland	134.9 [t-C/ha]	Default value (the 2006 IPCC Guidelines Table 2.3, Wetland soils/ Warm temperate).	
	Wetlands	88.0 [t-C/ha]	Default value (the 2006 IPCC Guidelines Table 2.3, Wetland soils/ Warm temperate).	
Settlements and Other land	-	These values are determined depending on land use after conversion.		
After conversion	Forest land	82.9 [t-C/ha]	Value of soil carbon stocks at 0-30 cm depth. Average carbon stocks per unit area in 20-year-old forests calculated by the CENTURY-jfos model.	
	Cropland	-	It is not indicated since it is included in the estimation in cropland remaining cropland.	
	Grassland	-	It is not indicated since it is included in the estimation in grassland remaining grassland.	
	Wetlands	-	Assumed to have no change before and after conversion as no method provided in the 2006 IPCC Guidelines.	
	Settlements and Other land	-	These values are determined depending on land use after conversion.	

Note: All carbon stocks in mineral soils before conversion to forest land are regarded as 80.0 t-C/ha due to expert judgment.



Table 6-13 Biomass stocks or Carbon stocks in each carbon pool in forest land before land-use conversion

Carbon pools	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Biomass	t-d.m./ha	113.4	113.4	113.4	113.4	99.8	100.6	123.2	98.5	99.0	99.5	99.9	100.3	100.4	145.3	146.4
Dead wood	t-C/ha	15.1	15.1	15.1	15.1	15.0	15.0	14.9	14.9	14.8	14.8	14.8	14.7	14.6	14.6	14.5
Litter	t-C/ha	7.2	7.2	7.2	7.2	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3
Soil	t-C/ha	85.1	85.1	85.1	85.1	85.2	85.2	85.3	85.3	85.3	85.4	85.7	85.5	85.4	85.5	85.5

## 6.5. Forest land (4.A.)

All forests in Japan are managed forests, and they consist of intensively managed forests, semi-natural forests, bamboo, and forests with less standing trees. The definitions of these subcategories are shown in Table 6-3. In terms of forest management types, forests with standing trees are divided into Ikusei-rin forests and Tennensei-rin forests depending on management types. Ikusei-rin forests are further divided into “intensively managed forests” which are mainly regenerated by planting, and a part of “semi-natural forests” which are regenerated by supplementary works such as site preparation. In Ikusei-rin forests, practices for establishment and maintenance of single- or multi-storied forests have been carried out after clear-cutting or selective cutting. In Tennensei-rin forests, practices for establishment and maintenance of forest mainly depending on natural power are carried out. Practices carried out to maintain the forest in an appropriate state in Ikusei-rin forests include regeneration, tending, thinning and harvesting. For Tennensei-rin forests, practices for protection or conservation of forests including controlling logging activities and land-use change have been carried out based on laws.

As described above, the forest types are broadly divided into “intensively managed forests in Ikusei-rin forests”, “semi-natural forests in Ikusei-rin forests” and “Tensei-rin forests”. However, for the sake of reporting under the Convention, “intensively managed forests in Ikusei-rin forests” are referred to as “intensively managed forests” and “semi-natural forests in Ikusei-rin forests” and “Tensei-rin forests” are collectively referred to as “semi-natural forests”. See section 11.3.1. to 11.3.2. for more details of the definitions.

Japan’s forest land area in FY2020 was about 24.98 million ha; about 66.1% of the total national land area. The net removal in this category in FY2020 was 57,139 kt-CO<sub>2</sub> (GHG emissions other than changes in carbon stock are not included). This represents an increase of 3.4% compared to FY2019, but a decrease of 27.7% compared to the FY1990 value, and it has been on a decreasing trend in the long term.

Table 6-14 Emissions and removals in forest land resulting from carbon stock changes

Category	Carbon pool	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
4.A. Forest land	Total	kt-CO <sub>2</sub>	-79,061	-87,606	-90,637	-92,636	-76,345	-78,085	-77,653	-69,968	-68,258	-63,088	-58,545	-60,835	-59,238	-55,243	-57,139
	Living Biomass	kt-CO <sub>2</sub>	-73,002	-79,826	-83,660	-87,526	-73,888	-76,216	-76,244	-68,871	-67,329	-62,242	-57,733	-59,983	-58,359	-54,379	-56,255
	Dead Wood	kt-CO <sub>2</sub>	-2,860	-3,803	-2,837	-1,082	934	1,360	1,672	1,846	1,887	1,867	1,799	1,675	1,554	1,450	1,347
	Litter	kt-CO <sub>2</sub>	-2,697	-2,352	-1,774	-1,078	-567	-496	-448	-411	-382	-370	-353	-348	-328	-291	-266
	Mineral soil	kt-CO <sub>2</sub>	-503	-1,625	-2,367	-2,950	-2,824	-2,734	-2,634	-2,532	-2,434	-2,344	-2,257	-2,179	-2,106	-2,023	-1,965
	Organic soil	kt-CO <sub>2</sub>	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4.A.1. Forest land remaining Forest land	Total	kt-CO <sub>2</sub>	-72,390	-84,316	-88,279	-90,891	-75,063	-76,834	-76,431	-68,780	-67,123	-62,012	-57,522	-59,867	-58,336	-54,408	-56,373
	Living Biomass	kt-CO <sub>2</sub>	-68,101	-77,409	-81,928	-86,251	-72,953	-75,303	-75,352	-68,000	-66,497	-61,453	-56,984	-59,271	-57,695	-53,765	-55,691
	Dead Wood	kt-CO <sub>2</sub>	-1,792	-3,276	-2,459	-799	1,143	1,564	1,872	2,037	2,070	2,041	1,964	1,829	1,699	1,583	1,469
	Litter	kt-CO <sub>2</sub>	-2,233	-2,124	-1,610	-955	-477	-407	-361	-328	-303	-294	-282	-281	-266	-233	-213
	Mineral soil	kt-CO <sub>2</sub>	-264	-1,507	-2,282	-2,887	-2,777	-2,688	-2,589	-2,489	-2,393	-2,305	-2,220	-2,145	-2,074	-1,994	-1,938
	Organic soil	kt-CO <sub>2</sub>	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4.A.2. Land converted to Forest land	Total	kt-CO <sub>2</sub>	-6,671	-3,290	-2,358	-1,745	-1,281	-1,251	-1,222	-1,188	-1,135	-1,077	-1,023	-968	-902	-835	-767
	Living Biomass	kt-CO <sub>2</sub>	-4,900	-2,417	-1,732	-1,275	-936	-913	-892	-872	-833	-789	-749	-712	-663	-614	-564
	Dead Wood	kt-CO <sub>2</sub>	-1,069	-527	-378	-284	-209	-204	-200	-191	-183	-174	-165	-155	-144	-133	-122
	Litter	kt-CO <sub>2</sub>	-463	-228	-164	-123	-90	-88	-86	-83	-79	-75	-72	-67	-62	-58	-53
	Mineral soil	kt-CO <sub>2</sub>	-239	-118	-84	-63	-47	-46	-45	-43	-41	-39	-37	-35	-32	-30	-27
	Organic soil	kt-CO <sub>2</sub>	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

### 6.5.1. Forest land remaining Forest land (4.A.1.)

#### a) Category Description

This subcategory deals with carbon stock changes in forest land remaining forest land, which has remained forested without conversion for the past 20 years as of FY2020. The net removal in this subcategory in FY2020 was 56,373 kt-CO<sub>2</sub> (GHG emissions other than changes in carbon stock are not included). This represents a decrease of 22.1% compared to FY1990 and an increase of 3.6% compared to FY2019. It had been on an increasing trend from FY1990 to FY2004, but has been decreasing since FY2005. The increase in net removals in the first half of the reporting period is mainly due to the growth in intensively managed forests, and the decrease in net removals in the latter half of the period is mainly due to progression in the maturation of those intensively managed forests.

As for a factor in influencing changes on the growth of forest, growing stock becomes slow in growing stock over 50. Large-scale plantation was carried out in Japan in the 1960s, but the amount of plantation has decreased since then. Therefore, this large-scale plantation had contributed to the increase in removals until around FY2004, but the removals began to decrease from around FY2005 due to progression in the maturation. Since then, the distribution of the age class of planted forests has further shifted to the elderly side, with these forests over 51 years old accounting for 50% of the total intensively managed forests area in FY2017 (Figure 6-1).

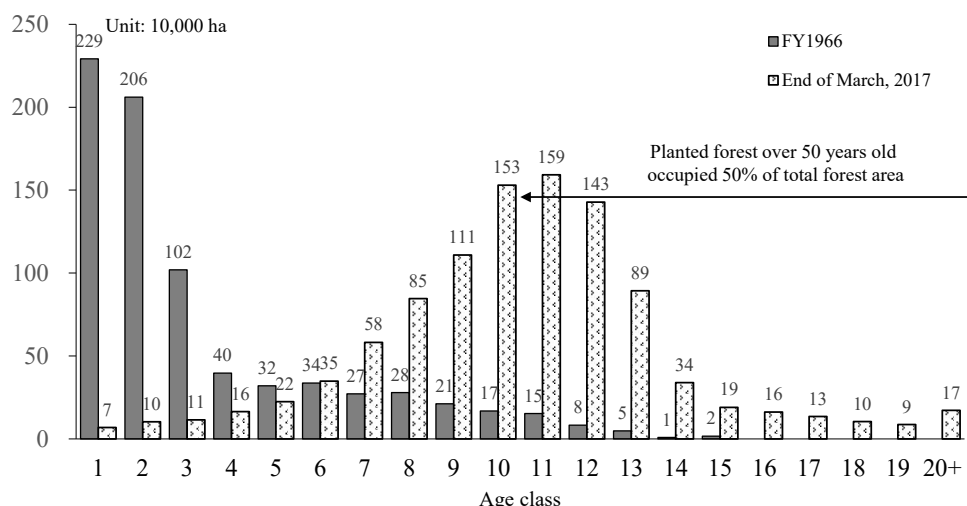


Figure 6-1 Changing forest age class configuration of planted forests

Sources: State of Forest Resources (March 31, 2017) (Forestry Agency); Forest Resources of Japan (April 1968) (Forestry Agency)

Note: Age-classes are divided by 5 year-period steps. "Age-class 1" includes the 1st to 5th year after plantation with the year of plantation counted as the 1st year.

Recently, domestic wood supply has been on an increasing trend. The changes in supply of domestically produced wood since 1990 are shown in Figure 6-2. The supply of domestic wood had been declining from FY1990 to FY2002, but since then, the supply has turned to an increasing trend and has been continuously increasing. As mentioned above on the trend of growing stock in the forests, forest resources in Japan have become enriched to be able to meet the demand for wood supply since those forests planted in the 1960s have grown enough to be harvested around 2000, and the use as woody biomass in power generation facilities has increased in recent years, both of which affect the increase in wood supply from FY2003.

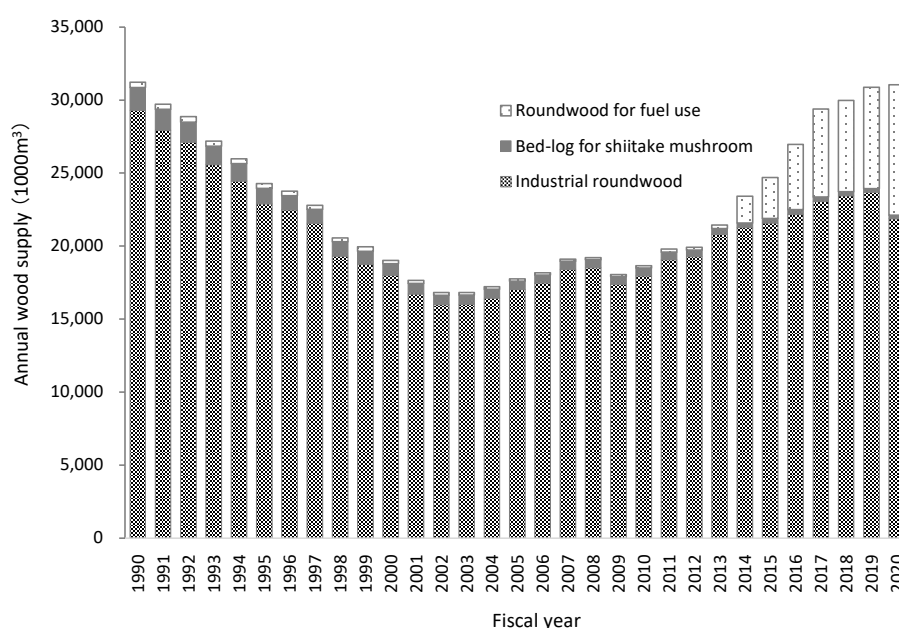


Figure 6-2 Changes in the supply of domestic wood (except logging residue)

Source: Table of supply and demand of wood (FY2020) (Forestry Agency)

## b) Methodological Issues

### 1) Carbon stock changes in Living Biomass in “Forest land remaining Forest land”

#### ● Estimation Method

#### ➤ Carbon stock changes in Living Biomass in intensively managed forests, semi-natural forests and forests with less standing trees

The Tier 2 stock difference method is used for the estimation in the subcategories. Since the NFRDB collectively deals with carbon stock changes in living biomass in “forest land remaining forest land” and “land converted to forest land”, it is difficult to separate those in “forest land remaining forest land” from the total. Therefore, those in “forest land remaining forest land” ( $\Delta C_{FF\_LB}$ ) are obtained by subtracting those amount in “land converted to forest land” ( $\Delta C_{LF\_LB}$ ) calculated by estimation from the amount of carbon stock change in the entire forest land ( $\Delta C_{F\_LB}$ ). See section 6.5.2.b)1) for the method of estimating the amount of carbon stock changes in “land converted to forest land”.

$$\Delta C_{FF\_LB} = \Delta C_{F\_LB} - \Delta C_{LF\_LB}$$

$$\Delta C_{F\_LB} = \sum_k \{(C_{t2} - C_{t1}) / (t_2 - t_1)\}_k$$

$\Delta C_{FF\_LB}$  : Annual change in carbon stocks in living biomass in forest land remaining forest land [t-C/yr]

$\Delta C_{F\_LB}$  : Annual change in carbon stocks in living biomass in entire forest land [t-C/yr]

$\Delta C_{LF\_LB}$  : Annual change in carbon stocks in living biomass in the land converted to forest land [t-C/yr]

$t_1, t_2$  : Time points of carbon stock measurement

$C_{t1}$  : Total carbon stock in biomass calculated at time  $t_1$  [t-C]

$C_{t2}$  : Total carbon stock in biomass calculated at time  $t_2$  [t-C]

$k$  : Type of forest management, or forests with less standing trees

$$C_{F\_LB} = \sum_j \{V_j \times D_j \times BEF_j \times (1 + R_j) \times CF\}$$

$C_{F\_LB}$	: Carbon stock in living biomass in entire forest land[t-C]
$V$	: Merchantable volume [m <sup>3</sup> ]
$D$	: Wood density [t-d.m./m <sup>3</sup> ]
$BEF$	: Biomass expansion factor for conversion of merchantable volume
$R$	: Root-to-shoot ratio
$CF$	: Carbon fraction of dry matter [ t-C/t-d.m.]
$j$	: Tree species (Private forests or National forests in the case of forests with less standing trees)

$$V_j = \sum_m (A_{m,j} \times v_{m,j})$$

$V$	: Merchantable volume [m <sup>3</sup> ]
$A$	: Area [ha]
$v$	: Merchantable volume per unit area [m <sup>3</sup> /ha]
$m$	: Age class or forest age
$j$	: Tree species

### ➤ **Carbon stock changes in Living Biomass in Bamboo**

Carbon stock changes in living biomass in Bamboo are reported as “NA” because annual growth and death of bamboo trunk in established bamboo can be regarded as equivalent. Bamboo does not have a vascular cambium, therefore, it reaches the limit of growth in the first year of the emergence and then do not exhibit secondary growth, and as such, in bamboo forests that have reached a certain density, the amount of bamboo emerged is said to be equal to the amount that dies. The result of FAO’s survey (2007) of bamboo resource status in 2000 and 2005 in several countries in Asia and Africa also showed that the carbon stock per unit area for the 5 years from 2000 to 2005 remained almost flat.

#### ● **Parameters**

### ➤ **Parameters for calculating Merchantable Volume of standing trees (Volume per unit area by tree species and by forest ages)**

The area by tree species and by forest ages used to calculate the merchantable volume is based on the information of forest area, tree species and forest ages obtained from the Forest Register. The Forest Register is developed through the procedures shown in Figure 6-3 and the data of the private forests are updated by prefectures while the ones of the national forests are updated by the Regional Forest Offices of National Forests every year. At the time of updates, the data may be corrected or modified to correctly reflect the current state of the forests (tree species and area) and changes in volume due to growth, harvesting and disturbance.

The merchantable volume per unit area is set based on the yield tables developed for each tree species by Private or National forests as shown in Table 6-15. “Yield tables” provide stand growth in the case that typical forest practices are implemented for each region, tree species and site class, and also provide estimated values of the volumes per unit area with respect to the forest ages. With respect to estimating the volumes of Japanese cedar, Hinoki cypress and Japanese larch in private forests, which are major tree species of intensively managed forests in Japan, the volumes per unit area reported in the “New Yield Tables” that reflect the latest survey results are applied. These three tree species cover 82% of

intensively managed forests of private forests in terms of areas. Regional differences were considered in the development of the New Yield Tables; the tables were developed for 7 regions for Japanese cedar, 4 regions for Hinoki cypress and 2 regions for Japanese larch.

Data of merchantable volume calculated by using the area by tree species and forest ages and the volume per unit area is stored in the NFRDB.

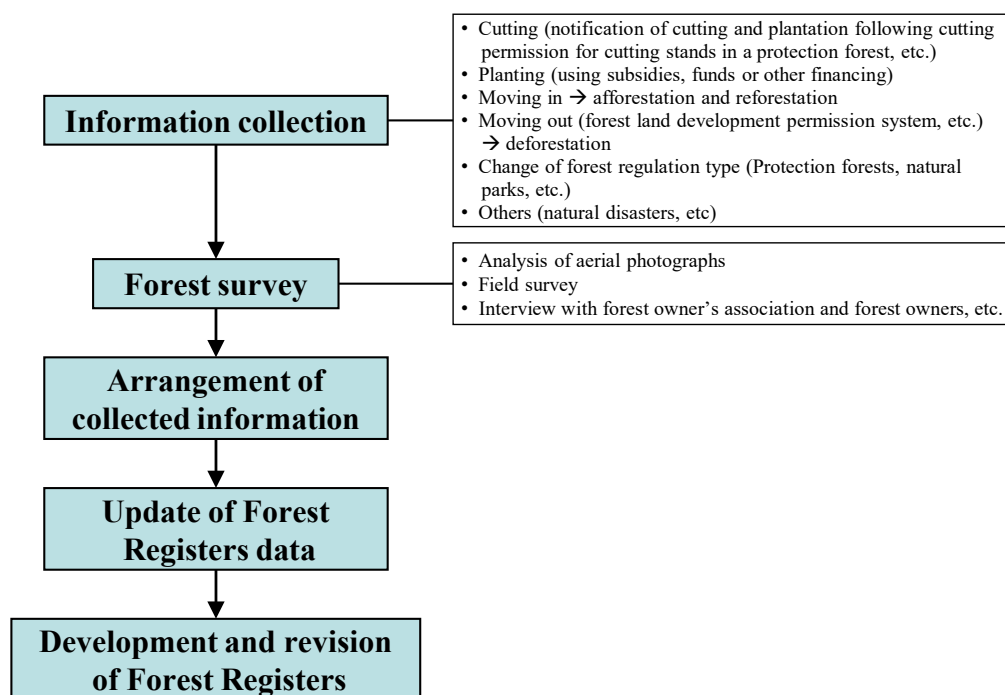


Figure 6-3 Procedures for developing Forest Registers

Table 6-15 Yield tables used to estimate merchantable volume

Tree species			Yield tables in use	
			Private forest	National forest
Intensively managed forests	Conifer	Japanese cedar, Hinoki cypress, Japanese larch	New Yield Tables	Yield tables developed by Regional Forest Offices
		Other conifer	Yield tables developed by prefectures	
	Broad leaf			
Semi-natural forests				

➤ **Parameters for estimating Carbon Stock in Living Biomass (Biomass expansion factor and Root-to-shoot ratio, Wood density and Carbon fraction of dry matter)**

The biomass expansion factors (BEF) [above-ground biomass/below-ground biomass], root-to-shoot ratios (R) and Wood density (D) were set based on the results of biomass surveys on dominant tree species, and existing research reports which were developed by the Forestry and Forest Products Research Institute (Table 6-16).

BEFs were calculated for two age classes (20 years and below / 21 years and above) and for each tree species, because BEFs were found to differ between young forests and mature forests. On the other hand, R and D values were established only for tree species, because no clear correlation was found between these values and forest ages.

Carbon fractions (CF) of dry matter were set by conifer trees or broad leaf trees based on Japan's research results.

Table 6-16 Parameters for estimations of Living Biomass for each tree species

		BEF [-]		R [-]	D [t-d.m./m <sup>3</sup> ]	CF [t-C/t-d.m.]	Note
		≤ 20	> 20				
Forests with standing trees (Conifer trees)	Japanese cedar	1.57	1.23	0.25	0.314	0.51	
	Hinoki cypress	1.55	1.24	0.26	0.407		
	Sawara cypress	1.55	1.24	0.26	0.287		
	Japanese red pine	1.63	1.23	0.26	0.451		
	Japanese black pine	1.39	1.36	0.34	0.464		
	Hiba arborvitae	2.38	1.41	0.20	0.412		
	Japanese larch	1.50	1.15	0.29	0.404		
	Momi fir	1.40	1.40	0.40	0.423		
	Sakhalin fir	1.88	1.38	0.21	0.318		
	Japanese hemlock	1.40	1.40	0.40	0.464		
	Yezo spruce	2.18	1.48	0.23	0.357		
	Sakhalin spruce	2.17	1.67	0.21	0.362		
	Japanese umbrella pine	1.39	1.23	0.20	0.455		
	Japanese yew	1.39	1.23	0.20	0.454		
	Ginkgo	1.50	1.15	0.20	0.450		
	Exotic conifer trees	1.41	1.41	0.17	0.320		
	Other conifer trees	2.55	1.32	0.34	0.352	Applied to Hokkaido, Aomori, Iwate, Miyagi, Akita, Yamagata, Fukushima, Tochigi, Gunma, Saitama, Niigata, Toyama, Yamanashi, Nagano, Gifu and Shizuoka prefectures	
		1.39	1.36	0.34	0.464	Applied to Okinawa prefecture	
		1.40	1.40	0.40	0.423	Applied to prefectures other than above	
Forests with standing trees (Broad leaf trees)	Japanese beech	1.58	1.32	0.26	0.573	0.48	
	Oak (evergreen tree)	1.52	1.33	0.26	0.646		
	Japanese chestnut	1.33	1.18	0.26	0.419		
	Japanese chestnut oak	1.36	1.32	0.26	0.668		
	Oak (deciduous tree)	1.40	1.26	0.26	0.624		
	Japanese poplar	1.33	1.18	0.26	0.291		
	Alder	1.33	1.25	0.26	0.454		
	Japanese elm	1.33	1.18	0.26	0.494		
	Japanese zelkova	1.58	1.28	0.26	0.611		
	Cercidiphyllum	1.33	1.18	0.26	0.454		
	Japanese big-leaf magnolia	1.33	1.18	0.26	0.386		
	Maple tree	1.33	1.18	0.26	0.519		
	Amur cork	1.33	1.18	0.26	0.344		
	Linden	1.33	1.18	0.26	0.369		
	Kalopanax	1.33	1.18	0.26	0.398		
	Paulownia	1.33	1.18	0.26	0.234		
Exotic broad leaf trees	1.41	1.41	0.16	0.660			
Japanese birch	1.31	1.20	0.26	0.468			
	Other broad leaf trees	1.37	1.37	0.26	0.469	Applied to Chiba, Tokyo, Kochi, Fukuoka, Nagasaki, Kagoshima, and Okinawa prefectures	
		1.52	1.33	0.26	0.646	Applied to Mie, Wakayama, Oita, Kumamoto, Miyazaki, and Saga prefectures	
		1.40	1.26	0.26	0.624	Applied to prefectures other than above	
Forests with less standing trees	Private Forests	1.27		0.26	0.48	0.50	
	National Forests	1.30		0.26	0.47		

Note: BEF: Biomass expansion factor (20 = age class); R: Root-to-shoot ratio; D: Wood density; CF: Carbon Fraction

- **Activity Data**

- **Determining the forest area**

Forest areas of intensively managed forests, semi-natural forests, forests with less standing trees and bamboo under the forest planning system were obtained from the *Forest Status Survey* until FY2004 and has been obtained from the NFRDB since FY2005 and onward. Data from FY1991 to FY1994, FY1996 to FY2001, and FY2003 to FY2004 are estimated by linear interpolation. In addition, area data of Sakhalin fir, Yezo spruce, Japanese chestnut oak and Oak (deciduous tree) before FY1990 are not available individually; therefore, these data are estimated from “other conifer” and “other broad leaf” area divided by the area ratio in FY1995.

Table 6-17 Classifications in Forest Status Survey (before 2004) and NFRDB (after 2005)

Conifer trees		Broad leaf trees	
Before 2004	After 2005	Before 2004	After 2005
Japanese cedar	Japanese cedar	Japanese chestnut oak	Japanese chestnut oak
Hinoki cypress	Hinoki cypress	Oak (deciduous tree)	Oak (deciduous tree)
Pine	Japanese red pine	Other broad leaf	Japanese beech
	Japanese black pine		Oak (evergreen tree)
Japanese larch	Japanese larch		Japanese chestnut
Sakhalin fir	Sakhalin fir		Japanese poplar
Yezo spruce	Yezo spruce		Alder
	Sakhalin spruce		Japanese elm
Other conifer	Sawara cypress		Japanese zelkova
	Hiba arborvitae		Cercidiphyllum
	Momi fir		Japanese big-leaf magnolia
	Japanese hemlock		Maple tree
	Japanese umbrella pine	Amur cork	
	Japanese yew	Linden	
	Ginkgo	Kalopanax	
	Exotic conifer trees	Paulownia	
	Other needle leaf	Japanese birch	
		Exotic broad leaf trees	
		Other broad leaf	

- **Obtaining the land area of “Forest land remaining Forest land”**

This land area is estimated by subtracting the cumulative total area of land converted to forest land during the past 20 years from the total area of forest land in the year subject to estimation. All areas of land converted to forest land are assumed to be intensively managed forests. For the activity data of land converted to forest land, see section 6.5.2.b)1).

Table 6-18 Area of forest land remaining forest land within the past 20 years

Category	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Forest land remaining Forest land	kha	24,502.2	24,675.9	24,717.5	24,873.3	24,878.7	24,882.5	24,875.8	25,092.8	25,037.3	24,833.2	24,739.5	24,811.6	24,854.5	24,870.5	24,933.6
Intensively managed forests	kha	9,839.7	10,134.6	10,172.0	10,217.6	10,197.5	10,195.0	10,188.1	10,160.7	10,148.7	10,128.9	10,056.6	10,075.5	10,079.2	10,059.0	10,048.2
Semi-natural forests	kha	13,354.5	13,220.3	13,195.2	13,315.7	13,360.8	13,359.5	13,355.2	13,369.3	13,380.7	13,401.4	13,389.2	13,426.2	13,441.2	13,457.9	13,465.1
Cut-over forests and lesser stocked forests	kha	1,159.0	1,171.0	1,197.4	1,186.0	1,161.7	1,169.0	1,170.8	1,400.6	1,355.6	1,150.0	1,146.9	1,155.2	1,167.0	1,185.4	1,251.2
Bamboo	kha	149.0	150.0	152.9	154.0	158.6	159.1	161.7	162.3	152.4	153.0	146.8	154.8	167.0	168.2	169.1

Reference: *Forest Status Survey, NFRDB* (Forestry Agency)

## 2) Carbon Stock Changes in Dead Organic Matter and Soils in “Forest land remaining Forest land”

- **Estimation Method**

- **Carbon Stock Changes in Dry Organic Matter and Mineral Soils in Forests with Standing Trees**

In accordance with the decision tree provided in the *2006 IPCC Guidelines*, these pools are estimated by the Tier 3 method. Average carbon stock changes per unit area in forests with standing trees for dead wood, litter and mineral soils are calculated by forest type, forest management type and age class or forest age by using the CENTURY-jfos model.

The carbon stock changes in pools of dead wood, litter and mineral soils of all forests with standing trees are summed up for each pools by multiplying each of the calculated average carbon stock changes per unit area by the land area of tree species, forest management type, age class or age of the forest. The carbon stock changes in pools of dead wood, litter and mineral soils in “Forest land remaining Forest land (forests with standing trees)” ( $\Delta C_{FF\_dls}$ ) are obtained by subtracting those amounts in “land converted to forest land (forests with standing trees)” ( $\Delta C_{LF\_dls}$ ) from the amounts of all forests with standing trees estimated above ( $\Delta C_{F\_dls}$ ). See section 6.5.2.b)2) for the method of estimating the amount of carbon stocks in “land converted to forest land”

$$\Delta C_{FF\_dls} = \Delta C_{F\_dls} - \Delta C_{LF\_dls}$$

$$\Delta C_{F\_dls} = \sum_{k,m,j} \{A_{k,m,j} \times (d_{k,m,j} + l_{k,m,j} + S_{k,m,j})\}$$

$\Delta C_{FF\_dls}$  : Annual change in carbon stocks in dead wood, litter and mineral soils in forest land remaining forest land (forests with standing trees) [t-C/yr]

$\Delta C_{F\_dls}$  : Annual change in carbon stocks in dead wood, litter and mineral soils in entire forest land (forests with standing trees) [t-C/yr]

$\Delta C_{LF\_dls}$  : Annual change in carbon stocks in dead wood, litter and mineral soils in the land converted to forest land (forests with standing trees) [t-C/yr]

$A$  : Area [ha]

$d$  : Average carbon stock change per unit area in dead wood [t-C/ha/yr]

$l$  : Average carbon stock change per unit area in litter [t-C/ha/yr]

$s$  : Average carbon stock change per unit area in mineral soil [t-C/ha/yr]

$k$  : Type of forest management

$m$  : Age class or forest age

$j$  : Tree species

#### ➤ **Carbon Stock Changes in Dry Organic Matter and Mineral Soils in Forests with Less Standing Trees and Bamboo**

With respect to forests with less standing trees and Bamboo, carbon stock changes in dead organic matter and mineral soils are reported as “NA” because gains and losses of carbon stocks in the dead organic matter and mineral soils are equivalent on a long-term basis (FRA, 2010).

#### ➤ **CO<sub>2</sub> emissions from organic soils caused by cultivation and drainage**

Since it is unlikely in Japan that the treatment of drainage would be taken and then to plant trees on land with organic soil not suitable for growing forestry tree species, it was assumed that organic soils do not exist in intensively managed forests, forests with less standing trees and bamboo, but exist only in semi-natural forests. Moreover, when we consulted with forest experts, they said they had never heard of such cases in Japan. In addition, there are many cases where areas with organic soils have a precious natural environment, and the change of the land configuration or characteristics are being regulated in these places by law and regulations. Given the above, it was concluded that drainage in forest land with organic soils is not implemented in Japan; therefore, the emissions for this category are reported as “NO”, since emissions from organic soils under the estimation methodology of Tier 1 or Tier 2 are estimated only when drainage is implemented in accordance with the *2006 IPCC Guidelines*.



- **Parameters**

- **Key Assumptions, Modification and Use of Parameters for the CENTURY-jfos Model for estimating Carbon Stock Changes in Dry Organic Matter and Mineral Soils**

CENTURY-jfos model is a soil carbon cycle model based on the CENTURY model, which is an ecosystem carbon cycle model developed by Colorado State University and is one of the most widely used models, with some adjustments to be applicable to forests in Japan.

When adjusting the CENTURY-jfos model, it was assumed that forests have continually existed and been used for a long term without undergoing conversion from/to other land use, and that their soil carbon stocks have reached a nearly steady state. The parameters for the net primary production and tree mortality used in the model were adjusted to predict soil carbon dynamics by prefecture and by forest type as below. Note that the forest biomass growth is defined as net primary production minus mortality.

Forest types were classified into the following eight types: Japanese Cedar, Hinoki Cypress, Pine species, Japanese Larch, Sakhalin Fir, Sakhalin Spruce, broad leaf trees and other conifer trees. Climate condition and average soil carbon stocks were calculated using the following 3 data sets: the NFRDB for the geographical forest distribution of the tree species, the mesh climate data of Japan for average temperature and precipitation from 1970 to 2000 (Japan Meteorological Agency, 2002); and average soil carbon stocks for each soil type (Morisada et al. 2004a, Morisada 2004b).

It should be noted that the yield tables represent the relations between forest age and yield, and include the effects of forest management, such as thinning. The parameter of biomass growth in the model should be adjusted to reflect the condition with no thinning, since the model also runs simulations for intensively managed forests by considering standard thinning scenarios conducted at forest age of 25 (with 20% thinning and 80% residues) and at forest age of 40 (with 20% thinning and 20% residues). Therefore, the biomass growth in the model was not directly taken from the yield tables, but was parameterized by using the forest biomass stock data whose relative yield index value are 0.85 or greater, because these data were thought to be largely unaffected by thinning.

Based on literature information, the average amount of litterfall for forests up to 60 year-old was adjusted to be 2.2 to 2.3 t-C/ha/yr for coniferous forests and 2.5 t-C/ha/yr for broadleaf forests, respectively. Because no reference information was available for the amount of fallen log and root mortality, the default mortality rates (trunk 0.96%/yr and roots 1.2%/yr) of the CENTURY model were used.

Before conducting this simulation, spin-up of 3,000 years was conducted with the assumption of a cutting rotation age of 60 years for broadleaf forests. As a result, the coefficient of the transition rate to passive soil organic matter in the decomposition process were modified so that the soil carbon stocks calculated by the model match the soil carbon stocks in 30cm depth for each prefecture by forest type described above. The parameters were determined in accordance with the CENTURY manual (Metherell et al. 1993).

Using the adjusted model, the average annual carbon stock changes per unit area were calculated for dead wood, litter, and soil pools, for each age class 1-19 (100 years), by forest management type – one in managed forests with thinning and the other in the natural forests with and without thinning.

During the reviews (ARR 2020 L.2 (L.4 2018) (L.11. 2016)), it was pointed out that the carbon stock

of dead wood showed relatively higher values compared to the values of carbon stock of the living biomass in Japanese forests. Considering that the ratio of the amount of dead wood to the amount of living biomass currently reported is only slightly higher than the ratio of the below-ground biomass to the above ground biomass, and that the stumps left at the logged-sites will be transferred to the dead wood pool, and that a large amount of dead wood will be supplied due to thinning and other forest management activities in intensively managed forests, it was concluded that the values do not significantly deviate from the actual situation.

Furthermore, the updating of the amount of dead wood based on the results of new monitoring surveys is also being considered in near future.

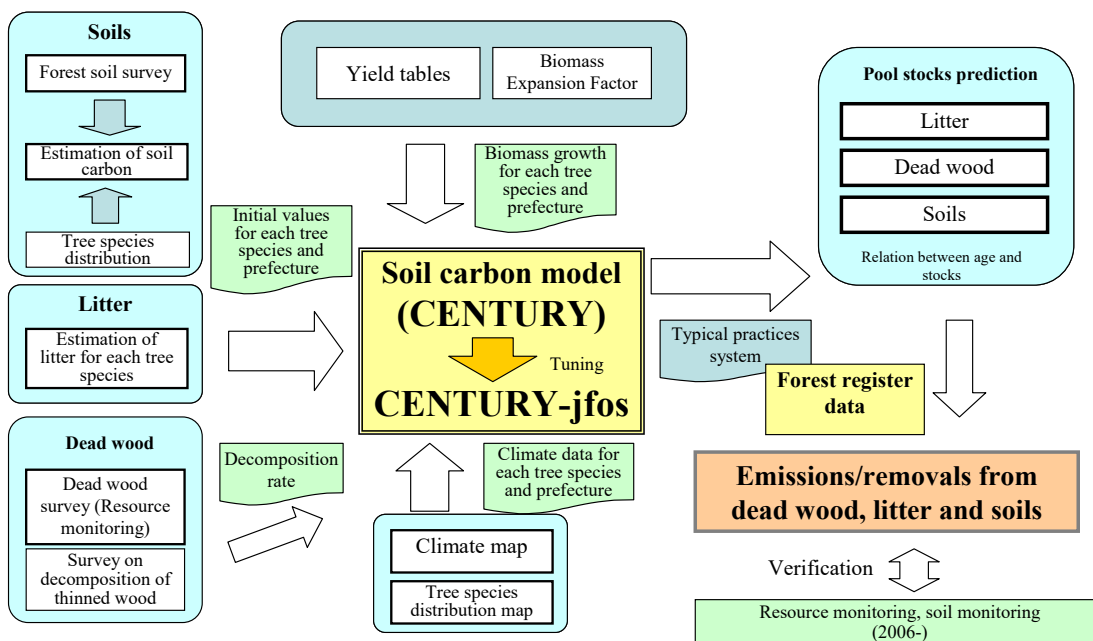


Figure 6-4 Estimation of emissions/removals in dead wood, litter and soils

Table 6-19 Standard soil carbon stocks used for the modification of the parameters in the CENTURY-jfos model (in 30cm depth) [t-C/ha]

Prefecture No.	Prefecture	Tree Species							
		Japanese Cedar	Hinoki Cypress	Pine species	Japanese Larch	Sakhaline Fir	Sakhaline Spruce	Broad Leaf Trees	Other Conifer Trees
1	Hokkaido	98.0	NA	95.0	91.0	88.0	93.7	91.0	83.5
2	Aomori	92.1	NA	94.3	83.3	109.1	NA	89.0	89.8
3	Iwate	89.5	93.6	92.7	93.9	98.1	NA	91.3	93.3
4	Miyagi	86.1	70.8	78.5	90.3	110.9	NA	82.8	80.5
5	Akita	81.1	NA	72.4	81.0	108.5	NA	82.6	79.6
6	Yamagata	83.2	79.7	68.0	81.0	97.4	NA	74.4	76.9
7	Fukushima	84.3	83.7	81.1	89.3	108.6	NA	81.4	85.0
8	Ibaraki	84.3	83.4	97.6	NA	NA	NA	91.2	90.8
9	Tochigi	83.0	86.1	91.6	100.6	133.4	NA	93.1	96.4
10	Gunma	88.7	88.3	93.9	95.1	98.1	NA	86.5	93.9
11	Saitama	81.3	82.4	96.2	106.8	NA	NA	85.8	94.7
12	Chiba	93.9	85.7	65.6	NA	NA	NA	84.6	76.4
13	Tokyo	79.2	81.6	85.7	94.7	NA	NA	63.9	84.3
14	Kanagawa	91.9	99.8	89.8	NA	NA	NA	94.9	99.1
15	Niigata	83.9	51.3	63.4	86.7	133.0	NA	85.3	86.9
16	Toyama	90.3	NA	72.5	88.5	106.0	NA	94.5	100.2
17	Ishikawa	82.7	80.2	70.2	NA	133.4	NA	86.6	74.3
18	Fukui	88.7	85.8	79.8	NA	NA	NA	90.1	80.6
19	Yamanashi	93.0	93.9	98.0	99.3	NA	NA	93.9	95.6
20	Nagano	102.1	100.5	96.0	108.4	106.0	NA	97.9	103.3
21	Gifu	100.5	94.8	79.1	99.6	107.8	NA	95.8	93.9
22	Shizuoka	94.6	96.7	69.1	90.7	NA	NA	90.0	93.7
23	Aichi	91.2	85.0	60.1	NA	NA	NA	78.5	77.2
24	Mie	92.1	84.4	63.8	97.1	NA	NA	78.7	80.5
25	Shiga	83.5	73.0	59.6	NA	NA	NA	79.5	65.8
26	Kyoto	74.0	67.4	63.3	NA	NA	NA	66.4	64.6
27	Osaka	78.9	74.0	60.9	NA	NA	NA	67.5	66.0
28	Hyogo	88.3	71.8	53.0	123.6	NA	NA	63.4	61.9
29	Nara	79.6	69.8	65.5	NA	NA	NA	73.4	69.4
30	Wakayama	72.1	70.5	58.2	NA	NA	NA	62.8	69.9
31	Tottori	73.8	74.9	75.6	121.2	NA	NA	72.3	75.4
32	Shimane	69.0	66.6	61.2	77.3	NA	NA	64.6	63.2
33	Okayama	80.3	73.7	51.4	121.2	NA	NA	65.2	63.6
34	Hiroshima	74.0	71.8	54.0	71.2	NA	NA	65.0	58.7
35	Yamaguchi	64.9	60.9	49.3	NA	NA	NA	55.2	54.8
36	Tokushima	72.9	63.7	63.6	NA	NA	NA	66.7	63.7
37	Kagawa	57.7	61.9	56.6	NA	NA	NA	57.2	57.7
38	Ehime	80.1	75.1	63.2	85.4	NA	NA	67.4	74.1
39	Kochi	81.4	76.1	73.8	NA	NA	NA	74.1	76.2
40	Fukuoka	97.3	88.9	77.5	NA	NA	NA	86.5	88.3
41	Saga	83.6	83.0	69.1	NA	NA	NA	79.6	82.9
42	Nagasaki	82.9	84.5	82.6	NA	NA	NA	78.9	84.5
43	Kumamoto	108.7	96.0	79.3	NA	NA	NA	93.5	95.6
44	Oita	109.9	100.5	108.3	130.3	NA	NA	99.1	101.4
45	Miyazaki	106.1	102.0	93.7	NA	NA	NA	98.0	99.6
46	Kagoshima	108.4	102.4	75.7	NA	NA	NA	90.8	97.0
47	Okinawa	58.5	NA	58.9	NA	NA	NA	58.0	58.5

Sources: based on NFRDB and amount of carbon stocks by soil type by Morisada et.al. (2004a)

● **Activity Data**

➤ **Area of Mineral Soils**

Forest area data provided by the NFRDB were used as activity data to be multiplied by the annual carbon stock changes per unit area calculated by the CENTURY-jfos model.

➤ **Area of Organic Soils**

Areas of organic soils in forest land were estimated by means of soil maps and status of distribution of

organic soils in each prefecture. Furthermore, organic soils exist only in semi-natural forests in Japan; hence, all areas of organic soils are reported in semi-natural forests, and areas of organic soils in intensively managed forests, forests with less standing trees and bamboo are reported as “NO”.

### c) Uncertainties and Time-series Consistency

#### ● Uncertainty Assessment

The uncertainties of the parameters and activity data for living biomass were individually assessed on the basis of field study results, expert judgment, or the default values described in the *2006 IPCC Guidelines*. The uncertainty estimates for dead organic matter and soil were assessed by calculating the variance of outputs from the CENTURY-jfos model. As a result, the uncertainty estimate was 13% for the total removals by forest land remaining forest land. Uncertainty estimates regarding the major parameters in this category are shown in Table 6-20.

Table 6-20 Uncertainty estimates regarding major parameters in the forest land category

			Uncertainty Estimates [%]	Country Specific (CS) or Default(D)	Remarks
Forest land area			5.9	CS	Estimated based on uncertainty estimates of land areas in the NFRDB. Used 5.9% without distinguishing tree species.
Volume of timber per area			22.0	CS	Estimated based on analysis of comparison between yield table and measured data
Biomass Expansion Factor	Japanese cedar	≤20	3.5	CS	Estimated based on measured values
		>20	1.1	CS	
	Hinoki cypress	≤20	3.2	CS	
		>20	1.6	CS	
	Oak (deciduous tree)	≤20	8.6	CS	
		>20	2.1	CS	
Wood density	Japanese cedar		2.5	CS	
	Hinoki cypress		1.7	CS	
	Oak (deciduous tree)		1.6	CS	
Carbon fraction of dry matter	All tree species		6.0	D	Estimated taking into account the <i>2006 IPCC Guidelines</i> default value.
Dead wood			22.1	CS	Result of uncertainty analysis of CENTURY-jfos model.
Litter	All forests		51.0		
Soils			19.9		

#### ● Time-series Consistency

There were no data for forest areas from FY1991 to FY1994, from FY1996 to FY2001, and from FY2003 to FY2004. Therefore, the time-series consistency was ensured by estimating these forest areas by means of interpolation.

### d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

### e) Category-specific Recalculations

#### ● Correction in accordance with revision of AR area

Areas of intensively managed forests in forest land remaining forest land was recalculated to be consistent with the revision of areas of afforestation and reforestation (AR areas), which are used as original data for determining areas of forests converted from other land-use. Following the revision, carbon stock changes in living biomass, dead organic matter and mineral soils in this category were recalculated for all years. For details in the revision of estimation method of AR and D areas, please see the Chapter 11, 11.5.1.7, “Review of AR and D areas”. See Chapter 10 for impact on trend.

### f) Category-specific Planned Improvements

Currently, we are continuously working refining the input data used for CENTURY-jfos, including the investigation of estimating methodology of living biomass at older stands of forest.

## 6.5.2. Land converted to Forest land (4.A.2.)

### a) Category Description

This subcategory deals with the carbon stock changes in forest land converted from other land-use categories within 20 years. The net removal in this subcategory in FY2020 was 767 kt-CO<sub>2</sub> (GHG emissions other than changes in carbon stock are not included). This represents a decrease of 88.5% compared to FY1990 and a decrease of 8.2% compared to FY2019. Removals since 1990 have been in consistent decreasing trend.

### b) Methodological Issues

#### 1) Carbon stock change in Living Biomass in “Land converted to Forest land”

#### ● Estimation Method

The Tier 2 method which is estimated by summing the loss of carbon stock due to conversion ( $\Delta C_{LB\_conversion\_to\_F}$ ) and the change of carbon stock accumulated after conversion ( $\Delta C_{LF\_LB\_SC}$ ) was used for the annual carbon stock change in land converted to forest land ( $\Delta C_{LF\_LB}$ ). Moreover, it was assumed that all land conversion occurred in intensively managed forests. And the  $\Delta C_{LF\_LB}$  value was reported for each land-use category before conversion and for each subcategory basis in cropland.

$$\Delta C_{LF\_LB} = \Delta C_{LB\_conversion\_to\_F} + \Delta C_{LF\_LB\_SC}$$

$$\Delta C_{LB\_conversion\_to\_F} = \sum_i \{ \Delta A_i \times (B_a \times CF_a - B_{b,i} \times CF_{b,i}) \}$$

$$\Delta C_{LF\_LB\_SC} = \Delta A_{LF} \times IEF_{AR}$$

$\Delta C_{LF\_LB}$  : Annual carbon stock change in land converted to forest land [t-C/yr]

$\Delta C_{LB\_conversion\_to\_F}$  : Annual carbon stock change at the land conversion (loss) [t-C/yr]

$\Delta C_{LF\_LB\_SC}$  : Carbon stock gains due to biomass growth in the converted forest land within 20 years from conversion [t-C/yr]

$i$  : Land-use category before conversion

$\Delta A_i$  : Annual land area that has been converted from land-use type  $i$  to forest land [ha/yr]

$B_a$  : Dry matter weight biomass per unit area immediately after conversion to forest [t-d.m./yr] (default value=0)

$B_{b,i}$  : Dry matter biomass weight per unit area before conversion from land-use type  $i$  to forestland [t-d.m./yr]

$CF_a$	: Carbon fraction of dry matter after conversion (forest land) [t-C/t-d.m.]
$CF_{bi}$	: Carbon fraction of dry matter in land-use type before conversion [t-C/t-d.m.]
$\Delta A_{LF}$	: Area of converted forest land within 20 years [ha]
$IEF_{AR}$	: Average carbon stock gain per unit area due to AR activities (equal to the implied removal factor) [t-C/ha/yr]. See Table 6-9.

### ● Parameters

#### ➤ Parameters for estimating Living Biomass Stocks

##### - Per unit area removals used in the estimation after conversion ( $IEF_{AR}$ )

Annual increase in biomass carbon stocks due to biomass growth in “land converted to forest land” uses the value of the carbon stock gain per unit area caused from AR activities (Table 6-9) which is estimated in the forest land subjected to AR activities under Article 3, paragraph 3, of the Kyoto Protocol, since it can be considered that growth in “land converted to forest land” is similar to that in the land subjected to AR activities.

##### - Biomass stock or Carbon stock in each Land-Use Category ( $B_0$ )

The parameter in cropland (rice fields and upland fields) and grassland before conversion, shown in Table 6-8, is used. For conversions from wetlands, settlements and other land, carbon stock losses in living biomass are assumed as 0, the carbon losses are reported as “NA”.

##### - Carbon Fraction of Dry Matter (CF)

For carbon fraction of dry matter of forest, average value of broad leaf trees and conifer trees (0.50 t-C/t-d.m.) was applied. For that of grassland, the default value for herbaceous biomass (0.47 t-C/t-d.m) was applied in accordance with the 2006 IPCC Guidelines.

### ● Activity Data

The areas of land converted to forest land within 20 years were calculated by summing the annually converted areas during the past 20 years. The estimation methods for total converted areas and for annually converted areas from each land-use category are described below.

#### ➤ Total area of “Land converted to Forest land”

It is logically presumed that the areas of land converted to forest land include AR areas, forest land restored from degraded land by natural succession, and land whose land-use categories are changed to forest land due to other reasons. However, it is not common in Japan that forest land restored from degraded land by natural succession is determined as “Forests under Forest Law Article 5 and 7.2” as indicated in Table 6-2. Therefore, such areas are classified as remaining land categories. Hence, it is regarded that the areas of land converted to forest land are similar to the AR areas, and that the areas are determined in accordance with the concept of “overlap” described as a time series consistency and recalculation approach on section 5.3.3.1 in Volume 1 of the 2006 IPCC Guidelines, by using the AR areas and areas of forested cropland reported in the *Statistics of Cultivated and Planted Area*. Since the AR areas are identified in detail by utilizing orthophotos taken at the end of 1989 and satellite images taken from FY2005 onwards, the annual areas of land converted to forest land in and after 2005 were regarded as the same as the areas obtained by utilizing the method of estimating annual AR areas in KP-LULUCF and the annual AR areas were used. For further information on determining AR areas, see section 11.4.2.3. in Chapter 11.

The annual AR areas before FY2005 are not directly obtained from satellite images interpretation. Thus, the area of land converted to forest land before FY2005 are estimated by the following method.

- **From FY1990 to FY2004**

The annual areas of land converted to forest land from FY1990 to FY2004 are calculated by averaging the total AR area of FY 2005, obtained from interpreting aerial orthophotos taken at the end of FY1989 and satellite images taken in 2005, and allocating it to each year from FY1990 to FY2004.

- **From FY1971 to FY1989**

The annual areas of land converted to forest land are calculated by using forest area and deforestation area obtained from statistics provided by the *Census of agriculture and Forestry* (MAFF). The procedure of the calculation method is as follows.

1. Changes in forest area in 10 years ( $A_{t2}-A_{t1}$ ) from FY1970 to FY1980 and FY1980 to FY1990 and deforested area in 10 years ( $\Delta A_{D10}$ ) are calculated by using the forest areas obtained from the statistics in FY1970, FY1980 and FY1990 respectively.
2. Total areas of land converted to forest land in the same 10 years' periods ( $\Delta A_{LF10}$ ) are calculated by summing of those areas calculated in Step 1 ( $\Delta A_{LF10}=(A_{t2}+\Delta A_{D10})-A_{t1}=(A_{t2}-A_{t1})+\Delta A_{D10}$ ).
3. The values from Step 2 are allocated to each year according to the area of afforested land based on the statistical values which are from "the *Statistics of Cultivated and Planted Area* (MAFF)".

➤ **Areas of "Cropland and Grassland converted to Forest Land" among the total areas**

- **From FY2005 onwards**

The areas of cropland or grassland converted to forest land since FY2005 were respectively estimated by multiplying the percentage of the number of plots interpreted as conversion from cropland or grassland to forest land in the total number of AR plots. The areas of cropland converted to forest land is further divided into "rice fields converted to forest land", "upland fields converted to forest land" and "orchards converted to forest land" by using area data obtained by statistics.

- **From FY1971 to FY2004**

The areas of cropland converted to forest land were determined by utilizing the areas of forested cropland reported in the *Statistics of Cultivated and Planted Area*. As its subcategories, the areas of cropland converted to forest land are categorized to rice fields converted to forest land, upland fields converted to forest land and orchards converted to forest land. The areas of rice fields converted to forest land are determined by utilizing the areas of forested by planting on rice fields provided by the *Statistics of Cultivated and Planted Area*. The areas of upland fields and orchards converted to forest land are estimated by dividing the areas of forested by planting on arable land, also provided by the *Statistics of Cultivated and Planted Area*, by means of the existing area ratios of upland fields, orchards and pasture land.

The areas of grassland converted to forest land are calculated by summing the areas of forested by planting on pasture land estimated from the data in the *Statistics of Cultivated and Planted Area* and those of forested by planting on grazed meadow reported in *A Move and Conversion of Cropland* (MAFF).

➤ **Areas of "Wetlands, Settlements or Other land converted to Forest land"**

- **From FY2005 onwards**

The areas of wetlands, settlements or other land converted to forest land since FY2005 were respectively estimated by multiplying the percentage of the number of plots interpreted as conversion from each land-use to forest land in the total number of AR plots.

- **From FY1971 to FY2004**

Since the areas of wetlands, settlements, and other land converted to forest land cannot be obtained directly from statistics for the years before FY2004, they are estimated by subtracting the summed areas of cropland converted to forest land and grassland converted to forest land from the total area of land converted to forest land, and by multiplying the difference by ratios of areas of wetlands, settlements, and other land converted to forest land, which are estimated based on trend of results of AR identification in 2007. The allocation ratio was fixed at wetlands: settlements: other land = 0: 1: 1.

Table 6-21 Area of land converted to forest land within the past 1 year

Category	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Land converted to Forest land	kha	4.58	4.58	4.58	4.58	3.16	2.66	2.66	1.02	1.02	0.96	0.96	0.17	0.17	0.03	0.03
Cropland converted to Forest land	kha	2.71	1.22	1.08	2.76	1.80	1.38	1.38	0.58	0.58	0.35	0.35	0.09	0.09	NO	NO
Rice field	kha	0.92	0.47	0.41	0.83	0.77	0.50	0.50	0.21	0.20	0.12	0.12	0.04	0.04	NO	NO
Upland field	kha	1.31	0.57	0.51	1.51	0.81	0.70	0.70	0.29	0.30	0.19	0.18	0.04	0.04	NO	NO
Orchard	kha	0.49	0.19	0.15	0.43	0.22	0.18	0.18	0.08	0.08	0.05	0.05	0.01	0.01	NO	NO
Grassland converted to Forest land	kha	0.67	0.31	0.28	0.82	0.75	0.92	0.92	0.27	0.27	0.49	0.49	0.05	0.05	0.03	0.03
Wetlands converted to Forest land	kha	NO	NO	NO	0.00	NO	0.03	0.03	0.03	0.03	NO	NO	NO	NO	NO	NO
Settlements converted to Forest land	kha	0.60	1.53	1.62	0.81	0.50	0.27	0.27	0.09	0.09	0.09	0.09	0.01	0.01	NO	NO
Other land converted to Forest land	kha	0.60	1.53	1.62	0.19	0.12	0.06	0.06	0.05	0.05	0.03	0.03	0.01	0.01	NO	NO

Reference: *Forestry Status Survey, NFRDB* (Forestry Agency)

Table 6-22 Area of Land converted to forest land within the past 20 years

Category	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Land converted to Forest land	kha	448.1	220.9	158.5	118.9	87.5	85.6	83.7	80.1	76.5	72.9	69.3	64.9	60.4	55.9	51.3
Cropland converted to Forest land	kha	121.9	57.7	40.6	32.2	30.7	29.7	29.3	28.4	27.6	26.8	25.9	24.9	23.8	22.7	21.6
Rice field	kha	53.8	23.7	15.9	11.7	11.8	11.5	11.3	10.9	10.5	10.2	9.8	9.4	9.0	8.5	8.1
Upland field	kha	46.8	23.7	17.7	15.2	14.4	14.0	14.0	13.6	13.3	12.9	12.6	12.1	11.6	11.1	10.6
Orchard	kha	21.4	10.3	6.9	5.3	4.4	4.2	4.1	3.9	3.8	3.6	3.5	3.4	3.2	3.0	2.9
Grassland converted to Forest land	kha	19.3	11.6	9.0	7.9	8.8	9.1	9.6	9.5	9.5	9.7	9.9	9.6	9.4	9.1	8.9
Wetlands converted to Forest land	kha	NO	NO	NO	0.03	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Settlements converted to Forest land	kha	153.4	75.8	54.4	39.7	25.5	24.9	24.0	22.7	21.3	19.9	18.5	16.9	15.3	13.7	12.1
Other land converted to Forest land	kha	153.4	75.8	54.4	39.1	22.6	21.8	20.7	19.3	17.9	16.4	14.9	13.3	11.8	10.2	8.6

Reference: *Forestry Status Survey, NFRDB* (Forestry Agency)

## 2) Carbon Stock Changes in Dead Organic Matter and Soils in “Land converted to Forest land”

### ● Estimation Method

#### ➤ Carbon Stock Changes in Dead Organic Matter and Mineral Soils in forests with standing trees

Carbon stock changes in dead wood, litter and mineral soils were calculated under the assumption that these carbon stocks change linearly over 20 years from those in land-use categories other than forest land to those in forest land. Thus, average of annual carbon stock change per year is calculated by subtracting the carbon stock in land use before conversion from the average carbon stock in 20-year-old forests obtained from the CENTURY-jfos model, and divided by 20 years. The amount of change in each carbon stock was calculated by multiplying the area of the category.

$$\Delta C_{LF\_dls} = \sum_i \{ \Delta A_{LF_i} \times (C_{F20\_dls} - C_{i\_dls}) / 20 \}$$

$\Delta C_{LF\_dls}$  : Annual change in carbon stocks in dead wood, litter or mineral soils in land-use category  $i$  converted to forest land (forests with standing trees) [t-C/yr]

$\Delta A_{LF_i}$  : Area of land-use category  $i$  being converted to forest land (forests with standing trees) within the past 20 years [ha]

$C_{F20\_dls}$  : Average carbon stocks in dead wood, litter or mineral soils per unit area in 20-year-old-forests obtained by the CENTURY-jfos model [t-C/ha]

$C_{i\_dls}$  : Average carbon stocks in dead wood, litter or mineral soils per unit area in land-use category  $i$  before conversion [t-C/ha]

$i$  : Land-use category before conversion



➤ ***CO<sub>2</sub> emissions from organic soils due to cultivation and drainage***

Emissions from organic soils in this category were reported as “NO” in the same manner as forest land remaining forest land.

● ***Parameters***

➤ ***Parameters for estimating carbon stock changes in dry organic matter and soils***

Parameters for each carbon pool in Table 6-10 (dead wood), Table 6-11 (litter) and Table 6-12 (mineral soils) were used, in particular, for the categories cropland, grassland, wetlands, settlements and other land before conversion and for the category forest land after conversion.

● ***Activity Data***

➤ ***Total areas of “Land converted to Forest land”***

Areas of land converted to forest land used as the same as that used for estimation of living biomass. See Table 6-22.

***c) Uncertainties and Time-series Consistency***

● ***Uncertainty Assessment***

The uncertainties of the parameters and activity data for living biomass, dead organic matter, and soil were individually assessed on the basis of field study results, expert judgment, or the default values described in the *2006 IPCC Guidelines*. As a result, the uncertainty estimate was 13% for the entire removal from land converted to forest land.

● ***Time-series Consistency***

Time-series consistency for this subcategory is ensured.

***d) Category-specific QA/QC and Verification***

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

***e) Category-specific Recalculations***

● ***Correction in accordance with revision of AR area***

As it was mentioned in 6.5.1.e), areas of forest land converted from other land-use categories due to the correction of AR area were recalculated. Accordingly, carbon stock changes in living biomass, dead organic matter and mineral soils in this category were recalculated for all years. See Chapter 10 for impact on trend.

***f) Category-specific Planned Improvements***

● ***Carbon Stock Changes in Soils in “Cropland and Grassland converted to Forest Land”***

The areas converted to forest land from upland fields, orchards and pasture land are estimated by multiplying the total areas converted from cropland to forest land by each area ratio of upland fields, orchards and pasture land. However, this estimation method may not represent the actual condition of these areas. Hence, improvement of the validity of the estimation method and land-area identification is an issue to be examined in the future.

## 6.6. Cropland (4.B.)

Cropland is the land that produces annual and perennial crops; it includes temporarily fallow land. Cropland in Japan's inventory consists of rice fields, upland fields, orchards and dilapidated farmland.

In FY2020, Japan's cropland area was about 4.06 million ha, which is equivalent to about 10.7% of the national land. The area of organic soil in cropland is about 0.168 million ha. The emissions from this category in FY2020 were 4,657 kt-CO<sub>2</sub> (GHG emissions other than changes in carbon stock are not included in this value.); this represents a decrease of 48.0% compared to FY1990 and a decrease of 0.1% compared to FY2019.

Table 6-23 Emissions and removals in cropland resulting from carbon stock changes

Category	Carbon pool	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
4.B. Cropland	Total	kt-CO <sub>2</sub>	8,958	3,924	4,028	3,947	5,876	6,875	6,569	5,488	6,208	5,710	5,457	4,561	3,969	4,660	4,657
	Living Biomass	kt-CO <sub>2</sub>	1,343	450	214	231	291	286	267	203	203	252	255	174	202	229	283
	Dead Wood	kt-CO <sub>2</sub>	291	58	18	31	43	42	42	28	27	26	26	12	12	19	19
	Litter	kt-CO <sub>2</sub>	140	28	9	15	21	20	20	13	13	13	13	6	6	9	9
	Mineral soil	kt-CO <sub>2</sub>	5,933	2,159	2,573	2,474	4,342	5,354	5,068	4,073	4,795	4,253	4,001	3,206	2,585	3,237	3,180
	Organic soil	kt-CO <sub>2</sub>	1,250	1,228	1,214	1,197	1,180	1,173	1,172	1,171	1,169	1,166	1,166	1,162	1,163	1,164	1,165
4.B.1. Cropland remaining Cropland	Total	kt-CO <sub>2</sub>	7,407	3,591	3,909	3,758	5,643	6,645	6,333	5,355	6,070	5,569	5,313	4,507	3,922	4,549	4,539
	Living Biomass	kt-CO <sub>2</sub>	280	245	157	121	154	151	127	144	137	179	175	165	205	181	229
	Dead Wood	kt-CO <sub>2</sub>	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Litter	kt-CO <sub>2</sub>	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Mineral soil	kt-CO <sub>2</sub>	5,933	2,159	2,573	2,474	4,342	5,354	5,068	4,073	4,795	4,253	4,001	3,206	2,585	3,237	3,180
	Organic soil	kt-CO <sub>2</sub>	1,194	1,187	1,179	1,163	1,147	1,141	1,138	1,138	1,138	1,137	1,136	1,135	1,133	1,131	1,129
4.B.2. Land converted to Cropland	Total	kt-CO <sub>2</sub>	1,551	333	119	189	233	230	236	133	138	141	145	54	46	111	118
	Living Biomass	kt-CO <sub>2</sub>	1,064	205	57	110	137	135	139	59	66	73	80	9	-3	48	53
	Dead Wood	kt-CO <sub>2</sub>	291	58	18	31	43	42	42	28	27	26	26	12	12	19	19
	Litter	kt-CO <sub>2</sub>	140	28	9	15	21	20	20	13	13	13	13	6	6	9	9
	Mineral soil	kt-CO <sub>2</sub>	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
	Organic soil	kt-CO <sub>2</sub>	56	41	35	34	33	32	34	34	31	29	27	28	32	35	37

### 6.6.1. Cropland remaining Cropland (4.B.1.)

#### a) Category Description

This subcategory deals with carbon stock changes in cropland, which has remained as cropland during the past 20 years. The emissions from this subcategory in FY2020 were 4,539 kt-CO<sub>2</sub> (GHG emissions other than changes in carbon stock are not included in this value.); this represents a decrease of 38.7% compared to FY1990 and a decrease of 0.2% compared to FY2019. CO<sub>2</sub> emissions from mineral soil pool in FY2020 were 3,180 kt-CO<sub>2</sub>; a 46.4% decrease compared to FY1990 and a 1.8% decrease compared to FY2019. The trend on emissions in time-series data in this category started from a decreasing trend of emissions from FY1990 to FY2003, turned to continuously increasing trend of emissions from FY2004 to FY2008, which is the peak of emissions for whole time series, and shown a declining trend of emissions again since then. It is considered that the time-series variability is mainly caused by annual variability of carbon input amount into mineral soils (especially, carbon input of compost) and annual fluctuation of temperature that affects decomposition of the carbon input. Among the three subcategories of cropland (rice field, upland field and orchard), the annual fluctuations have been largely affected by the trends in upland fields, especially occurred in Hokkaido prefecture, which holds more than 25% of upland field in Japan. This is because that the amount of emissions are calculated by multiplying the carbon stock change factor by the area of prefecture, so even if the fluctuation of the carbon stock change factor is small, it will be amplified when there is a fluctuation in a prefecture with a large area.

In addition, estimation of carbon stock changes in mineral soils by biochar amendments in cropland have been reported since the 2020 submission. The amount of reduction in emission by the effect of carbon storage by biochar amendment in FY2020 is 3.51 kt-CO<sub>2</sub>.

The area of cropland remaining croplands within the past 20 years was shown in Table 6-24. Besides, this area contained both land of mineral soils and organic soils.

Table 6-24 Areas of cropland remaining cropland within the past 20 years

Category	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Cropland remaining Cropland	kha	4,541	4,418	4,315	4,272	4,236	4,194	4,178	4,166	4,151	4,140	4,116	4,088	4,056	4,034	4,005
Rice fields	kha	2,767	2,707	2,628	2,545	2,484	2,462	2,453	2,446	2,438	2,425	2,411	2,394	2,377	2,363	2,346
Upland fields	kha	1,182	1,137	1,116	1,136	1,154	1,152	1,153	1,150	1,147	1,142	1,139	1,132	1,125	1,119	1,113
Orchards	kha	424	370	326	318	306	303	300	296	293	289	284	280	274	269	264
dilapidated farmland	kha	167	204	244	272	292	278	272	273	273	283	281	283	280	284	282

## b) Methodological Issues

### 1) Carbon Stock Changes in Living Biomass in “Cropland remaining Cropland (Orchard)”

#### ● Estimation Method

#### ➤ Carbon Stock Changes in Living Biomass in Rice Fields, Upland Fields and Dilapidated farmland

As for carbon stock changes in living biomass, only perennial woody species are considered for estimation according to the section 5.2.1.1 in Volume 4 of the 2006 IPCC Guidelines.

In rice fields and upland fields where annual crops are grown, the biomass increased by growth is lost by harvesting and decomposition in a short period of time, so it does not contribute to carbon stock storage over time. Therefore, it is not included in the calculation of carbon stock changes. In addition, the anthropogenic biomass carbon stock change was not considered and reported as zero or “NA” in the dilapidated farmland, since there is no direct human management for changing biomass stock.

#### ➤ Carbon Stock Changes in Living Biomass in Orchard

Carbon stock changes in living biomass in orchard are estimated by applying the Tier 2 estimation method of the stock-difference method described in section 5.2.1.1 in Volume 4 of the 2006 IPCC Guidelines.

The carbon stocks in living biomass in orchard are calculated by multiplying area of each orchard tree type by dry matter biomass weight per tree taken by existing research reports, standard planting density, and carbon fraction of dry matter. The carbon stocks in above- and below ground biomass were calculated by using the root-to-shoot ratio.

$$\Delta C_{CLB} = C_{t+1} - C_t$$

$$C_t = \sum_j (A_{t,j} \times D_j \times W_j) \times \frac{10}{1000} \times CF$$

Note: 10/1000 is for unit conversion

$\Delta C_{CLB}$  : Carbon stock change in living biomass in Orchard [t-C/yr]

$C_t$  : Total Carbon in living biomass at time  $t$  [t-C]

$A_t$  : Cultivation area of orchard at time  $t$  [ha]

$D$  : Planting density [tree/10a]

$W$  : Dry matter weight of above-ground biomass per tree [kg/tree]

- CF* : Carbon fraction of dry matter [t-C/t-d.m.]  
*j* : Type of orchard tree

- **Parameters**

- **Parameters for Living Biomass Estimation in Orchard tree**

Country specific parameters of the planting density, dry matter biomass weight per tree, and root-to-shoot ratio were set for major orchard trees based on existing research reports.

Dry matter biomass weight for tea tree are 48 t-d.m./ha; the dry matter biomass weight for fruit orchard tree are 8 - 24 t-d.m./ha, the root-shoot ratio is 7:3 - 5:4. The country specific carbon fraction of dry matter of forest (broad leaf: 0.48 t-C/t-d.m.) was applied as the carbon fraction of dry matter of orchard trees.

- **Activity Data**

- **Area for Orchard**

The cultivation areas for 15 major orchard trees were identified by *the Statistics of Cultivated and Planted Area* and for fruit trees other than 15 major orchard trees were identified by *Survey on Productive Movement of Local Fruits*. Even when the survey is conducted only in the main producing prefectures for major orchard trees, all the area of the orchard trees at each prefecture are estimated in line with the method to assume the national total area in the statistics or using interpolation. As the area of “newly-established” and “deserted” is not identified by orchard type in this statistic, only the apparent amount of change after land conversion is used as activity data. Therefore, this value includes area of orchard land converted from other land-use.

## 2) Carbon Stock Changes in Dead Organic Matter in “Cropland remaining Cropland”

- **Estimation Method**

Carbon stock changes in dead organic matter are estimated as zero by applying the Tier 1 method, assuming that the carbon stocks are not changed, according to section 5.2.2.1 in Volume 4 of the 2006 IPCC Guidelines. Thus, the carbon stock changes are reported as “NA”.

## 3) Carbon Stock Changes in Soils in “Cropland remaining Cropland”

For mineral soils, the estimations are conducted separately to agricultural land and dilapidated farmland. Carbon stock changes in agricultural land consist on carbon stock changes due to normal practices in farming as well as carbon accumulation by biochar amendment. For organic soils, the emission associated with cultivation of organic soils (on-site) and the emission due to water-soluble carbon loss from drained organic soils (off-site) in rice fields and upland fields in agricultural land were estimated.

- **Estimation Method**

- **Carbon Stock Changes in Mineral soils**

- **Carbon Stock Changes in Mineral soils in agricultural land (rice fields, upland fields and orchard)**

Japan uses a Tier 3 method, the Rothamsted Carbon Model (Roth C), to estimate soil organic carbon stock changes in agriculture land (cropland and managed grassland) over time.

As shown in Figure 6-5, amounts of soil carbon [t C/ha (for each 100m x 100m mesh)] by each of the five compartments with different rates of carbon decomposition are calculated monthly, using inputs

from weather data (monthly average temperature, precipitation, and open-pan evaporation), soil property data (soil clay content, depth of surface soil, carbon content at the starting year, and bulk density), land-use data, and carbon input from crop residue and organic manure. The annual soil carbon stock changes [t-C/ha/yr] for each mesh were calculated by taking the difference between the annual total carbon of all compartment for all months in this year and those in the previous year. In order to classify the report category of the GHG inventory, the average amount of soil carbon stock changes per unit area by each subcategory and by each prefecture [t-C/ha/yr] were estimated by identifying the land use in subcategory for each mesh and by superimposing the map with the prefectural administrative boundaries on the mesh data. The total carbon stock changes in agriculture land [t-C/year] were calculated by multiplying the carbon stock change parameter obtained from the model by the mineral soil area of each prefecture level obtained from statistics.

$$\Delta C_{C\_ms} = \sum_{i,j} (\Delta SOC_{i,j} \times A_{i,j})$$

$\Delta C_{C\_ms}$  : Carbon stock changes in mineral soils in agricultural land [t-C/yr]

$\Delta SOC_{i,j}$  : Carbon stock changes in mineral soils per unit area [t-C/ha/yr] by subcategory  $j$  and by prefecture  $i$ , estimated from the Roth C model

$A$  : Area of cropland with mineral soil obtained from statistics [ha]

$i$  : Prefecture

$j$  : Type of land-use subcategory in cropland (rice fields, upland fields and orchard)

In the model calculation, land unit which was recorded once as cropland since FY1970 was regarded as cropland and used for calculation; the result of the calculation includes all croplands, regardless of whether converted or not. Therefore, it is reported without distinction between converted or not, and the carbon stock changes in mineral soils in agricultural land converted from other land uses are included in this calculation.

#### - **Carbon Stock Changes in Mineral Soils Associated by Biochar amendment**

Carbon stocks change in mineral soils in cropland by biochar amendments were estimated by applying Tier 1 method provided in *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories* (hereafter *2019 Refinement*). This estimation includes hard charcoal, soft charcoal, bamboo charcoal, fine coal and sawdust coal produced in Japan considering the availability of its production data.

Furthermore, since information on amount of biochar applied into each subcategory is not available, the carbon stock changes were estimated and reported collectively in mineral soils in cropland remaining cropland. The estimation equation is as follows:

$$\Delta BC_{C\_ms} = \sum_p (BC_{TOT_p} \times F_{C_p} \times F_{perm_p})$$

$\Delta BC_{C\_ms}$  : Carbon stock changes in mineral soils land associated with biochar amendment in agricultural land, tonnes [t-C/yr]

$BC_{TOT_p}$  : Mass of biochar applied into mineral soil during the inventory year for each biochar production type  $p$  [t-d.m./yr]

$F_{C_p}$  : Organic carbon content of biochar for  $p$  [t-C/t-d.m.]

$F_{perm_p}$  : Fraction of biochar carbon for biochar  $p$  remaining (unmineralized) after 100 years [t-C/t-C]

$p$  : Biochar type (hard charcoal, soft charcoal, bamboo charcoal, fine coal and sawdust coal)

- **Carbon Stock Changes in Mineral soils in dilapidated farmland**

As it is described in the carbon stock changes in the biomass pool, carbon stock changes due to direct human management were considered zero in the dilapidated farmland area and so reported as "NA".

➤ **CO<sub>2</sub> Emissions from Organic Soils Caused by Cultivation and Drainage**

- **On-site CO<sub>2</sub> emissions from organic soils in rice fields and upland fields caused by cultivation and drainage**

On-site CO<sub>2</sub> emissions from organic soils in rice fields and upland fields were estimated by applying Tier 1 or Tier 2 estimation method described in section 5.2.3.1 in Volume 4 of the *2006 IPCC Guidelines*. Tier 2 method was applied to land-use subcategories for which country-specific emission factors were available.

$$L_{C\_os} = \sum_{j,z} (A_{j,z} \times EF_{j,z})$$

$L_{C\_os}$	: Loss of Carbon in organic soils [t-C/yr]
$A_{j,z}$	: Area of organic soils in subcategory $j$ in Climate zone $z$ [ha]
$EF_{j,z}$	: CO <sub>2</sub> emission factor in subcategory $j$ in Climate zone $z$ [t-C/ha/yr]
$j$	: Subcategory in cropland (rice fields, upland fields)
$z$	: Climate zone (Cold temperate zone, warm temperate zone)

- **Off-site CO<sub>2</sub> emissions via waterborne carbon losses from drained inland organic soils in rice fields and upland fields**

Off- site CO<sub>2</sub> emissions via waterborne carbon losses from drained inland organic soils in rice fields and upland fields were estimated by applying Tier 1 estimation method described in 2.2.1.2 section in the *Wetlands Guidelines*. The estimation equation is as follows. See section 6.13.b) for the methodology of methane emission.

$$CO_2-C_{DOC_{C\_os}} = \sum_j (A_j \times EF_{DOC})$$

$$EF_{DOC} = DOC_{FLUX_{NATURAL}} \times (1 + \Delta DOC_{DRAINAGE}) \times F_{rac_{DOC-CO_2}}$$

$CO_2-C_{DOC_{C\_os}}$	: Annual off-site CO <sub>2</sub> -C emissions due to DOC loss from drained organic soils [t-C/yr]
$A_j$	: Land area of drained organic soils in land-use subcategory $j$ [ha]
$j$	: subcategory in cropland (rice fields, upland fields)
$EF_{DOC}$	: Emission factors for annual CO <sub>2</sub> emissions due to DOC loss from drained organic soils [t-C/ha/yr]
$DOC_{FLUX_{NATURAL}}$	: Flux of DOC from natural (undrained) organic soil [t-C/ha/yr]
$\Delta DOC_{DRAINAGE}$	: Proportional increase in DOC flux from drained sites relative to undrained sites
$F_{rac_{DOC-CO_2}}$	: Conversion factor for proportion of DOC converted to CO <sub>2</sub> following export from site

- **CO<sub>2</sub> Emissions from Organic Soils Caused by Cultivation and Drainage in Orchard and Dilapidated farmland**

There are few organic soils area in orchard and it is common to grow fruit trees by either a method of cultivation by clean cultivation system or a method of cultivation by sod culture without cultivation and drainage of soils are not also implemented in dilapidated farmland. So, since no emissions occur in these inactive areas the emissions were reported as "NO" in accordance with the *2006 IPCC Guidelines*.

- **Parameters**

- **Key Assumption and parameters necessary for Roth C model estimating carbon stock changes in mineral soils in agricultural land (rice fields, upland fields and orchard)**

- **Application of Roth C model for Agricultural Land in Japan**

Roth C is a soil carbon dynamic model validated by using long-term field experiments (Coleman and Jenkinson, 1996). The model had been tested against long-term experimental data sets in Japanese agricultural lands and some modifications were made after that in order to apply the model to Japanese agricultural conditions. It was found that the original model could be applied for non-volcanic upland soils without any modification or calibration (Shirato and Taniyama, 2003), however, for Andosols, the decomposition rate constant of the HUM (humified organic matter) pool of Roth C was reduced because the presence of Al-humus complexes enhances its stability and resistance to decomposition (Shirato *et al.* 2004). And, for paddy soils, the decomposition rate constants of all four active C pools was reduced on the basis of differences in organic matter decomposition rates between upland and paddy (submerged in the rice growing season) soil conditions (Shirato and Yokozawa, 2005).

- **Input data for Roth C model estimation**

Weather data with 1km mesh resolution, soil property and land-use data obtained by 100m mesh were used. The statistical data and the questionnaire survey by prefecture were used for amount of carbon input from crop residue and organic manure. The input amount of crop residue was calculated in each crop by multiplying the crop yield by the ratio of residue generation and the ratio of plow-into soils. Since the amount of crop residue is related to the amount of crops rather than the amount of harvest, it is not considered that reflecting the annual fluctuation of the amount of harvest leads to accurate estimation. So, we decided to use the average yield (for rice fields, the average value of yield of rice calculated by the MAFF was used, and for upland fields and orchard, the average values of actual yield from 1970 to 2017 were used) for each year. The residue generation ratio is set by a same value all over the country for each crop from the literature values. And the ratio of plow-into soils are determined by the actual treatment ratio of plowing from the annual questionnaire survey. For rice, annual values are used for each region and for other crops, unified values for the entire period are used. For the farmland manure input, the amount of manure application in the item of “production cost of rice” in the *Statistics on Farm Management* is used for rice and the amount of manure application estimated by the questionnaire survey are used for crops other than rice (upland crops, vegetables, fruit trees, tea, feedstuff, pasture grass). However, since surveys are conducted over the course of several years except for rice fields, the values for the years when results of the survey are not compiled are complemented by interpolation or extrapolation, and if the number of samples is too small to assure representativeness, those data are used after statistical processing, such as exclusion from the usage for estimation.

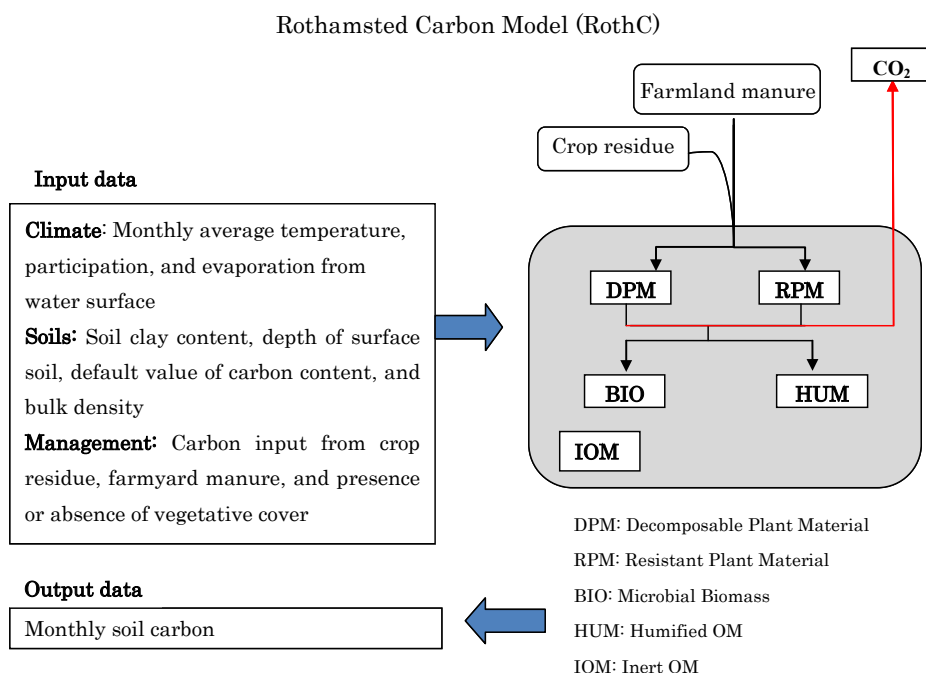


Figure 6-5 Roth C model

● **Parameters of biochar (carbon content and fraction of carbon remaining after 100 years)**

As for organic carbon content of biochar, the default value (0.77 t-C/t-d.m.) of heat treatment process for wood material provided in the *2019 Refinement* (Table 4Ap.1), was applied.

Fraction of carbon remaining after 100 years is based on the firing temperature of each biochar in Japan and the default value provided in the *2019 Refinement* (Table 4Ap.2). The default value (0.89 t-C/t-C) corresponding to firing temperature of 600°C or more was applied to hard charcoal, soft charcoal and sawdust coal; default value (0.80t-C/t-C) corresponding to firing temperature of 450 to 600°C was applied to fine coal.

Regarding bamboo charcoal, since a research focusing on bamboo charcoal components in Japan was obtained by Nagumo et al. (2014), country-specific value (43.6%) was applied. This value corresponds to the value including the organic carbon content and the fraction of carbon remaining after 100 years.

➤ **CO<sub>2</sub> emission factors from organic soils (on-site)**

The following CO<sub>2</sub> emission factors from organic soils in rice fields and upland fields were applied to the estimation.

Table 6-25 CO<sub>2</sub> emission factors resulting from cultivation of organic soils

Type of land use	Climate zone	Emission factors [t-C/ha/yr]	Reference
Rice fields	Cold temperate	1.55	Measured data <sup>1)</sup>
	Warm temperate	1.55	Data measured for cold temperate was applied. <sup>2)</sup>
Upland fields	Cold temperate	4.18	Measured data
	Warm temperate	10.0	Default value ( <i>2006 IPCC Guidelines</i> , Vol.4, Table 5.6)

Note:

- 1) Measured data of rice field was set as if emission in waterlogging period was zero (0).
- 2) The emission factor of rice field in warm temperate was excluded in default values in the *2006 IPCC Guidelines*; hence, the country-specific factor in cold temperate was applied as substitute.



➤ **Parameters for calculating CO<sub>2</sub> emissions from organic soils (off-site)**

Tier 1 default parameters described in the *Wetlands Guidelines* were applied to the estimation.

Table 6-26 Parameters for calculating CO<sub>2</sub> emissions from organic soils (off-site)

Climate zone	DOC <sub>FLUX_NATURAL</sub> [t-C/ha/yr]	DOC <sub>DRAINAGE</sub>	Frac <sub>DOC-CO2</sub>	EF <sub>DOC</sub> [t-C/ha/yr]
Temperate	0.21	0.60	0.9	0.31

Reference: the *Wetlands Guidelines*: Table 2.2

● **Activity Data**

➤ **Area of mineral soils**

Areas of mineral soils in cropland which are multiplied by carbon stock changes per unit area calculated by Roth C model were estimated from the reported area in the *Statistics of Cultivated and Planted Area*, divided as rice field (only the area with rice really planted), upland field (including the area divided into rice field with other crops planted and with no crops) and orchards; and the areas of organic soils in each divided area (Table 6-27) is subtracted. Since the model calculation includes the agricultural land converted from other land use, the area of the agricultural land (mineral soils) converted from other land use are also included for activity data.

➤ **Amount of biochar applied into cropland**

The amount of biochar applied to cropland, what is activity data, was calculated by multiplying the amount of wood charcoal production for agriculture use, by the proportion of biochar applied to cropland and the ratio of mineral soil area to total soil area.

As for the amount of wood charcoal production for agriculture use, the values classified as “agricultural use” obtained from *Statistical Survey on production of Special Forest Products* (MAFF), were applied. In addition, complete time series data were made using interpolation and allocation methods (If only the total value is available, allocation is conducted using the proportion of a certain wood charcoal in a certain year) due to lack of data for some years. Moreover, since wood charcoal were also used for “feed and other uses”, the amount of biochar amendments applied to cropland were calculated by subtracting wood charcoal production for “feed and other uses”, from the amount of wood charcoal production for “agricultural use”. Based on experts’ comments, the proportion of biochar applied to cropland was estimated as 95%. In addition, since it is difficult to obtain the amount of biochar production applied to mineral soil and organic soil in cropland separately, it is assumed that the same proportion (amount of biochar applied to cropland per unit area) of biochar production applied to all cropland for mineral soil and for organic soil in Japan. Therefore, the amount of biochar production applied to cropland in mineral soil and in organic soils were calculated based on percentage of total cropland occupied by mineral and organic soils as reported in GHG inventories.

However, since there is no default fraction of biochar C remaining after 100 years for organic soil in the *2019 Refinement* and data and information are not also available in Japan, carbon stock change associated with biochar amendments to organic soil in cropland was not subject to estimation. In addition, since the amount of import and export of biochar for “agricultural use” is infinitesimal, import and export of biochar applied to cropland were not estimated.

➤ **Area of organic soils**

For the area of organic soils in subcategories of agricultural land, in the year when the soil area data by soil group is obtained, the proportion of soil classified as organic soil is calculated from the soil area data by soil group by prefecture and is multiplied by each area by prefecture (in 1992, 2001 and 2010).

In other years, area of organic soils is calculated by adding or subtracting on or from the starting value at each fixed point in 1992, 2001, and 2010, using a certain rate for organic soils in the expanded / converted area. When the land is converted from other land use due to the expansion of agricultural land, the ratio of organic soil in the land-use category before conversion is basically used. However, regarding the conversion from wetlands, which covering reclaimed land from shallow water body, the ratio of organic soil was set to 0% (reported as "NO") because organic soil did not exist in the soil map around the reclaimed land in the reclaimed land corresponding to this activity.). In the case of conversion from agricultural land, the ratio of the changed area of the organic soil area to the changed total area that occurred during each survey year (1992-2001 or 2001-2010) is basically used. However, for land conversion before 1992, the organic soil ratio of each subcategory at the time of the 1992 survey is used, and for conversion after 1992, the value from 1992 to 2001 is used, and for conversion after 2001 onwards, the values from 2001 to 2010 is used.

Table 6-27 shows the total areas of organic soils (total organic soil area of cropland remaining cropland and land converted to cropland) by subcategories in cropland in Japan calculated by the method above. The CRF of the LULUCF sector requires the total area of organic soils to be reported regardless of cultivation or drainage as shown in Table 6-27, but the values used for activity data for emission estimation are the actual areas where those activities are conducted. The values of the areas of organic soils reported in the CRF Table in the Agricultural sector is the actually cultivated areas out of the total organic soils in the agricultural land. So, the values of the areas in the Agricultural sector were different from these in this table below (see section 5.5.1.6).

Table 6-27 Areas of organic soils in cultivated cropland

Category	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Cropland remaining Cropland	kha	170.4	168.3	168.6	167.4	166.0	165.4	165.6	165.8	166.0	166.1	166.0	166.6	167.1	167.5	168.0
Rice fields	kha	131.5	129.8	129.1	127.3	125.3	124.7	124.8	125.0	125.0	124.9	124.7	124.8	124.9	124.9	124.9
Upland fields	kha	16.7	16.7	17.0	16.9	16.8	16.6	16.5	16.4	16.3	16.2	16.1	16.1	16.1	16.1	16.2
Orchards	kha	1.3	1.0	0.5	0.4	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.5	0.5
dilapidated farmland	kha	20.9	20.9	22.0	22.8	23.6	23.7	23.9	24.0	24.3	24.6	24.8	25.3	25.7	26.0	26.3

### c) Uncertainties and Time-series Consistency

#### ● Uncertainty Assessment

For the parameters and the activity data in biomass in orchards, the uncertainties of existing statistics and the default values described in the *2006 IPCC Guidelines* were applied. For the uncertainties of carbon stock changes in mineral soil estimated by Roth C model, the comparison of simulation results and observed values, when both input values and current measurement values of mineral soils are available, revealed that the uncertainty due to model structure was estimated about 10%. The uncertainty caused by input values has not been quantified yet and remains as an issue to be solved. For the uncertainties of change in mineral soil organic carbon stocks from biochar amendments, the uncertainties of statistical data and default values given in *2019 Refinement* are used. For the uncertainties of organic soil, the uncertainties of statistical data and default values given in the *2006 IPCC Guidelines* are used. As a result, the uncertainty was estimated as 24% for the entire emission from the cropland remaining cropland.

#### ● Time-series Consistency

Time-series consistency for this category is ensured.

**d) Category-specific QA/QC and Verification**

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

Although calibration for Roth C model has not been carried out, it was confirmed that the simulation results of Roth C have matched well with the observed data using the three modified versions of the Roth C model classified by land uses and soil types (Paddy soils, Andosols and non-Andosols). Verification and modification of plot scale were done with measured data.

Experiment fields are classified by soil characteristics into Paddy soils group, Andosols group and non-Andosols group. These 3 soil types are considered to be covered with all soil type. For detailed information, see references; Shirato & Taniyama, (2003), Shirato et al., (2004), Shirato & Yokozawa, (2005), Takata et al., (2011), Shirato, (2011) listed in this chapter.

**e) Category-specific Recalculations**

- ***Correction in Accordance with Revision of D area***

Areas of deforestation (D area) is used for determining each land-use area converted from forest land. Since the D area were recalculated, areas of cropland remaining cropland were recalculated for all years. With this recalculation, carbon stock changes in mineral soils and CO<sub>2</sub> emissions from organic soils were recalculated for all years. For more details on correction of estimation methodology of areas of deforestation, please see Chapter 11, 11.5.1.7 in NIR “Review of AR areas and D areas”.

- ***Correction of input data used for Roth C model calculation***

The five-year moving average of the plowing rates in each region for the carbon input data (rice straw) was used for the Roth C model calculations.

Updating the data in 2019, the amount of crop residue input after 2017 was corrected.

In addition, for the 2019 weather data, climate change scenarios were used instead of AMeDAS observations. These changes in the input data lead recalculation in the soil carbon stock changes per unit area in each land category for the FY2017-2019.

- ***Changes in the methodologies for estimating un-surveyed cultivation areas of orchard trees in some prefectures***

Due to the abolition of conducting annual surveys on the cultivation areas of orchard trees in some prefectures since 2017, those missing data are complemented by an assumption. With the revision in estimation method of this assumption, the area of the orchard trees and the amount of change in carbon stock of biomass from FY2017 to FY2019 were recalculated.

- ***Recalculation of correction in area of mineral soils and organic soils***

The minerals soil and organic soils areas in farmland and lands converted from/to farmland for the years between 1992, 2001, and 2010, when area data in soil groups were available, are estimated by an assumption. As there was an incompleteness in methodologies of estimating these areas in land-use conversion categories, estimation method of an assumption was modified. With this recalculation, the CO<sub>2</sub> emissions from organic soils were recalculated in all years.

- **Recalculation for reconstruction of time series data of Dilapidated farmland**

For “cultivation abandoned agricultural land” (now called as “dilapidated farmland”) as a subcategory of cropland, the time-series of area data was reconstructed. Since the area survey of cultivation abandoned agricultural land which had been conducted every five years was discontinued any more, the data source of determining these area has been switched to use the results of the survey on the area of “dilapidated farmland” which has been conducted every year since 2008. With this change estimation method to assume dilapidated farmland before 2008 has also newly considered.

No recalculation of emissions and removals has occurred as a result of this change. See Chapter 10 for impact on trend.

**f) Category-specific Planned Improvements**

No improvements are planned.

## 6.6.2. Land converted to Cropland (4.B.2.)

**a) Category Description**

This subcategory deals with the carbon stock changes which occurred in the lands that were converted from other land-use categories to cropland within the past 20 years. Total area of land converted to cropland within the past 20 years by FY2020 is 54.2 kha, which represents 0.1% of the national total area.

The emissions from this subcategory in FY2020 were 118 kt-CO<sub>2</sub> (GHG emissions other than changes in carbon stock are not included in this value.); this represents a decrease of 92.4% compared to FY1990 and an increase of 6.9% compared to FY2019. Emissions from land converted to croplands decreased significantly from 1990 to 1993, but have not changed much since then. This decrease in the early 1990s was mainly due to the decrease in the area converted from forestland with high carbon stock to cropland.

**b) Methodological Issues**

**1) Carbon stock changes in Living Biomass in “Land converted to Cropland”**

- **Estimation Method**

The Tier 2 method which is estimation by summing the loss of carbon stock due to conversion ( $\Delta C_{LB\_conversion\_to\_C}$ ) and the change of carbon stock accumulated after conversion ( $\Delta C_{LC\_LB\_SC}$ ) was used for the annual carbon stock change in land converted to cropland ( $\Delta C_{LC\_LB}$ ). And the country specific value of the amount of biomass accumulation is used for forest land converted to cropland. The Tier 1 method using default values is applied for land uses other than forest land converted to cropland.

$$\Delta C_{LC\_LB} = \Delta C_{LB\_conversion\_to\_C} + \Delta C_{LC\_LB\_SC}$$

$$\Delta C_{LB\_conversion\_to\_C} = \sum_i \{ \Delta A_i \times (B_a \times CF_a - B_{b_i} \times CF_{b_i}) \}$$

$$\Delta C_{LC\_LB\_SC} = \sum_j (\Delta A_j \times C_j)$$

$\Delta C_{LC\_LB}$  : Annual carbon stock change in the converted land [t-C/yr]

$\Delta C_{LB\_conversion\_to\_C}$  : Annual carbon stock change at the time of land conversion [t-C/yr]

$\Delta C_{LC\_LB\_SC}$  : Annual carbon stock change accumulated due to biomass growth in the converted land after conversion [t-C/yr]

$i$	: Land use before conversion
$\Delta A_i$	: Area converted from land-use type $i$ to cropland for the current year [ha/yr]
$B_a$	: Dry matter biomass weight per unit area immediately following conversion to cropland [t-d.m./ha/yr], default value=0
$B_{bi}$	: Dry matter biomass weight per unit area before conversion from land-use type $i$ to cropland [t-d.m./ha/yr]
$CF_a$	: Carbon fraction of dry matter after conversion [t-C/t-d.m.]
$CF_{bi}$	: Carbon fraction of dry matter in land-use type $i$ before conversion [t-C/t-d.m.]
$\Delta A_j$	: Area converted to subcategory $j$ in cropland for the current year [ha/yr]
$C_j$	: Change of dry matter biomass weight per unit area accumulated after conversion [t-d.m./ha/yr], see Table 6-9.
$j$	: Land use in cropland subcategory after conversion (rice fields, upland fields) Carbon stock changes accumulated after conversion in Orchard is estimated collectively in cropland remaining cropland.

### ● **Parameters**

#### ➤ **Biomass stock in each Land-Use Category**

Table 6-8 is used for the estimation of biomass stock changes upon land-use conversion and Table 6-9 is used for subsequent changes in biomass stock due to biomass growth in the converted land. The carbon stock changes accumulated due to biomass growth after conversion in rice fields and upland fields equal to the amount of carbon stock acquired in one year after conversion (Table 6-9), so the same value was used assuming that the amount of carbon stock of annual crops set in Table 6-8 would be reached in one year.

The amount of crop residue which was used to estimate N<sub>2</sub>O emissions from crop residues plowed into agricultural soil after harvesting in the Agriculture sector (3.D.a.4) was used for the amount of carbon stock in rice fields and upland fields in this Table 6-8. In addition, since the amount of crop residues plowed into cropland differs depending on the type of crop, the carbon content of the crop residues plowed into cropland per unit cultivation area was weighted average according to the annual cultivation area. And the average value from FY1990 to FY2017 was calculated using the weighted average value each year calculated above and was applied as parameter uniformly over the whole years (Table 6-8).

In addition, biomass carbon stocks of annual crops per unit area were also applied as biomass growth of annual crops for one year after conversion (Table 6-9).

#### ➤ **Carbon Fraction of Dry Matter**

For carbon fraction of dry matter of forest, average value of broad leaf trees and conifer trees (0.50 t-C/t-d.m.) was applied. The default value (0.47 t-C/t-d.m. for herbaceous biomass in grassland and 0.5 t-C/t-d.m. for the others) was applied for other than forest in accordance with the *2006 IPCC Guidelines*.

### ● **Activity Data**

For the calculation of the carbon stock changes of living biomass in land converted to cropland, the annual area converted to cropland was used.

#### ➤ **Areas of Forest land Converted to Other Land-use Categories**

It was assumed that the areas of forest land converted to other land-use categories (cropland, grassland, wetlands, settlement and other land) were consistent with the area of deforestation reported under Article 3, paragraph 3, of the Kyoto Protocol. Thus, the area of forest land converted to cropland was estimated by allocating the deforested area. Since the D survey by satellite image has been conducted since FY2005, the applied method to calculate the deforested area for FY1971 to FY1989, for FY1990

to FY2004 and for FY2005 onwards are described as follows, respectively.

- ***From FY2005 onwards***

Total “D areas (deforested area identified by the D survey)” and the share of land use after land conversion are identified by utilizing the orthophotos taken at the end of 1989 and satellite images taken from FY2005 onwards as same as the AR areas are identified. The areas of forest land converted to cropland, grassland, wetlands, settlements and other land were estimated by multiplying the total D area by the land ratios of forest land converted to each land-use category. Both the ratio and the area were estimated by the D survey. For further information on determining D areas, see section 11.4.2.3. in Chapter 11. Regarding the land converted to cropland, we further estimated the area converted to rice fields, upland fields and orchard separately using statistical area data.

- ***From FY1990 to FY2004***

In the period from FY1990 to FY2004, annual conversion areas from forest land to other land-use categories were estimated dividing the total D areas occurred from FY1990 to FY2005 by the ratio of annual forest conversion areas for this period based on the Forest Agency’s record. To estimate areas of forest land converted to each land-use category, the ratios of conversions by land-use categories based on the same Forestry Agency’s records as above mentioned was used. This record only covers private forest, but the conversion from private forests to other land-use categories accounts for 90% of the total areas of conversion from forest land. Thus, the record above is assumed as the value for total forest.

- ***From FY1971 to FY1989***

With respect to the areas before 1989, since D survey is not conducted in this period, the areas were obtained from statistics provided by the *Census of Agriculture and Forestry* and the Forestry Agency’s records, but the areas obtained from the surveys on D areas were larger than those from statistics. Hence, the total areas converted from forest land are estimated by setting an adjustment factor from the ratio between the D areas since FY1990 and the areas converted from forests provided by and the Forestry Agency’s records, and multiplying the areas converted from forests since FY1970 by the adjustment factor.

➤ ***Areas of Conversion from Land-use Categories Other than Forest land***

The areas of land converted from land-use categories other than forest land to cropland are determined by applying expansion area values provided by the *Statistics of Cultivated and Planted Area*. The converted areas from arable land are divided into upland fields, orchards, and pasture land proportionately by means of the current situation. The areas of rice fields, upland fields, and orchards are allocated to cropland, while the area of pasture land is allocated to grassland. In addition, settlements converted to cropland are reported as “IE” because the areas are included in other land remaining other land.

It should be noted that the area presented in the CRF “Table 4.B Sectoral background data for land use, land-use change and forestry—Cropland” is not the annually converted area but the sum of annually converted areas during the past 20 years.

Table 6-28 Area of land converted to cropland within the past 1 year

Category	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Land converted to Cropland	kha	5.83	2.21	1.77	0.97	0.81	0.88	4.56	4.53	3.57	1.97	1.22	5.02	7.44	7.64	6.84
Forest land converted to Cropland	kha	5.27	1.05	0.33	0.55	0.78	0.76	0.76	0.50	0.50	0.48	0.48	0.22	0.22	0.35	0.35
Rice fields	kha	0.01	0.01	0.00	0.00	0.14	0.09	0.14	0.28	0.45	0.33	0.20	0.13	0.10	0.15	0.16
Upland fields	kha	3.83	0.78	0.25	0.43	0.50	0.53	0.49	0.18	0.04	0.12	0.23	0.07	0.10	0.16	0.15
Orchards	kha	1.43	0.26	0.08	0.12	0.13	0.14	0.13	0.05	0.01	0.03	0.06	0.02	0.02	0.04	0.04
Grassland converted to Cropland	kha	0.00	0.05	0.03	0.06	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.01	0.00	0.00	0.01
Wetlands converted to Cropland	kha	0.34	0.03	0.07	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Settlements converted to Cropland	kha	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Other land converted to Cropland	kha	0.21	1.07	1.34	0.36	0.04	0.11	3.79	4.03	3.06	1.48	0.74	4.79	7.22	7.29	6.49
Rice fields	kha	0.19	1.04	1.32	0.26	0.03	0.11	3.67	3.67	2.73	1.18	0.47	3.19	3.87	3.87	3.54
Upland fields	kha	0.02	0.03	0.02	0.08	0.01	0.01	0.10	0.28	0.26	0.24	0.21	1.29	2.69	2.75	2.38
Orchards	kha	0.01	0.01	0.01	0.02	0.00	0.00	0.03	0.07	0.07	0.06	0.05	0.32	0.66	0.66	0.56

## 2) Carbon Stock Change in Dead Organic Matter in “Land converted to Cropland”

### ● Estimation Method

Carbon stock changes in dead organic matter in forest land converted to cropland were estimated by applying Tier 2 estimation method using the value of carbon stock in dead organic matter in forest land obtained by the CENTURY-jfos model. All carbon stocks in dead organic matter in the subcategory are assumed oxidized and emitted as CO<sub>2</sub> within the year of conversion in accordance with the description in section 5.3.2.1 in the 2006 IPCC Guidelines. In addition, as described in the Parameters section below, carbon stocks of dead organic matter in cropland are assumed to be zero.

$$\Delta C_{DOM} = \sum_i \{ (C_{after,i} - C_{before,i}) \times \Delta A \}$$

$\Delta C_{DOM}$  : Carbon stock changes in dead organic matter in the converted land [t-C/yr]

$C_{after,i}$  : Average carbon stock per unit area in dead wood or litter after conversion [t-C/ha]

Note: carbon stocks after conversion are assumed as “0” (zero).

$C_{before,i}$  : Average carbon stock per unit area in dead wood or litter before conversion [t-C/ha]

$\Delta A$  : Area of converted land within the year of conversion [ha/yr]

$i$  : type of dead organic matter (dead wood, litter)

### ● Parameters

Average carbon stocks in dead wood and litter in forest land before conversion are shown in Table 6-10 and Table 6-11. In addition, it is assumed that they become zero immediately after conversion, and will not accumulate after conversion. With regard to grassland converted to cropland, carbon stocks of dead wood and litter carbon pools were assumed to be minor and the stock changes could be ignored, and were set to zero. With regard to wetlands and settlements converted to cropland, these were also reported as “NA”, since it is assumed that carbon stock changes are from zero to zero, supposing that basically no such carbon pools exist in reclaimed wetland and that carbon stocks in dead organic matter in settlements before conversion could be negligible. Other land converted to cropland, which is estimated to be cropland restoration, was set to zero, because dead wood and litter in non-forest land are assumed as zero based on the Tier 1 method described in the 2006 IPCC Guidelines.

### ● Activity Data

Annually converted areas from forest land to cropland are used for estimating carbon stock changes in

dead organic matter in land converted to cropland.

### 3) Carbon Stock Changes in Soils in “Land converted to Cropland”

#### ● Estimation Method

##### ➤ carbon stock changes in mineral soils

Carbon stock changes in mineral soils in “Land converted to Cropland” is reported under “Cropland remaining cropland” using Tier 3 modeling method as described in 6.6.1.b) 2). Therefore, carbon stock changes in mineral soils in cropland converted from other land-use categories was reported as “IE”.

##### ➤ CO<sub>2</sub> emissions from organic soils caused by cultivation and drainage

CO<sub>2</sub> emissions from organic soils were estimated in rice field and upland field converted from other land-use categories caused by cultivation (on-site) and from water soluble carbon loss from drained organic soils (off-site). For detailed information on the emission factors and activity data, see section 6.1.1. Note that no distinction is made here between land use prior to conversion, which is reported collectively in "agricultural land converted from grassland".

#### ● Activity Data

The areas of land converted to cropland including area of mineral soils and organic soils are shown in Table 6-29 below.

##### ➤ Area of mineral soils

The area of mineral soil in cropland converted from other land-use categories reported in the CRF “Table 4.B” was also used for estimating N<sub>2</sub>O emissions reported in the CRF “Table 4(III)”.

##### ➤ Area of organic soils

The methodology for estimating the area of organic soils in land converted to cropland is as same as that in cropland remaining cropland (4.B.1.) explained in section 6.6.1.b.3).

Table 6-29 Area of land converted to cropland within the past 20 years

Category	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Land converted to Cropland	kha	222.5	163.8	114.7	61.3	32.0	29.3	30.2	32.9	33.2	33.0	33.2	37.5	44.1	49.1	54.2
Forest land converted to Cropland	kha	130.0	121.0	99.8	48.3	18.1	15.9	13.4	12.8	12.2	11.6	11.4	10.9	10.5	10.2	10.2
Rice fields	kha	11.4	7.3	0.9	0.4	0.6	0.7	0.8	1.1	1.4	1.7	1.9	2.0	2.1	2.3	2.4
Upland fields	kha	79.2	79.8	69.8	34.7	13.2	11.6	9.7	9.1	8.4	7.7	7.4	7.0	6.5	6.2	6.1
Orchards	kha	39.3	34.0	29.1	13.2	4.3	3.6	2.9	2.7	2.4	2.2	2.1	1.9	1.8	1.7	1.6
Grassland converted to Cropland	kha	33.7	15.8	1.2	1.0	1.0	1.0	0.9	0.7	0.5	0.5	0.4	0.4	0.4	0.3	0.3
Wetlands converted to Cropland	kha	11.0	3.2	1.7	1.2	0.7	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.5	0.5	0.5
Settlements converted to Cropland	kha	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Other land converted to Cropland	kha	47.8	23.8	12.0	10.8	12.1	11.7	15.2	18.7	19.9	20.3	20.9	25.6	32.7	38.1	43.2
Rice fields	kha	24.0	13.7	10.7	9.4	10.8	10.4	13.8	17.1	18.2	18.4	18.7	21.8	25.6	27.6	29.8
Upland fields	kha	12.8	6.9	1.0	1.1	1.0	1.0	1.1	1.2	1.3	1.5	1.7	3.0	5.7	8.4	10.8
Orchards	kha	11.0	3.2	0.4	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.5	0.8	1.4	2.1	2.6

### c) Uncertainties and Time-series Consistency

#### ● Uncertainty Assessment

Uncertainties of the parameters and the activity data for living biomass, dead organic matter were individually assessed on the basis of field study results, expert judgment, or the default values described in the 2006 IPCC Guidelines. The uncertainty was estimated as 20% for the entire emission from the



land converted to cropland.

- ***Time-series Consistency***

The methods to estimate the area of forest land converted to other land-use categories are different between before FY1989 and after FY1990, however, the values before 1989 are adjusted using the ratio of the area before 1989 to the areas after 1990 as described in section 6.6.2.b)1). Thus, the time-series consistency for this subcategory is basically ensured.

- d) ***Category-specific QA/QC and Verification***

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

- e) ***Category-specific Recalculations***

- ***Correction in accordance with revision of D area***

Since the method of estimating D area, which is used for estimating the areas of cropland converted from forest land were recalculated, carbon stock changes in living biomass, dead organic matter and CO<sub>2</sub> emissions from organic soils in this category were recalculated for all years. See Chapter 10 for impact on trend.

- f) ***Category-specific Planned Improvements***

- ***Methods of Obtaining Data of the area of “Grassland converted to Cropland”***

Statistical data on the area of land converted from grassland to cropland are limited to land converted from grassland (pasture land) to cropland (rice field), so the carbon stock changes in these areas have not been estimated. Therefore, the methods to detect the following area data of conversion need to be developed.

- from pasture land / grazed meadow to upland field
- from pasture land / grazed meadow to orchard
- from grazed meadow to rice field

## **6.7. Grassland (4.C.)**

Grassland is generally covered with perennial pasture and is used mainly for harvesting fodder or grazing. In FY2020, Japan’s grassland area was about 0.95 million ha, which is equivalent to about 2.5% of the national land. The area of organic soil in the grassland is about 0.054 million ha. The emissions from carbon stock changes in this category in FY2020 were 551 kt-CO<sub>2</sub> (GHG emissions other than changes in carbon stock are not included in this value.); this represents a decrease of 16.4% compared to FY1990 and a decrease of 19.9% compared to FY2019.

Table 6-30 Emissions and removals from grassland resulting from carbon stock changes

Category	Carbon pool	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
4.C. Grassland	Total	kt-CO <sub>2</sub>	659	61	-896	-284	179	776	796	1,096	1,707	1,372	1,078	831	592	687	551
	Living Biomass	kt-CO <sub>2</sub>	106	13	-6	76	180	57	83	121	125	88	89	42	37	6	4
	Dead Wood	kt-CO <sub>2</sub>	41	9	3	26	67	29	29	47	46	34	34	20	20	8	8
	Litter	kt-CO <sub>2</sub>	20	4	1	12	33	14	14	23	23	17	17	10	10	4	4
	Mineral soil	kt-CO <sub>2</sub>	465	7	-923	-426	-128	644	636	874	1,477	1,196	911	731	497	641	507
	Organic soil	kt-CO <sub>2</sub>	27	28	29	28	27	33	34	31	36	38	28	28	28	28	28
4.C.1. Grassland remaining Grassland	Total	kt-CO <sub>2</sub>	486	31	-898	-401	-104	673	666	902	1,510	1,231	937	757	523	668	533
	Living Biomass	kt-CO <sub>2</sub>	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Dead Wood	kt-CO <sub>2</sub>	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Litter	kt-CO <sub>2</sub>	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Mineral soil	kt-CO <sub>2</sub>	465	7	-923	-426	-128	644	636	874	1,477	1,196	911	731	497	641	507
	Organic soil	kt-CO <sub>2</sub>	20	24	25	25	24	29	30	28	33	35	26	26	26	26	27
4.C.2. Land converted to Grassland	Total	kt-CO <sub>2</sub>	173	30	1	117	283	104	130	194	197	141	141	74	68	19	17
	Living Biomass	kt-CO <sub>2</sub>	106	13	-6	76	180	57	83	121	125	88	89	42	37	6	4
	Dead Wood	kt-CO <sub>2</sub>	41	9	3	26	67	29	29	47	46	34	34	20	20	8	8
	Litter	kt-CO <sub>2</sub>	20	4	1	12	33	14	14	23	23	17	17	10	10	4	4
	Mineral soil	kt-CO <sub>2</sub>	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO
	Organic soil	kt-CO <sub>2</sub>	7	4	3	3	3	4	4	3	3	3	2	2	1	1	1

### 6.7.1. Grassland remaining Grassland (4.C.1.)

#### a) Category Description

In this category carbon stock changes in grassland remaining grassland during the past 20 years are reported, divided into three subcategories: “pasture land”, “grazed meadow” and “wild land”.

The emissions from carbon stock changes in this category in FY2020 were 533 kt-CO<sub>2</sub> (GHG emissions other than changes in carbon stock are not included in this value.); this represents an increase of 9.9% over the FY1990 value and a decrease of 20.1% compared to FY2019. Regarding the trend of emissions and removals, a peak of removals was occurred in FY1999, then the amount of removals has been on a decreasing and hit a peak of emissions in FY2014. The amount of emissions has been on a decreasing trend since then. This high variability was considered mainly caused by annual changes of amount of carbon input into soils and annual fluctuation of temperature, as it is described in the estimation of mineral soil pools in cropland. The amount of manure application had been on an increasing trend in the 1990s and has been decreasing since 2000. In addition, recently there have been no cold year; the relatively mild weather might facilitate more organic matter decomposition. Thus, it is considered that these factors are mainly contribute to the trend.

With respect to living biomass, carbon stock changes in pasture land and grazed meadow are assumed to be in a steady state and reported as “NA” in accordance with the Tier 1 estimation method in section 6.2.1.1 in the *2006 IPCC Guidelines*.

Carbon stock changes in dead organic matter in pasture land and grazed meadow are estimated as zero (0) by applying the Tier 1 method described in section 6.2.2.1 in the *2006 IPCC Guidelines*, which assumes that the carbon stocks are not changed. Thus, the carbon stock changes are reported as “NA”.

In regard to carbon stock changes in mineral soils, the carbon stock changes in pasture land were estimated by applying the Tier 3 method using Roth C model same as cropland remaining cropland. Grazed meadows were non-degraded and sustainably managed grassland, but without significant management improvements. Therefore, the default value of the carbon stock change factor for “Nominally managed (non-degraded)” in table 6.2 of the *2006 IPCC Guidelines*, which was “1.0”, was

applied to grazed meadows. In this case, soil carbon stocks were not changed over time; therefore, the soil carbon stock changes in grazed meadows were reported as “NA”. On-site CO<sub>2</sub> emissions resulting from cultivation and drainage of organic soils and off-site CO<sub>2</sub> emissions via waterborne carbon losses from drained inland organic soils in pasture land were estimated by applying Tier 1 method.

CO<sub>2</sub> emission from organic soils in grazed meadow was reported as “NO” because the cultivation and drainage resulting from renewal of grazed meadow are not implemented.

Carbon stock changes in all carbon pools in wild land are reported as “NA” because anthropogenic management is not implemented to the wild land in general.

Table 6-31 Areas of grassland remaining grassland within the past 20 years

Category	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Grassland remaining Grassland	kha	705.1	854.5	951.0	978.3	965.6	927.9	926.4	923.7	930.0	928.3	914.7	921.7	918.3	915.6	913.0
Pasture land	kha	320.1	493.6	584.2	601.8	589.2	587.9	586.4	583.7	580.0	578.3	574.7	571.7	568.3	565.6	563.0
Grazed meadow	kha	105.0	100.9	96.8	96.5	96.4	96.4	96.4	96.3	96.3	96.3	96.3	96.3	96.2	96.2	96.2
Wild land	kha	280.0	260.0	270.0	280.0	280.0	243.6	243.6	243.7	253.7	253.7	243.7	253.7	253.8	253.8	253.8

## ***b) Methodological Issues***

### ***1) Carbon Stock Changes in Soils in “Grassland remaining Grassland”***

#### **● Estimation Method**

##### **➤ Estimation of Carbon stock changes in mineral soils**

Carbon stock change in mineral soils in pasture land was estimated by using the Tier 3 modeling method same as 6.6.1.b)2) cropland remaining cropland (4.B.1.).

##### **➤ Estimation of on-site CO<sub>2</sub> emissions resulting from cultivation in organic soils**

With respect to CO<sub>2</sub> emissions from organic soils in pasture land were estimated by applying the Tier 1 estimation method described in section 6.2.3.1 in the *2006 IPCC Guidelines*. The estimation method is the same as cropland remaining cropland (4.B.1.).

##### **➤ Estimation of off-site CO<sub>2</sub> emissions via waterborne carbon losses from drained inland organic soils**

Off-site CO<sub>2</sub> emissions via waterborne carbon losses from drained inland organic soils were estimated by applying Tier 1 estimation method described in section 2.2.1.2 in the *Wetlands Guidelines*. The estimation method is the same as cropland remaining cropland (4.B.1.).

#### **● Parameters**

##### **➤ Assumption for the Roth C model and parameters for estimating mineral soils**

The parameters used are omitted because they are the same as cropland remaining cropland (4.B.1.).

##### **➤ Parameters for estimation of CO<sub>2</sub> emissions from organic soils**

Because there is little research data on CO<sub>2</sub> emission factor that is suitable for grassland in Japan, the default value provided in the *Wetlands Guidelines* (Table 2.1, 6.1 t-C/ha/year) which is considered to be most appropriate for the emission factor under the distribution of pasture land and current management system in Japan, was applied. As for off-site CO<sub>2</sub> emissions, the same parameters as cropland remaining cropland (4.B.1.) were used.

- **Activity Data**

- **Area of mineral soils**

The area of mineral soils applied for Roth C model is calculated by subtracting area of organic soils in pasture land from total area of pasture land reported in the *Statistics of Cultivated and Planted Area*.

- **Area of organic soils**

Areas of organic soils in pasture land remaining pasture land and in pasture land converted from other land-use were obtained by applying the method same as section 6.6.1.b)2). The activity data (the actual area for conducting cultivation and drainage) was calculated by multiplying renewal ratio of pasture land by the area of organic soils in pasture land. For the renewal ratio of pasture land, the values (Hokkaido and other than Hokkaido) published in the report of “Survey on actual situation of grassland management for feed” (Hatano, 2017) which investigated the management status of pastures were applied (see section 5.5.1.6. in Chapter 5 in this NIR). Moreover, about renewal ratio of pasture land before FY2005, the average value between FY2006 and FY2010 was applied because the survey has not been implemented. Also, since there are no survey values for FY2016 and for FY2017, the average values from FY2006 to FY2010 were used as well. The area of organic soil in grazed meadow and in wild land in FY2009 were calculated by multiplying the area of grazed meadow (*Census of agriculture and Forestry*) and wild land (*Land Use Status Survey*) in FY2009, by ratio of organic soil area obtained from GIS (Geographic information system) data analysis results in FY2009. The area of organic soil before FY2009 and after FY2009 were calculated by adding organic soil area in grazed meadow and wild land converted other land-use to FY2009, and by subtracting organic soil area in land converted from grazed meadow and wild land from FY2009.

In addition, as described in section 6.6.1, since the area of organic soil reported in the Agriculture sector does not include areas of organic soil in grazed meadow and in wild land, the area of organic soil reported in LULUCF sector is different to the value reported in the Agriculture sector.

Table 6-32 Area of organic soil in grassland remaining grassland within the past 20 years

Category	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Grassland remaining Grassland	kha	46.9	51.0	53.4	53.6	53.1	51.3	51.2	51.6	52.5	52.8	52.7	53.5	53.8	54.0	54.3
Pasture land	kha	29.2	34.2	36.2	35.9	35.4	35.3	35.3	35.7	36.0	36.4	36.7	37.1	37.3	37.6	37.8
Grazed meadow	kha	4.6	4.6	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
Wild land	kha	13.2	12.2	12.7	13.2	13.2	11.4	11.4	11.4	11.9	11.9	11.4	11.9	11.9	11.9	11.9

### c) **Uncertainties and Time-series Consistency**

- **Uncertainty Assessment**

Uncertainties of carbon stock change in mineral soil are the same as cropland remaining cropland (4.B.1); therefore, the description is omitted. Uncertainties of existing statistical data and the default values described in the *Wetlands Guidelines* were applied to estimate CO<sub>2</sub> emissions from organic soil. As a result, the uncertainty was estimated as 10% of the total emissions grassland remaining grassland.

- **Time-series Consistency**

Time-series consistency for this category is ensured.

### d) **Category-specific QA/QC and Verification**

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*.

The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

#### *e) Category-specific Recalculations*

##### ● *Correction in accordance with revision of D area*

Areas of deforestation (D area) is used for determining each land use area converted from forest land. Since the D area were recalculated, areas of grassland remaining grassland were recalculated for all years. With this recalculation, carbon stock change in mineral soils and CO<sub>2</sub> emissions from organic soils were recalculated for all years. See Chapter 10 for impact on trend.

See Chapter 10 for impact on trend.

#### *f) Category-specific Planned Improvements*

No improvements are planned.

### **6.7.2. Land converted to Grassland (4.C.2.)**

#### *a) Category Description*

This subcategory deals with the carbon stock changes, which occurred in the lands that were converted from other land-use categories to grassland within the past 20 years. The emissions from carbon stock changes in this category in FY2020 were 17.1 kt-CO<sub>2</sub> (GHG emissions other than changes in carbon stock are not included in this value.); this represents a decrease of 90.1% compared to FY1990 and a decrease of 12.1% compared to FY2019. With respect to living biomass, its carbon stock changes as a result of land-use conversion from other land use to grassland are estimated. The carbon stock changes include both temporary loss of living biomass in the land before and subsequent gain after conversion.

With respect to dead organic matter, Japan used the CENTURY-jfos model to estimate carbon stocks in dead organic matter in forest land, and then estimated carbon stock changes in forest land converted to grassland. Carbon stock changes in grassland converted from land-uses other than forest land were reported as “NA” or “NO” because suitable knowledge for estimating carbon stocks for the land-use categories was not available, or because it was assumed that no carbon stock change occurred, respectively.

Carbon stock changes in soils as a result of land-use conversion from other land use to grassland were estimated. With respect to carbon stock changes in mineral soils, the carbon stock changes in grassland converted from forest land, cropland, wetlands and other land were estimated together for the whole grassland, and reported in grassland remaining grassland (“IE” in land converted to grassland). CO<sub>2</sub> emissions from organic soils in pasture land converted from cropland were estimated. CO<sub>2</sub> emissions in forest land converted to grassland were reported as “NO” because conversion of organic soil area from forest land to grassland was not implemented in general in Japan. CO<sub>2</sub> emissions from organic soils in grassland converted from wetlands and Other land were reported as “IE” because the emissions were included in those in grassland remaining grassland.

Carbon stock changes in each carbon pool in settlements converted to grassland are reported as “NO” because the land conversion from settlements to grassland is not implemented in general in Japan.

## **b) Methodological Issues**

### **1) Carbon stock changes in Living biomass in “Land converted to Grassland”**

#### ● **Estimation Method**

The Tier 2 method was applied to estimate forest land and cropland (rice fields) converted to grassland (pasture lands) using country specific and provisional values of the amount of biomass accumulation. The Tier 1 method was used for land uses other than forest land and cropland (rice fields) converted to grassland (pasture lands) using default value. The equations are given in section 6.6.2.b)1). While the annually converted areas were used for estimating the loss of living biomass upon land-use conversion, the biomass growth after land-use conversion was estimated by summing the converted areas for the latest five years, assuming that it takes five years after conversion to reach a steady state with a constant growing rate.

#### ● **Parameters**

##### ➤ **Biomass stock in each Land-Use Category**

The values shown in Table 6-8 and Table 6-9 are used for the estimation of biomass stock changes upon land-use conversion and subsequent changes in biomass stock due to biomass growth in converted land.

##### ➤ **Carbon Fraction of Dry Matter**

Average value of broad leaf trees and conifer trees (0.50 t-C/t-d.m.) was applied as the carbon fraction of dry matter of forest. The default value (0.47 t-C/t-d.m. for herbaceous biomass in grassland and 0.5 t-C/t-d.m. for the others) was applied for other than forest in accordance with the *2006 IPCC Guidelines*.

#### ● **Activity Data (Area)**

For the estimation of carbon stock change in living biomass in grassland converted from other land-use categories, the annually converted areas were used for estimating the loss (Table 6-33) and the areas of summing the converted areas for the latest five years are used for estimating the biomass growth after land-use conversion (Table 6-34).

##### ➤ **Area Converted from Forestland**

As described in 6.6.2.b)1), the methodology of “Areas of forest land converted to other land-use categories” is applied.

##### ➤ **Area Converted from other than Forestland**

As shown in Table 6-2, grassland is treated as a part of arable land in statistics of Japan. Therefore, the procedure to obtain the area of the grassland converted from other land-use categories is as described in 6.6.2.b)1). Areas of settlements converted to grassland are reported as “NO” because land conversion from settlements to grassland does not occur.

It should be noted that the area presented in the CRF “Table 4.C Sectoral background data for land use, land-use change and forestry – Grassland” is not the annually converted area in FY2020 but the sum of annually converted areas during the past 20 years.

Table 6-33 Area of land converted to grassland within the past 1 year

Category	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Land converted to Grassland	kha	1.8	0.8	1.1	2.2	1.9	1.1	0.9	1.3	1.3	1.1	1.3	1.6	2.2	2.0	1.9
Forest land converted to Grassland	kha	0.7	0.2	0.1	0.5	1.2	0.5	0.5	0.9	0.9	0.6	0.6	0.4	0.4	0.2	0.2
Cropland converted to Grassland	kha	0.9	0.6	1.0	1.7	0.7	0.6	0.4	0.3	0.3	0.4	0.5	0.5	0.4	0.4	0.5
Wetlands converted to Grassland	kha	0.1	0.0	0.0	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Settlements converted to Grassland	kha	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Other land converted to Grassland	kha	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.7	1.4	1.4	1.3

Table 6-34 Area of land converted to grassland within the past 5 years

Category	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Land converted to Grassland	kha	11.6	5.1	5.1	7.1	10.3	9.5	8.2	7.2	6.6	5.8	5.9	6.6	7.4	8.1	9.0
Forest land converted to Grassland	kha	4.7	1.4	0.5	0.6	5.4	5.4	4.7	4.4	4.0	3.4	3.5	3.3	2.8	2.1	1.7
Cropland converted to Grassland	kha	6.5	3.4	4.5	6.2	4.6	3.8	3.2	2.6	2.2	1.9	1.9	2.0	2.1	2.2	2.4
Wetlands converted to Grassland	kha	0.3	0.1	0.0	NO	0.2	0.2	0.2	NO	NO	NO	NO	NO	NO	NO	NO
Settlements converted to Grassland	kha	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Other land converted to Grassland	kha	0.1	0.2	0.0	0.3	0.1	0.0	0.1	0.2	0.3	0.5	0.6	1.2	2.5	3.8	4.9

## 2) Carbon Stock Change in Dead Organic Matter in “Land converted to Grassland”

### ● Estimation Method

In this category, carbon stock changes in dead organic matter in forest land converted to grassland were estimated. The Tier 2 estimation method was applied to the subcategory using country specific values of the carbon stocks before and after conversion. It should be noted that the carbon stocks of dead organic matter after conversion to grassland are assumed as zero (Tier 1 method in the *2006 IPCC Guidelines*, Vol.4, section 6.3.2), because there are no quantitative data of them, although a subtle but certain amount of carbon stocks does generally exist on the soil surface. As described in section 6.6.2.b)2), cropland converted to grassland were reported as “NA” since the carbon stocks before and after conversion were assumed as zero. As for wetlands and other land converted to grassland, they include only reclamation and restoration. Thus, they were reported as “NA”<sup>4</sup>, for the same reasons as described in section 6.6.2.b)2).

### ● Parameters

The average carbon stocks in dead wood and litter in forest land before conversion are shown in Tables 6-9 and 6-10. The average carbon stocks in these categories from FY1990 to FY2004 are not estimated; therefore those in FY2005 are substituted for them. In addition, it is assumed that they become zero immediately after conversion, and are not accumulated after conversion. All carbon stocks in dead organic matter in the subcategory are assumed oxidized and emitted as CO<sub>2</sub> within the year of conversion in accordance with the description in section 6.3.2.2 in the *2006 IPCC Guidelines*.

### ● Activity Data (Area)

The sum of annually converted areas from other land-use categories to grassland for the past 20 years was regarded as the area of land converted to grassland during the past 20 years. The areas are shown in Table 6-35.

<sup>4</sup> Cropland in the Japanese statistics includes pasture land which falls into grassland.

Table 6-35 Areas of land converted to grassland within the past 20 years

Category	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Land converted to Grassland	kha	326.5	167.1	60.5	28.8	27.5	27.3	26.9	27.4	27.8	28.2	28.7	29.3	30.3	31.2	32.1
Forest land converted to Grassland	kha	182.6	106.3	35.0	7.1	7.8	8.0	8.0	8.7	9.4	9.9	10.4	10.6	10.9	11.0	11.1
Cropland converted to Grassland	kha	70.6	38.5	23.9	20.7	18.8	18.5	18.0	17.7	17.5	17.3	17.2	16.8	16.2	15.6	15.2
Wetlands converted to Grassland	kha	1.7	1.6	1.0	0.4	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Settlements converted to Grassland	kha	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Other land converted to Grassland	kha	71.6	20.7	0.5	0.6	0.6	0.5	0.6	0.6	0.7	0.8	0.9	1.6	3.0	4.4	5.7

### 3) Carbon Stock Change in Soils in “Land converted to Grassland”

#### ● Estimation Method

Carbon stock changes in mineral soils in pasture land was estimated by applying the Tier 3 estimation method same as the one for Cropland remaining Cropland (4.B.1.) in section 6.6.1.b)2). For the estimation, land which was once pasture land since 1970's was regarded as pastures land and used for calculation; the result of the calculation includes all grassland, regardless of land conversion. Therefore, carbon stock pools in mineral soil was reported regardless of whether or not land conversion has been occurred and carbon stock changes in mineral soils in pasture land converted from other land use was reported as “IE” since it was included in carbon stock changes in mineral soils in pasture land remaining pasture land. CO<sub>2</sub> emissions (on-site and off-site) from organic soils were estimated in pastures land converted from other land use using the same method as in cropland converted from other land use. For detailed information on the emission factors and activity data, see section 6.6.1.b)2).

#### c) Uncertainties and Time-series Consistency

##### ● Uncertainty Assessment

Uncertainties of the parameters and the activity data for living biomass, dead organic matter, and soil were individually assessed on the basis of field study results, expert judgment, or the default values described in the *2006 IPCC Guidelines*. The uncertainty was estimated as 19% for the entire removal from the land converted to grassland.

##### ● Time-series Consistency

Although the methods to estimate the area of forest land converted to other land use are different between FY1990-2004 and post FY2005, as described in section 6.6.1.b)1), time-series consistency for this subcategory is basically ensured.

#### d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

#### e) Category-specific Recalculations

##### ● Correction in accordance with revision of D area

Since the D area, which is used for estimating the areas of grassland converted from forest land were recalculated, carbon stock changes in living biomass, dead organic matter and CO<sub>2</sub> emissions from organic soils in this category were recalculated for all years.

See Chapter 10 for impact on trend.



### f) Category-specific Planned Improvements

#### ● Method of Obtaining Data of the “Areas of Cropland converted from Other Land-use Categories to Grassland”

The method used to obtain data on the area converted to grassland needs to be improved. For example, currently, the area of lands converted from forest land to grassland is estimated by multiplying the summed areas of forest land converted to cropland and grassland by the ratio of grazing land to the summed area. However, this estimation method may not represent the actual status of these areas. Therefore, the validity of the estimation method needs to be reviewed, and, if necessary, a new method of obtaining the area data should be developed.

#### ● Method of Obtaining Data of the “Area of Cropland converted to Grassland”

The area of Cropland converted to Grassland cannot be obtained from statistics except for the land-use conversion from cropland (rice field) to grassland (pasture land). For this reason, the estimates of the carbon stock changes in this land-use category may not fully reflect the actual conditions. Therefore, the methods used to detect the following area data need to be developed.

- from upland field / orchard to pasture land
- from rice field / upland field / orchard to grazed meadow

#### ● Estimation Method of Soil Carbon Stock Change upon “Land-Use Conversion from Other Land to Cropland”

The estimation method will be revised when new data and information are obtained.

## 6.8. Wetlands (4.D.)

Wetlands are lands that are covered with or soaked in water throughout the year. They do not fall into the categories of forest land, cropland, grassland, or settlements. The 2006 IPCC Guidelines divides wetlands into three large groups: peat land, flooded land, and other wetlands. However, emissions and removals from other wetlands are not reported in Japan.

In FY2020, Japan’s wetland area was about 1.35 million ha, which is equivalent to about 3.6% of the national land. The emissions from this category in FY2020 were 27 kt-CO<sub>2</sub> (GHG emissions other than changes in carbon stock are not included in this value.); this represents a decrease of 70.3% compared to FY1990 and an increase of 0.5% compared to FY2019.

Table 6-36 Emissions and removals in wetlands resulting from carbon stock changes

Category	Carbon pool	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
4.D. Wetlands	Total	kt-CO <sub>2</sub>	91	359	426	47	112	62	71	24	24	75	75	31	31	27	27
	Living Biomass	kt-CO <sub>2</sub>	65	257	305	33	78	43	52	16	16	52	52	21	21	21	21
	Dead Wood	kt-CO <sub>2</sub>	17	69	82	9	23	13	13	5	5	15	15	6	6	4	4
	Litter	kt-CO <sub>2</sub>	8	33	39	4	11	6	6	2	2	8	8	3	3	2	2
	Mineral soil	kt-CO <sub>2</sub>	N,NA	N,NA	N,NA	N,NA	N,NA	N,NA	N,NA	N,NA	N,NA	N,NA	N,NA	N,NA	N,NA	N,NA	N,NA
	Organic soil	kt-CO <sub>2</sub>	NO,N,NA	NO,N,NA	NO,N,NA	NO,N,NA	NO,N,NA	NO,N,NA	NO,N,NA	NO,N,NA	NO,N,NA	NO,N,NA	NO,N,NA	NO,N,NA	NO,N,NA	NO,N,NA	NO,N,NA
4.D.1. Wetlands remaining Wetlands	Total	kt-CO <sub>2</sub>	NO,N,NA	NO,N,NA	NO,N,NA	NO,N,NA	NO,N,NA	NO,N,NA	NO,N,NA	NO,N,NA	NO,N,NA	NO,N,NA	NO,N,NA	NO,N,NA	NO,N,NA	NO,N,NA	NO,N,NA
	Living Biomass	kt-CO <sub>2</sub>	N,NA	N,NA	N,NA	N,NA	N,NA	N,NA	N,NA	N,NA	N,NA	N,NA	N,NA	N,NA	N,NA	N,NA	N,NA
	Dead Wood	kt-CO <sub>2</sub>	NO,N,NA	NO,N,NA	NO,N,NA	NO,N,NA	NO,N,NA	NO,N,NA	NO,N,NA	NO,N,NA	NO,N,NA	NO,N,NA	NO,N,NA	NO,N,NA	NO,N,NA	NO,N,NA	NO,N,NA
	Litter	kt-CO <sub>2</sub>	NO,N,NA	NO,N,NA	NO,N,NA	NO,N,NA	NO,N,NA	NO,N,NA	NO,N,NA	NO,N,NA	NO,N,NA	NO,N,NA	NO,N,NA	NO,N,NA	NO,N,NA	NO,N,NA	NO,N,NA
	Mineral soil	kt-CO <sub>2</sub>	N,NA	N,NA	N,NA	N,NA	N,NA	N,NA	N,NA	N,NA	N,NA	N,NA	N,NA	N,NA	N,NA	N,NA	N,NA
	Organic soil	kt-CO <sub>2</sub>	N,NA	N,NA	N,NA	N,NA	N,NA	N,NA	N,NA	N,NA	N,NA	N,NA	N,NA	N,NA	N,NA	N,NA	N,NA
4.D.2. Land converted to Wetlands	Total	kt-CO <sub>2</sub>	91	359	426	47	112	62	71	24	24	75	75	31	31	27	27
	Living Biomass	kt-CO <sub>2</sub>	65	257	305	33	78	43	52	16	16	52	52	21	21	21	21
	Dead Wood	kt-CO <sub>2</sub>	17	69	82	9	23	13	13	5	5	15	15	6	6	4	4
	Litter	kt-CO <sub>2</sub>	8	33	39	4	11	6	6	2	2	8	8	3	3	2	2
	Mineral soil	kt-CO <sub>2</sub>	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE
	Organic soil	kt-CO <sub>2</sub>	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO

### 6.8.1. Wetlands remaining Wetlands (4.D.1.)

#### a) Category Description

This subcategory deals with carbon stock changes in wetlands which have remained as wetlands during the past 20 years.

For carbon stock change in organic soil managed for peat extraction, as a result of the domestic survey, it is found out that although peat extraction is carried out in Japan, estimating emissions with high accuracy is difficult. Therefore, based on the amount of emissions expected, carbon stock changes in organic soils that are managed for peat extraction are reported as “NE” under the revision of the UNFCCC Guidelines. “Flooded land remaining flooded land” is not calculated at the present time as this is treated in an appendix in the *2006 IPCC Guidelines* and reported as “NE”. “Other wetlands remaining other wetlands” are reported as “NA” because the activity is not defined at the present time in Japan.

Table 6-37 Areas of wetlands remaining wetlands within the past 20 years

Category	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Wetlands remaining Wetlands	kha	1,280.5	1,293.9	1,321.3	1,316.6	1,308.0	1,318.1	1,319.0	1,319.5	1,320.0	1,321.4	1,314.1	1,334.5	1,336.7	1,338.8	1,340.8
Organic soils managed for peat extraction	kha	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Flooded land	kha	1,280.5	1,293.9	1,321.3	1,316.6	1,308.0	1,318.1	1,319.0	1,319.5	1,320.0	1,321.4	1,314.1	1,334.5	1,336.7	1,338.8	1,340.8
other wetlands	kha	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

#### b) Methodological Issues

##### 1) Emission from peats extraction

For adaptation of standard for small emission, the following estimation was implemented. A result of domestic survey, peats are extracted in Japan, but accurate emissions are not able to estimate. A rough calculation of emission from peat extraction was made both at “on-site” and “off-site” with the Tier1 methodology in Chapter 7 of the *2006 IPCC guidelines*. The peat extraction is carried out mainly in Hokkaido area, where is located in the northernmost part of Japan. So that we applied climatic zone as “Boreal and Temperate” and its soil condition as “Nutrient-Poor” under expert judgment in our preliminary calculation. To calculate on-site CO<sub>2</sub> emissions, we use the value, about “150 ha” for peat extraction area that from private company of peat extraction. And we also use the default values of EF, 0.2 t-C/ha (Boreal and Temperate, Nutrient- Poor on Table 7.4, Chp.7, Vol.4, *2006 IPCC Guidelines*), and the result of this calculation is approximately 0.1 kt-CO<sub>2</sub>. To calculate off-site CO<sub>2</sub> emissions, we use the value from National production data, which is available since 2003, ranged from 17 to 34 kt-d.m.. And we also use the default value of carbon fractions, 0.45 t-C/t-d.m. (Boreal and Temperate, Nutrient- Poor on Table 7.5, Chp.7, Vol.4, *2006 IPCC Guidelines*). So the result of this calculation is ranged from 30 to 50 kt-CO<sub>2</sub>. Furthermore, N<sub>2</sub>O emissions from peat extraction are not included in these calculations, as the estimation is necessary only for “Nutrient –Rich” area in Tier 1 method. As a result of these calculations, we regarded that the emissions from peat extraction as “NE” in insignificant level of emissions. This value is below from threshold suggested by paragraph 37b) of Annex 1 in Decision 24/CP19 and country specific standard of 90 kt-CO<sub>2</sub> (this value is 0.1 % of the removals from LULUCF section in 2005). Please refer to annex 5 of NIR, for more information about our criteria for “NE”.

#### c) Category-specific Recalculations

No recalculations are conducted.

## 6.8.2. Land converted to Wetlands (4.D.2.)

### a) Category Description

This subcategory deals with the carbon stock changes which occurred in the land that was converted from other land-use categories to wetlands, particularly to flooded land (i.e., dams) within the past 20 years. The emissions from this subcategory in FY2020 were 27 kt-CO<sub>2</sub> (GHG emissions other than changes in carbon stock are not included in this value.), this represents a decrease of 70.3% compared to FY1990 and an increase of 0.5% compared to FY2019.

With respect to living biomass, its carbon stock change (losses of living biomass in the land before conversion) as a result of land-use conversion from other land use to wetlands is estimated.

With respect to dead organic matter, Japan used the CENTURY-jfos model to estimate carbon stocks in dead organic matter in forest land, and then estimated the carbon stock change in wetlands converted from forest land. Carbon stock changes in other subcategories were reported as “NA”, supposing that no carbon stock change occur.

Carbon stock changes in soils in forest land converted to wetlands were reported as “NA”. This was because after the areas came to be reservoirs (dams), and their soils were supposed to become anaerobic condition; hence CO<sub>2</sub> emissions resulting from organic matter decomposition seemed to be extremely little. Since methodology is not provided by the 2006 IPCC Guidelines and due to lack of data, carbon stock changes in soils in wetlands (flooded land) converted from land use other than forest land were not estimated. Therefore, the carbon stock changes in the carbon pool were reported as “NE”.

### b) Methodological Issues

#### 1) Carbon stock change in Living biomass in “Land converted to Wetlands”

##### ● Estimation Method

The Tier 2 method was applied for the land converted to wetlands (flooded land). The equations are given in section 6.6.2.b)1).

##### ● Parameters

##### ➤ Biomass stock in each Land-Use Category

The values shown in Table 6-8 and Table 6-9 are used for the estimation of biomass stock changes resulting from land-use conversion and subsequent changes in biomass stock due to biomass growth in converted land.

##### ➤ Carbon Fraction of Dry Matter

For carbon fraction of dry matter of forest, average value of broad leaf trees and conifer trees (0.50 t-C/t-d.m.) was applied. The default value (0.47 t-C/t-d.m. for herbaceous biomass in grassland and 0.5 t-C/t-d.m. for the others) was applied for other than forest in accordance with the 2006 IPCC Guidelines.

##### ● Activity Data (Area)

Areas of land converted to wetlands (dam) were estimated based on the area of dam converted from forest land and the ratio of forest land among the area of land-use categories before conversion. The area of forest land converted to wetlands was calculated by the method described in section 6.6.2.b)1). With respect to areas of each land-use type before conversion to dam, percentages of each land area converted to dams from agricultural land (cropland and grassland), settlements and Other land were

estimated based on the numbers of dwellings and agricultural land which were submerged into some large-scale dams. Breakdown of wetland areas converted from agricultural land into from cropland and grassland was determined based on the ratio of current area the same manner of other land-use categories. The differences between the areas of wetlands converted from forest land, cropland, grassland, and settlements and the total dam conversion area were regarded as other land converted to wetlands.

It should be noted that the area presented in the CRF “Table 4.D Sectoral background data for land use, land-use change and forestry – Wetlands” is not the annually converted area in FY2020 but the sum of annually converted areas during the past 20 years.

Table 6-38 Area of land annually converted to wetlands within the past 1 year

Category	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Land converted to Wetlands	kha	0.43	1.72	2.04	0.22	0.59	0.32	0.32	0.12	0.12	0.39	0.39	0.16	0.16	0.11	0.11
Forest land converted to Wetlands	kha	0.31	1.24	1.48	0.16	0.43	0.23	0.23	0.09	0.09	0.28	0.28	0.12	0.12	0.08	0.08
Cropland converted to Wetlands	kha	0.02	0.10	0.13	0.02	0.04	0.02	0.02	0.01	0.01	0.02	0.03	0.01	0.01	0.01	0.01
Rice field	kha	0.01	0.02	0.09	0.01	0.02	0.01	0.01	0.00	0.00	0.02	0.02	0.01	0.00	0.00	0.00
Upland field	kha	0.01	0.05	0.03	0.00	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00
Orchard	kha	0.00	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wetlands converted to Wetlands	kha	0.01	0.03	0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Settlements converted to Wetlands	kha	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other land converted to Wetlands	kha	0.09	0.34	0.41	0.04	0.12	0.06	0.06	0.02	0.02	0.08	0.08	0.03	0.03	0.02	0.02

## 2) Carbon Stock Change in Dead Organic Matter in “Land converted to Wetlands”

### ● Estimation Method

#### ➤ Carbon stock changes in Dead Organic Matter

Carbon stock changes in dead organic matter in forest land converted to wetlands were estimated by applying the Tier 2 estimation method as described in section 6.6.2.b)2).

### ● Parameters

#### ➤ Carbon Stocks in Dead Organic Matter

The average carbon stocks in dead wood and litter in forest land before conversion are shown in Tables 6-9 and 6-10. It is assumed that they become zero immediately after conversion, and are not accumulated after conversion.

### ● Activity Data (Area)

The area of land that was converted to wetlands during the past 20 years is determined by subtracting the estimated area that was not converted during the past 20 years from the total area of wetlands in those years. The areas are shown in Table 6-39 below.

Table 6-39 Area of land converted to wetlands within the past 20 years

Category	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Land converted to Wetlands	kha	28.5	24.7	27.0	21.5	20.0	20.0	19.1	18.5	18.1	16.7	14.1	13.7	11.5	9.4	7.5
Forest land converted to Wetlands	kha	20.6	17.9	19.6	15.6	14.5	14.4	13.8	13.4	13.1	12.1	10.2	9.9	8.3	6.8	5.4
Cropland converted to Wetlands	kha	1.8	1.5	1.6	1.3	1.2	1.2	1.2	1.1	1.1	1.0	0.9	0.9	0.7	0.6	0.5
Rice field	kha	0.7	0.5	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.5	0.5	0.4	0.4	0.3
Upland field	kha	0.8	0.7	0.7	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.3	0.3	0.2	0.2	0.2
Orchard	kha	0.3	0.3	0.3	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0
Grassland converted to Wetlands	kha	0.3	0.3	0.4	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1
Settlements converted to Wetlands	kha	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0
Other land converted to Wetlands	kha	5.7	4.9	5.4	4.3	4.0	4.0	3.8	3.7	3.6	3.3	2.8	2.7	2.3	1.9	1.5

## c) Uncertainties and Time-series Consistency

### ● Uncertainty Assessment

Uncertainties of the parameters and the activity data for living biomass, dead organic matter, and soil

were individually assessed on the basis of field study results, expert judgment, or the default values described in the *2006 IPCC Guidelines*. The uncertainty was estimated as 22% of the total emissions from the land converted to wetlands for year which emissions are calculated.

- ***Time-series Consistency***

Although the methods to estimate the area of forest land converted to other land use are different between FY1990-2004 and post FY2005, as described in section 6.6.2.b)1), time-series consistency for this subcategory is basically ensured.

***d) Category-specific QA/QC and Verification***

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

***e) Category-specific Recalculations***

- ***Correction in accordance with revision of D area***

Since the D area, which is used for estimating the areas of wetlands converted from forest land were recalculated, carbon stock changes in living biomass and dead organic matter after FY2005 in this category were recalculated. See Chapter 10 for impact on trend.

***f) Category-specific Planned Improvements***

- ***Validity of the Assumption used in the Method of Estimating the Area of Wetlands***

Under the present estimation method, wetlands are assumed to consist of “water surfaces”, “rivers” and “canals”, as defined in the national land-use classification, and the whole area is estimated by summing the areas covered by these three land types. However, this estimation method may fail to cover the entire wetland area. The validity of the assumption used in the estimation method is now under revision.

- ***Method of Obtaining Data of the Area of Storage Reservoirs***

Storage reservoirs (excluding dams) can be considered as artificial flooded land, but the area they cover are not included in the area of flooded land. Therefore, a method used to obtain data on the area covered by the reservoirs needs to be considered.

- ***Estimation Method of Soil Carbon Stock Change upon “Land-Use Conversion from Other Land to Wetlands”***

The estimation method will be considered when new data and information are obtained.

## **6.9. Settlements (4.E.)**

Settlements are all developed land, including transportation infrastructure and human habitats, and preclude lands that have been placed in other land-use categories. In settlements, trees existing in urban green areas such as urban parks and special greenery conservation zones absorb carbon.

In FY2020, Japan’s settlement area was about 3.89 million ha, equivalent to about 10.3% of the national land. The emissions from carbon stock changes in this category in FY2020 were 178 kt-CO<sub>2</sub> (GHG emissions other than changes in carbon stock are not included in this value.); this represents a decrease of 93.8% compared to FY1990 and an increase of 67.3% compared to FY2019 value.

Urban green areas included in the activity data are divided into two categories; urban green facilities established as urban parks and others, and special greenery conservation zones for which conservation measures are taken and permanent protection is ensured.

➤ **Urban green areas**

- Urban Green Facilities (urban parks, green areas on roads, green areas at ports, green areas around sewage treatment facilities, green areas by greenery promoting system for private green space, green areas along rivers and erosion control sites, green areas around government buildings and green areas around public rental housing).
- Special Greenery Conservation Zones

Table 6-40 Emissions and removals in settlements resulting from carbon stock changes

Category	Carbon pool	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
4.E. Settlements	Total	kt-CO <sub>2</sub>	2,873	1,293	-426	-936	-382	-771	-532	-423	-266	152	240	33	132	106	178
	Living Biomass	kt-CO <sub>2</sub>	1,814	685	-559	-943	-586	-842	-602	-577	-422	-93	-9	-135	-41	55	119
	Dead Wood	kt-CO <sub>2</sub>	805	560	283	224	353	260	259	311	310	367	366	307	306	218	217
	Litter	kt-CO <sub>2</sub>	374	253	118	89	153	108	109	135	135	164	164	136	136	94	94
	Mineral soil	kt-CO <sub>2</sub>	-267	-320	-366	-392	-380	-371	-367	-360	-354	-351	-345	-338	-331	-320	-311
	Organic soil	kt-CO <sub>2</sub>	147	115	98	87	79	74	69	67	65	64	63	62	62	60	59
4.E.1. Settlements remaining Settlements	Total	kt-CO <sub>2</sub>	-1,365	-1,646	-1,866	-2,030	-2,032	-1,986	-1,953	-1,905	-1,780	-1,661	-1,582	-1,509	-1,422	-1,357	-1,298
	Living Biomass	kt-CO <sub>2</sub>	-1,135	-1,360	-1,532	-1,664	-1,669	-1,629	-1,598	-1,555	-1,434	-1,317	-1,244	-1,176	-1,096	-1,040	-989
	Dead Wood	kt-CO <sub>2</sub>	IE,NE	IE,NE	IE,NE	IE,NE	IE,NE	IE,NE	IE,NE	IE,NE	IE,NE	IE,NE	IE,NE	IE,NE	IE,NE	IE,NE	IE,NE
	Litter	kt-CO <sub>2</sub>	-11	-13	-15	-17	-17	-16	-16	-16	-16	-16	-15	-15	-15	-14	-14
	Mineral soil	kt-CO <sub>2</sub>	-219	-273	-319	-349	-347	-341	-340	-334	-331	-328	-323	-318	-312	-303	-295
	Organic soil	kt-CO <sub>2</sub>	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4.E.2. Land converted to Settlements	Total	kt-CO <sub>2</sub>	4,237	2,939	1,439	1,094	1,651	1,216	1,422	1,482	1,514	1,813	1,823	1,543	1,554	1,463	1,475
	Living Biomass	kt-CO <sub>2</sub>	2,949	2,045	972	721	1,082	788	996	978	1,012	1,224	1,235	1,042	1,054	1,095	1,108
	Dead Wood	kt-CO <sub>2</sub>	805	560	283	224	353	260	259	311	310	367	366	307	306	218	217
	Litter	kt-CO <sub>2</sub>	384	266	134	105	170	125	125	151	151	180	180	151	151	108	108
	Mineral soil	kt-CO <sub>2</sub>	-49	-47	-47	-43	-33	-30	-27	-25	-24	-22	-21	-20	-19	-17	-17
	Organic soil	kt-CO <sub>2</sub>	147	115	98	87	79	74	69	67	65	64	63	62	62	60	59

### 6.9.1. Settlements remaining Settlements (4.E.1.)

#### a) Category Description

This subcategory deals with carbon stock changes in living biomass, litter of dead organic matter and soils in urban green areas in settlements remaining settlements, which have remained settlements without conversion during the past 20 years. This subcategory is divided into three subparts: “Special Greenery Conservation Zones”, “Urban Green Facilities” and “Other”. In these subparts, carbon stock changes in the “Special Greenery Conservation Zones” and “Urban Green Facilities” are estimated. In addition, carbon stock changes reported in “Revegetation (RV)” activities under Article 3, paragraph 4, of the Kyoto Protocol correspond to those in the “Urban Green Facilities” constructed in and after 1990<sup>5</sup>. However, “Special Greenery Conservation Zones” are not included in the areas of the Revegetation activities. In the CRF tables, “Special Greenery Conservation Zones” are described as “Urban Green Areas not subject to RV”, “Urban Green Facilities” as “Urban Green Areas subject to RV”, and “Other” as “Other than Urban Green Areas”, respectively. Carbon stock changes that are possibly included in the subpart “Other”, such as trees in gardens in personal residences, are reported as “NE” because their activity data are not available. Moreover, with respect to litter and soils, carbon stock changes in urban

<sup>5</sup> The “Special Greenery Conservation Zones” are not included in Revegetation because they do not meet its definition.

parks and green areas at ports are reported due to limited availability of parameters. The net removal by this subcategory in FY2020 was 1,298 kt-CO<sub>2</sub>; this represents a decrease of 4.9% compared to FY1990 value and a decrease of 4.4 % compared to FY2019.

## **b) Methodological Issues**

### **1) Carbon Stock Changes in Living Biomass in “Settlements remaining Settlements”**

#### **● Estimation Method**

Due to the differences of characteristics of urban green areas, the Tier 2a method is used for special greenery conservation zones that are communal green areas, and Tier 2b is used for urban green facilities methodology in section 8.2.1.1, Vol.4 of the 2006 IPCC guidelines.

The results of field survey on green area in settlements in Japan revealed that the trees have been growing for more than default growth period of 20 years, which are set in the Tier 2a and Tier 2b of the 2006 IPCC Guidelines. It was concluded that, for up to 30 year tree, estimating gain of carbon stocks using the same factor as the 0 - 20 year trees absorption would be possible. Therefore, carbon stock changes in urban green areas younger than 30 years after establishment are estimated in the same way as 0-20 year urban green area.

#### **➤ Tier 2a: Special greenery conservation zones**

$$\Delta C_{SSaLB} = \Delta C_{LBaG} - \Delta C_{LBaL}$$

$$\Delta C_{LBaG} = A \times PW \times BI$$

$\Delta C_{SSaLB}$  : Changes in carbon stocks in living biomass in special greenery conservation zones [t-C/yr]

$\Delta C_{LBaG}$  : Gains in carbon stocks due to growth in living biomass in special greenery conservation zones [t-C/yr]

$\Delta C_{LBaL}$  : Losses in carbon stocks due to losses in living biomass in special greenery conservation zones [t-C/yr].

Note: assumed as “0” (zero) in accordance with the 2006 IPCC Guidelines

$A$  : Area of special greenery conservation zones younger than or equal to 30 years since designation [ha]

$PW$  : Rate of forested area (rate of forested area per park area). Note: assumed as 100%

$BI$  : Growth per crown cover area [t-C/ha crown cover/yr]

#### **➤ Tier 2b: Urban green Facilities**

$$\Delta C_{SSbLB} = \sum_i (\Delta C_{LBbGi} - \Delta C_{LBbLi})$$

$$\Delta C_{LBbGi} = \Delta B_{LBbGi}$$

$$\Delta B_{LBbGi} = \sum_j NT_{i,j} \times C_{Rate_{i,j}}$$

$\Delta C_{SSbLB}$  : Changes in carbon stocks in living biomass in urban green facilities [t-C/yr]

$\Delta C_{LBbGi}$  : Gains in carbon stocks due to growth in living biomass in urban green facilities  $i$  [t-C/yr]

$\Delta C_{LBbLi}$  : Losses in carbon stocks due to losses in living biomass in urban green facilities  $i$  [t-C/yr]. Note: assumed as “0” (zero) in accordance with the 2006 IPCC Guidelines

$\Delta B_{LBbGi}$  : Annual biomass growth in urban green facilities  $i$  [t-C/yr]

$C_{Rate_{i,j}}$  : Annual living biomass growth in urban green facility  $i$  in climate type  $j$  per tree [t-C/tree/yr]  
See Table 6-41

$NT_{i,j}$  : Number of trees in urban green facility  $i$  in climate type  $j$

- i* : Types of urban green facilities (urban parks, green areas on roads, green areas at ports, green areas around sewage treatment facilities, green areas by greenery promoting systems for private green space, green areas along rivers and erosion control sites, green areas around government buildings, or green areas around public rental housing)
- j* : Climate type (Hokkaido, other than Hokkaido)

● **Parameters**

➤ **Tier 2a: Annual rate of living biomass growth per crown cover area (special greenery conservation areas)**

The default value, 2.9 t-C/ha crown cover/yr, indicated in Table 8.1 in vol.4 of the *2006 IPCC Guidelines* is taken for the annual rate of living biomass growth of trees per crown cover area in special greenery conservation zones.

➤ **Tier 2b: Annual rate of living biomass growth per tree (urban green facilities)**

The following parameters are taken as the annual living biomass growth rates per tree in urban green facilities.

Table 6-41 Annual biomass growth rate per tree in urban green facilities

Climate category		Annual living biomass growth per tree [t-C/tree/yr]	Remarks
Urban green facilities	Hokkaido	(Other than green areas on roads) 0.0098 (Green areas on roads) 0.0103	Default values 0.0033-0.0142 [t-C/tree/y] provided in Table 8.2, Vol.4 of the <i>2006 IPCC Guidelines</i> and the annual growth rates of living biomass for the trees in Japan (0.0204 for Japanese zelkova, 0.0103 for ginkgo, 0.0095, for bamboo-leaf oak and 0.0122 t-C/tree/yr for camphor tree) are combined with the distribution ratio of tree types in sampled urban parks <sup>6</sup> . For green areas on roads, the distribution ratio of tree species indicated by the surveys in green areas on roads <sup>7</sup> is taken into account.
	Areas other than Hokkaido	(Other than green areas on roads) 0.0105 (Green areas on roads) 0.0108	

● **Activity Data**

The areas of settlements remaining settlements in a certain year reported in the CRF tables are estimated by subtracting the cumulative total area of land converted to settlements during the past 20 years in a year subject to estimation from the total area of settlements in the year subject to estimation. Moreover, in the CRF tables, the areas of settlements remaining settlements are reported in three subparts: “Special Greenery Conservation Zones”, “Urban Green Facilities” and “Other”. Within these subparts, carbon stock changes in trees less than or equal to 30-year growth in “Special Greenery Conservation Zones” and “Urban Green Facilities” are estimated.

Japan assumes trees less than or equal to 30-year growth as those growing in urban green areas less than or equal to 30 years since establishment or designation. With respect to Tier 2a, tree crown areas in the “Special Greenery Conservation Zones” are applied as activity data. Tier 2b applies the number of tall trees planted in the “Urban Green Facilities” as activity data.

<sup>6</sup> The annual growth rates of living biomass for these trees are calculated by using the growth curve for each tree species, which were developed based on the results of surveys conducted by the National Institute for Land and Infrastructure Management (NILIM) of the MLIT (Matsue et al., 2009) and the average trunk diameter at breast height for each tree species (Parks and Green Spaces Division of the MLIT, 2005), which were determined from the results of surveys in urban parks.

<sup>7</sup> The distribution ratio of tree types is taken from the MLIT (2009), which covered green areas on roads throughout Japan.



Table 6-42 Areas of settlements remaining settlements within the past 20 years

Category	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Settlements remaining Settlements	kha	2,288.3	2,637.4	2,873.9	3,070.0	3,270.7	3,301.4	3,356.2	3,391.5	3,429.3	3,452.2	3,474.5	3,508.5	3,529.3	3,560.4	3,568.2
Urban green facilities	kha	88.4	105.9	120.3	130.8	130.3	127.2	125.1	122.0	114.6	107.6	102.8	98.3	92.9	88.7	84.8
Special greenery conservation zones	kha	1.9	3.7	3.8	4.1	4.2	4.4	4.4	4.5	4.5	4.6	4.7	4.7	4.7	4.8	4.8
Other	kha	2,198.0	2,527.9	2,749.8	2,935.1	3,136.2	3,169.8	3,226.6	3,265.0	3,310.1	3,340.1	3,367.1	3,405.5	3,431.7	3,466.9	3,478.6

➤ **Tier 2a: Tree crown areas (“Special Greenery Conservation Zones”)**

The tree crown areas of the special greenery conservation zones are calculated by multiplying the area of special greenery conservation zones determined by the Ministry of Land, Infrastructure, Transport and Tourism by the rate of tree crown area, which is assumed to be 100%.

Table 6-43 Areas of special greenery conservation zones younger than or equal to 30 years since notification

Category	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Special greenery conservation zones	kha	1.9	3.7	3.8	4.1	4.2	4.4	4.4	4.5	4.5	4.6	4.7	4.7	4.7	4.8	4.8
Green space conservation zones	kha	0.6	0.9	1.4	1.9	1.9	1.9	2.0	2.0	2.0	2.1	2.2	2.2	2.2	2.2	2.2
Suburban green space conservation zones	kha	1.2	2.7	2.4	2.2	2.3	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5

➤ **Tier 2b: Number of tall trees (“Urban Green Facilities”)**

The number of tall trees in urban green facilities is calculated according to the same methods that are used for revegetation activities under Article 3, paragraph 4, of the Kyoto Protocol. Brief descriptions of the calculation methods for each urban green facility are stated below. In addition, for a detailed description of these calculation methods see section 11.4.2.7.a. in Chapter 11 in this NIR.

- **Urban parks, green areas at ports, green areas around sewage treatment facilities, green areas along rivers and erosion control sites, green areas around government buildings, and green areas around public rental housing**

The number of tall trees is calculated by (1) calculating the areas falling under this category by multiplying each area by the area ratio of land conversion area for the whole country, and then (2) calculating the number of tall trees in the calculated areas by multiplying each of the areas by the number of tall trees per area. The number of tall trees per area for each urban green facility is shown in the table below.

Table 6-44 Number of tall trees per area

Item	Unit	Number of tall trees per area	
		Hokkaido	Areas other than Hokkaido
Urban parks	tree/ha	329.5	222.3
Green areas at ports	tree/ha	329.5	222.3
Green areas around sewage treatment facilities	tree/ha	129.8	429.2
Green areas along rivers and erosion control	tree/ha	1470.8	339.0
Green areas around government buildings	tree/ha	108.8	108.8
Green areas around public rental housings	tree/ha	219.9	219.9

- **Green areas on roads**

Activity data (the number of tall trees) in these facilities are calculated by the following procedures.

1. The number of tall trees planted during 30 years after establishing green areas on roads is calculated by using data from the “Road Tree Planting Status Survey” which had been implemented in FY1987, FY1992, FY2007 and each corresponding fiscal year during the commitment period,

2. The number of tall trees calculated in Step 1 is multiplied by the ratio of the number of tall trees planted on the roads whose planted area is more than 500 m<sup>2</sup>,
3. The number of tall trees calculated in Step 2 is multiplied by the area ratio of settlements remaining settlements.

The values of Step 3 become the number of tall trees constituting the activity data on green areas on roads.

- **Green areas by greenery promoting systems for private green space**

Activity data (the number of tall trees) are available for each facility. Therefore, the total number of tall trees is used as activity data.

**2) Carbon Stock Changes in litter in “Settlements remaining Settlements”**

In this category carbon stock changes in litter in urban parks and green areas at ports are estimated. Carbon stock changes in dead wood result in “IE” because they are included in carbon stock changes in living biomass. Carbon stock changes in litter in the subcategories other than urban parks and green areas at ports are not estimated due to the difficulties of obtaining such activity data.

● **Estimation Method**

In accordance with the decision tree provided in the *2006 IPCC Guidelines*, a country-specific method is applied for this estimation. The estimation method is described below.

$$\Delta C_{SSLit} = \sum_i (A_i \times Lit_i)$$

$\Delta C_{SSLit}$  : Carbon stock changes in litter in settlements remaining settlements [t-C/yr]

$A$  : Area of urban parks and green areas at ports in settlements remaining settlements [ha]

$Lit$  : Carbon stock change in litter per area in urban parks or green areas at ports [t-C/ha/yr]

$i$  : Type of Urban Green Facilities (urban parks or green areas at ports)

● **Parameters**

For litter, Japan estimates carbon stock changes only in branches and leaves dropped naturally from tall trees. Carbon stock changes in litter per urban park area is calculated by using annual accumulation of litter per tree (Hokkaido and other prefectures: 0.0006 t-C/tree/yr) based on the results of field surveys in urban parks, and the number of tall trees per area and the ratio of litter moved to off-site due to management including cleaning (54.4%). As a result, carbon stock changes in litter per urban park area have been calculated to 0.0882 t-C/ha/yr for Hokkaido and 0.0594 t-C/ha/yr for other prefectures. In addition, the carbon fraction in litter is assumed to be 0.4 t-C/t-d.m. which is a default value provided in the *2006 IPCC Guidelines* (Vol.4, p. 8.21).

● **Activity Data**

Activity data on this category are the same as those on living biomass in urban parks and green areas at ports, as described in activity data of “Remaining land: Above-ground biomass, Below-ground biomass” (section 11.5.1.1.f. a) of Chapter 11.

**3) Carbon Stock Changes in Soils in “Settlements remaining Settlements”**

Newly established Urban parks, for which the carbon stock changes in soils per area were determined,

and Green areas at ports, whose management practices are similar with those for urban parks, are the subject to estimation. Those areas meet the definition of RV activity under the KP-LULUCF. In general, soils in RV land are not organic soils (peat soils and muck soils). Therefore, organic soils are reported as “NO”, and only mineral soils are estimated.

### ● *Estimation Method*

Carbon stock changes are assumed as zero for the areas not subject to land-use management change in Settlements remaining Settlements. Carbon stock changes in soils on settlements in newly established Urban parks or green areas at ports are estimated based on Tier 2 (Country specific data are used) estimation method.

$$\Delta C_{SSSoils} = \sum_i (\Delta C_{Mineral_i} - L_{Organic_i})$$

$$\Delta C_{Mineral_i} = A_i \times \Delta C_{Soil_i}$$

$\Delta C_{SSSoils}$  : Annual carbon stock changes in soils in settlements remaining settlements [t-C/yr]

$\Delta C_{Mineral}$  : Annual carbon stock changes in mineral soils in settlements remaining settlements [t-C/yr]

$L_{Organic}$  : Annual carbon stock changes in organic soils in settlements remaining settlements (=0) [t-C/yr]

$A$  : Area of Urban Green Facilities in settlements remaining settlements (within 30 years after establishment) [ha]

$C_{Soil}$  : Annual carbon stock changes in soils per area of settlements remaining settlements [t-C/ha/yr]

$i$  : Type of Urban Green Facilities (Urban parks and Green areas at ports)

### ● *Parameters*

As described in section 11.5.1.1.f. d), carbon stock changes in soils per area of Urban parks and Green areas at port (integrated annual amount change during 0-20 years after establishment is 1.28t-C/ha/yr, integrated annual amount change during 21-30 years after establishment is 1.38t-C/ha/yr) are estimated based on the results of surveys conducted in urban parks which have been established within 30 years (Tonosaki et al., 2013, Parks, Green Spaces and Landscape Division, Ministry of Land, Infrastructure, Transport and Tourism, 2015). Thus, this value is applicable to Urban parks and Green areas at port which were established within 30 years.

### ● *Activity Data*

Activity data on this category are the same as the area of urban parks and green areas at ports, as described in activity data of Remaining land: Above-ground biomass, Below-ground biomass (section 11.5.1.1.f. a) of Chapter 11).

## c) *Uncertainties and Time-series Consistency*

### ● *Uncertainty Assessment*

The default values shown in the 2006 IPCC Guidelines (Vol.4, page 8.10) were applied to the annual carbon stock changes for trees in special greenery conservation zones. Following the decision tree, the uncertainty was determined  $\pm 50\%$  through application of the standard value shown in the 2006 IPCC Guidelines (Vol.4, page 8.12).

Moreover, the uncertainty estimates for living biomass in special greenery conservation zones apply expert judgment according to the decision tree for activity data.

Meanwhile, the uncertainty estimates for living biomass, dead organic matter and soil in urban parks, green areas on roads, green areas at ports, green areas around sewage treatment facilities, green areas by greenery promoting systems for private green space, green areas along rivers and erosion control sites, green areas around government buildings and green areas around public rental housing are 41%, 61%, 38%.

As a result, the uncertainty estimate was 33% for the entire removal by settlements remaining settlements.

- ***Time-series Consistency***

Although the methods to estimate the area of forest land converted to other land use are different between FY1990-2004 and post 2005, as described in section 6.6.2.b)1), time-series consistency for this subcategory is basically ensured.

- d) ***Category-specific QA/QC and Verification***

General inventory QC procedures have been conducted in accordance with the 2006 IPCC Guidelines. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

- e) ***Category-specific Recalculations***

- ***Correction in accordance with revision of D area***

Areas of deforestation (D area) is used for determining each land use area converted from forest land. Since D area were recalculated, areas of Settlements remaining Settlements and carbon stock changes in living biomass, dead organic matter and mineral soils in this category were recalculated for all years.

- ***Recalculation due to revision of activity data of urban green areas***

A revision was conducted on some area of urban green areas for all years. Due to this revision, carbon stock changes in living biomass, dead organic matter and mineral soils in this category were recalculated for all years. See Chapter 10 for impact on trend.

- f) ***Category-specific Planned Improvements***

- ***Growth Rate of Living Biomass per Unit of Greening Area in “Special Greenery Conservation Zones”***

The default values in the 2006 IPCC Guidelines were applied to the living biomass growth rate per unit of greening area in special greenery conservation zones. However, the growth data needs to be further examined, and parameter that can be finally applied as the growth ratio should be determined. Therefore, based on the characteristics of greening activity, the most appropriate parameters need to be found.

- ***Validity of the Assumption used in the Method of Estimating the Area of Settlements***

The areas of forest land converted to settlements are presently assumed as “roads”, “human habitats”, “school reservations”, “parks and green areas”, “road sites”, “environmental facility sites”, “golf courses”, “ski courses” and “other recreation sites” in the national land-use categorization; however, this assumption may fail to cover all the areas. Therefore, the validity of the assumption needs to be re-examined.

## 6.9.2. Land converted to Settlements (4.E.2.)

### a) Category Description

This subcategory deals with the carbon stock changes in lands converted to settlements, which were converted from other land-use categories to settlements within the past 20 years. With respect to dead organic matter, Japan used the CENTURY-jfos model to estimate carbon stocks in dead organic matter in forest land, and then estimated carbon stock changes in forest land converted to settlements. However, the area of wetlands converted to settlements and other land converted to settlements cannot be obtained by the current method. Thus, carbon stock changes in these carbon pools were reported as “NO”.

The net emissions by this subcategory in FY2020 were 1,475 kt-CO<sub>2</sub> (GHG emissions other than changes in carbon stock are not included in this value.); this represents a decrease of 65.2% compared to FY1990 and an increase of 0.8% compared to FY2019. Emissions from land converted to settlements increased from FY1990 to FY1993. After 1993, the emissions have been on a decreasing trend by 2003, and have been fluctuated since 2003 up to now. These trends resulted from annual changes of areas of land-use conversion area from forest land to settlements.

### b) Methodological Issues

#### 1) Carbon stock changes in Living Biomass in “Land converted to Settlements”

##### ● Estimation Method

Carbon stock changes in living biomass in land converted to settlements are estimated by calculating the carbon stock changes before and after conversion and adding annual carbon stock changes in “urban green facilities established in Land converted to Settlements”. The carbon stock changes in living biomass before and after conversion are estimated by applying the equation 2.16 in section 2.3.1.2 in Volume 4 of the 2006 IPCC Guidelines (multiplying the land area converted from each land use to settlements by the difference between the values of living biomass stock before and after conversion, and by the carbon fraction). Biomass stocks in land converted to urban green areas are increased due to the growth of trees planted after conversion. Hence, carbon stock changes in living biomass in land converted to urban green facilities are estimated by calculating carbon stock changes before and after conversion and adding annual carbon stock changes after conversion that are estimated by applying the Tier 2b method in section 8.2.1.1 in Volume 4 of the 2006 IPCC Guidelines.

$$\Delta C_{LSLB} = \sum_I \{A_I \times (CR_a \times CF_a - CR_{bl} \times CF_{bl})\} + \sum_i (\Delta C_{LS(UG)G_i} - \Delta C_{LS(UG)L_i})$$

$$\Delta C_{LS(UG)G_i} = \Delta B_{LS(UG)G_i}$$

$$\Delta B_{LS(UG)G_i} = \sum_j NT_{ij} \times C_{Rate_{i,j}}$$

$\Delta C_{LSLB}$	: Carbon stock changes in living biomass in land converted to settlements [t-C/yr]
$A_I$	: Area of land converted annually to settlements from land-use type $I$ [ha/yr]
$CR_a$	: Carbon reserves immediately following conversion to settlements [t-d.m./ha], default=0
$CR_{bl}$	: Biomass dry matter in land-use type $I$ immediately before conversion to settlements [t-d.m./ha]
$CF_a$	: Carbon fraction of dry matter after conversion (settlements) [t-C/t-d.m.]
$CF_{bl}$	: Carbon fraction of dry matter in land-use type before conversion [t-C/t-d.m.]
$I$	: Type of land before conversion

$\Delta CLS(UG)Gi$	: Annual carbon stock gain in living biomass in urban green facility $i$ established in land converted to settlements due to growth in living biomass [t-C/yr]
$\Delta CLS(UG)Li$	: Annual carbon stock loss in living biomass due to loss of living biomass [t-C/yr] Note: the averaged ages of estimated trees are less than or equal to 30 years old; therefore, the loss is assumed as “0” (zero) based on the domestic survey and in accordance with the 2006 IPCC Guidelines
$\Delta BLS(UG)Gi$	: Annual living biomass growth in land converted to urban green facility $i$ [t-C/yr]
$C_{Rate\ i,j}$	: Annual living biomass growth in urban green facility $i$ in climate type $j$ per tree [t-C/tree/yr] See Table 6-41
$NT_{i,j}$	: Number of trees in urban green facility $i$ in climate type $j$
$i$	: Type of urban green area after conversion (urban parks, green areas on roads, green areas at ports, green areas around sewage treatment facilities, green areas by greenery promoting systems for private green space, green areas along rivers and erosion control sites, green areas around government buildings, or green areas around public rental housing)
$j$	: Climate type (Hokkaido, areas other than Hokkaido)

### ● Parameters

#### ➤ Living biomass stocks for each land-use category

Tables 6-8 and 6-9 show the living biomass stocks before and after conversion. Carbon stock losses due to loss of living biomass are assumed as “0” (zero) based on the domestic survey (*Parks, Green Spaces and Landscape Division, Ministry of Land, Infrastructure, Transport and Tourism (MLIT), 2015*) and in accordance with the 2006 IPCC Guidelines, because trees subject to estimation are all younger than or equal to 30 years old. Table 6-41 shows the annual living biomass growth of trees in land converted to urban green areas.

#### ➤ Carbon fraction of dry matter

For carbon fraction of dry matter of forest, average value of broad leaf trees and conifer trees (0.50 t-C/t-d.m.) was applied. The default value (0.47 t-C/t-d.m. for herbaceous biomass in grassland and 0.5 t-C/t-d.m. for the others) was applied for other than forest in accordance with the 2006 IPCC Guidelines.

### ● Activity Data

#### ➤ Land Areas converted to Settlements

With respect to the area of land converted to settlements, only the areas converted to settlements from forest land, cropland and grassland are determined. Since no data is available on the area converted to settlements from wetlands or other land, “IE” was allocated to those land-use categories. Instead, they are reported as “IE” since they are included in “Other land remaining Other land”.

It should be noted that the area presented in the CRF “Table 4.E Sectoral background data for land use, land-use change and forestry — Settlements” is not the annually converted area in FY2020 but the sum of annually converted areas during the past 20 years.

#### - Conversion from Forest land

Areas of forest land converted to settlements were estimated as described in section 6.6.2.b).1).

#### - Conversion from Cropland

For former rice fields, upland fields, and orchards (according to “*Area Statistics for Cultivated and Commercially Planted Land*”), the areas of land converted to factories, roads, housing, and forest roads are used.

### - Conversion from Grassland

Pasture land in land converted to factories, roads, housing, and forest roads in “Area Statistics for Cultivated and Commercially Planted Land” and grazed meadow land converted to settlements in “A Move and Conversion of Cropland” were subject to this category.

Table 6-45 Area of land converted to settlements within the past 1 year

Category	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Land converted to Settlements	kha	39.9	33.4	22.7	15.3	15.2	12.5	12.7	15.1	16.3	18.5	17.2	15.0	15.8	13.8	13.9
Forest land converted to Settlements	kha	14.6	10.1	5.1	4.0	6.4	4.7	4.7	5.7	5.7	6.8	6.8	5.7	5.7	4.1	4.1
Cropland converted to Settlements	kha	21.4	19.5	14.5	9.2	7.2	6.3	6.4	7.5	8.8	9.0	8.9	7.9	8.5	8.3	8.3
Rice field converted to Settlements	kha	13.0	12.1	9.5	6.0	4.1	3.5	3.9	4.3	5.0	5.1	5.3	4.7	5.2	5.0	5.0
Upland field converted to Settlements	kha	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Orchard converted to Settlements	kha	13.0	12.1	9.5	6.0	4.1	3.5	3.9	4.3	5.0	5.1	5.3	4.7	5.2	5.0	5.0
Grassland converted to Settlements	kha	3.2	3.1	2.1	1.3	1.3	1.2	1.1	1.4	1.6	1.6	1.5	1.4	1.4	1.4	1.4
Wetlands converted to Settlements	kha	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Other land converted to settlements	kha	0.8	0.7	0.9	0.8	0.3	0.4	0.5	0.5	0.2	1.1	0.0	0.1	0.2	0.0	0.1

### ➤ Area and number of trees in “urban green areas established in Land converted to settlements”

The areas of urban green areas established in land converted to settlements are calculated by multiplying the whole area of each urban green area by the area ratio of land conversion area for settlements. The number of trees is calculated by multiplying each urban green area converted from other land-use categories by the number of trees per area. For detailed information regarding these activity data see section 11.4.2.7.a. in Chapter 11 in this NIR.

### 2) Carbon Stock Change in Dead Organic Matter in “Land converted to Settlements”

In this category carbon stock changes in dead wood and litter in settlements converted from forest land, and those in litter in urban parks and green areas at ports established in land converted to settlements are estimated.

With respect to dead wood, only the carbon stock change in forest land converted to settlements was estimated. The Tier 2 method was applied to the estimation in accordance with the method for conversion from other land use to cropland in the *2006 IPCC Guidelines*. Carbon stock changes in dead wood in urban green facilities established in land converted to settlements are reported as “IE” because they are included in living biomass.

In regard to litter, the carbon stock changes in settlements converted from forest land and urban parks and green areas at ports established in land converted to settlements are estimated. The Tier 2 method is applied to the estimation of the carbon stock changes in settlements converted from forest land in accordance with the method for conversion from other land use to cropland in the *2006 IPCC Guidelines*. Carbon stock changes in litter in urban parks and green areas at ports established in land converted to settlements are estimated by applying Japan’s country-specific estimation method due to the lack of an estimation method in the *2006 IPCC Guidelines*. Carbon stock changes in litter in land converted to urban green areas other than urban parks and green areas at ports are not estimated due to the difficulties of obtaining their activity data.

The area of wetlands converted to settlements and other land converted to settlements cannot be obtained by the current method. Thus, carbon stock changes in these carbon pools were reported as “NO”.

● **Estimation Method**

$$\Delta C_{LS} = \Delta C_{FS} + \Delta C_{LSLit}$$

$\Delta C_{LS}$  : Carbon stock changes in dead organic matter in settlements converted from other land-use categories [t-C/yr]

$\Delta C_{FS}$  : Carbon stock changes in dead organic matter in settlements converted from forest land [t-C/yr]

$\Delta C_{LSLit}$  : Carbon stock changes in litter in urban parks and green areas at ports established in land converted from other land-use categories [t-C/yr]

➤ **Carbon stock changes in dead organic matter in “Settlements converted from Forest land”**

Carbon stock changes in dead organic matter in forest land converted to settlements are estimated by using the CENTURY-jfos model. In addition, all carbon stocks in dead organic matter in the subcategory are assumed oxidized and emitted as CO<sub>2</sub> within the year of conversion.

$$\Delta C_{FS} = \sum_i \{ (C_{after_i} - C_{before_i}) \times A \}$$

$\Delta C_{FS}$  : Carbon stock changes in dead organic matter in forest land converted to settlements [t-C/yr]

$C_{after,i}$  : Carbon stock in dead wood or litter after conversion [t-C/ha] Note: carbon stocks after conversion are assumed as “0” (zero).

$C_{before,i}$  : Carbon stock in dead wood or litter before conversion [t-C/ha]

$A$  : Area of forest land converted to settlements in a year subject to estimation [ha]

$i$  : Type of dead organic matter (dead wood or litter)

➤ **Carbon stock changes in litter in “Urban parks and green areas at ports established in land converted from land-use categories other than Forest land”**

$$\Delta C_{LSLit} = \sum_{I,i} \{ A_i \times (C_{AfterLit_i} - C_{BeforeLit_i}) + A_i \times Lit_i \}$$

$\Delta C_{LSLit}$  : Carbon stock changes in litter in urban parks and green areas at ports established in land converted from land-use categories [t-C/yr]

$A$  : Area of urban parks or green areas at ports established in land converted from land-use categories for the past year [ha]

$C_{AfterLit}$  : Carbon stock in litter after conversion [t-C/ha]

$C_{BeforeLit}$  : Carbon stock in litter before conversion [t-C/ha]

$Lit$  : Annual carbon stock changes per area in litter in urban parks or green areas at ports converted from land-use categories [t-C/ha/yr]

$I$  : Land-use type before conversion

$i$  : Type of urban green facilities after conversion (urban parks or green areas at ports)

● **Parameters**

➤ **Carbon stocks in dead organic matter in “Forest land converted to Settlements”**

Average carbon stocks in dead wood and litter in forest land before conversion are shown in Tables 6-9 and 6-10. The average carbon stocks in these categories from FY1990 to FY2004 are not estimated; therefore the carbon stocks in FY2005 are substituted for them. In addition, it is assumed that they become zero immediately after conversion, and are not accumulated after conversion.



➤ **Carbon stocks in litter in “Urban parks and green areas at ports established in land converted from land-use categories other than Forest land”**

When urban parks and green areas at ports are established in land converted from land-use categories other than forest land, litter stocked before conversion does not moved to off-site because the soil ground before conversion, including litter, stays after conversion, or is covered with additional soils by soil dressing. Hence, litter stocked before conversion does not decrease after conversion. In addition, litter stocks scarcely increase immediately after conversion because newly planted trees do not immediately produce litter. Due to these facts, carbon stock changes before and after conversion are regarded as “0” (zero). Litter stocks accumulated in a year after conversion are calculated by the same method with urban parks and green areas at ports in settlements remaining settlements. This is based on the research finding that litter stocks are accumulated in the same way with settlements remaining settlements, namely accumulated by natural drop of fallen leaves and branches from trees in land converted to urban parks and green areas.

● **Activity Data**

➤ **Carbon stocks in dead organic matter in “Forest land converted to Settlements”**

The cumulative value of the area of land that was converted from forest land to settlements within the past 20 years was used. For the areas, see Table 6-45.

Table 6-46 Area of land converted to settlements within the past 20 years

Category	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Land converted to Settlements	kha	911.7	790.6	720.1	628.0	508.3	477.6	443.8	416.5	397.7	382.8	368.5	353.5	340.7	329.6	320.8
Forest land converted to Settlements	kha	283.8	279.3	258.3	214.8	148.7	136.6	122.9	115.1	110.2	106.9	105.6	104.0	102.6	100.6	99.5
Cropland converted to Settlements	kha	520.6	409.1	376.8	338.8	293.7	278.0	261.3	247.9	236.5	226.0	215.3	204.0	194.5	187.1	180.9
Rice field converted to Settlements	kha	320.9	252.1	236.6	215.2	188.7	178.9	168.3	159.3	151.8	144.8	137.2	129.1	122.3	117.1	112.6
Upland field converted to Settlements	kha	137.2	110.5	101.8	91.9	79.8	75.7	71.3	68.3	65.5	63.1	60.9	58.6	56.7	55.1	53.9
Orchard converted to Settlements	kha	62.4	46.5	38.5	31.6	25.2	23.4	21.7	20.4	19.2	18.1	17.2	16.3	15.5	14.9	14.4
Grassland converted to Settlements	kha	59.3	57.2	55.3	50.3	44.0	41.7	39.2	37.5	36.0	34.5	33.2	31.9	30.8	29.8	29.1
Wetlands converted to Settlements	kha	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Other land converted to settlements	kha	48.0	45.1	29.7	24.2	21.9	21.3	20.5	15.9	15.0	15.3	14.3	13.6	12.9	12.1	11.3

➤ **Carbon stock changes in litter in “urban parks and green areas at ports established in Land converted to Settlements”**

Areas of urban green areas established in land converted to settlements are calculated in the same manner as the carbon stock changes in living biomass in urban green areas established in land converted to settlements. They are calculated by multiplying the areas of urban parks and green areas at ports by the area ratio of land conversion area to the settlements, respectively. For detailed information regarding these areas see section 11.5.1.1.f. f) in Chapter 11 in this NIR.

3) **Carbon Stock Change in Soils in “Land converted to Settlements”**

In this category, forest land converted to settlements, urban parks and green areas at ports, the management practices of which were similar with those in urban parks, were subject to estimation.

● **Estimation Method**

Carbon stock changes in soils in land converted to settlements are estimated based on Tier 2 (Country specific methodology and data are used) estimation method.

$$\Delta C_{LSSoils_{all}} = \Delta C_{FSSoils} + \Delta C_{LSSoils}$$

$\Delta C_{LSSoils\_all}$  : Carbon stock changes in soils in land converted to settlements [t-C/yr]

$\Delta C_{FSSoils}$  : Carbon stock changes in soils in forest land converted to settlements [t-C/yr]

$\Delta C_{LSSoils}$  : Carbon stock changes in urban parks and green areas at ports established in settlements converted from other land use [t-C/yr]

$$\Delta C_{LSSoils} = \sum_i (\Delta C_{LSMineral_i} - L_{LSOrganic_i})$$

$$\Delta C_{LSMineral_i} = \Delta A_i \times (C_{AfterSoil} - C_{BeforeSoil}) + A_i \times \Delta C_{Soil_i}$$

$\Delta C_{LSMineral}$  : Annual carbon stock changes in mineral soils in urban parks and green areas at port following land-use conversion [t-C/yr]

$L_{LSOrganic}$  : Annual carbon stock losses due to drained organic soils in urban parks and green areas at port established in settlements converted from land use other than from forest land (=0) [t-C/yr]

$\Delta A$  : Area of urban parks and green areas at port established in settlement converted from other land use within a year [ha/yr]

$C_{AfterSoil}$  : Soil carbon stocks immediately after land-use conversion [t-C/ha]

$C_{BeforeSoil}$  : Soil carbon stocks before land-use conversion [t-C/ha]

$A$  : Area of urban parks and green areas at port established in settlements converted from other land use [ha]

$\Delta C_{Soil}$  : Annual carbon stock changes in soils per land area of urban parks and green areas at port following land-use conversion [t-C/ha/yr]

$i$  : Type of urban green facilities (urban parks or green areas at ports)

### ● **Parameters**

Parameters described in Table 6-12 were applied to estimation of carbon stock changes in mineral soils in forest land converted to settlements. In addition, when urban parks were constructed, soils in the areas before conversion were almost never moved to off-site. In general, these soils stay in the same places after conversion or covered by additional soils. Therefore, carbon stock changes in soils resulting from land conversion did not occur.

The parameters same as for urban parks and green areas at port in settlements remaining settlements were used for estimation of carbon stock changes in mineral soils in urban green facilities converted from other land use.

### ● **Activity Data**

#### ➤ **Forest land converted to settlements**

The values shown in Table 6-46 were applied to forest land converted to settlements.

#### ➤ **Settlements converted from land use other than forest land**

The activity data of settlements converted from other land use were the same as urban parks and green areas at port described in section 11.5.1.1.f. f) in Chapter 11.

### 4) **CO<sub>2</sub> emissions from organic soils in “Land converted to Settlements”**

#### ● **Estimation Method**

When land with organic soil is converted to settlements, it is common for the ground to be improved in

accordance with the purpose of land use. However, it could not be denied that oxidation of organic soil occurred under construction work, for example, on road in soft ground being conducted on the premise of land subsidence. For CO<sub>2</sub> emissions from drainage of organic soils in land converted to settlements, according to the *Wetlands Guidelines*, CO<sub>2</sub> emissions from cultivation of organic soils (on-site emissions) and emissions from water-soluble carbon losses from drained organic solids (off-site emissions) in land converted to settlements are estimated. The estimation equation is the same as 6.6.1b) 2).

- **Parameters**

For CO<sub>2</sub> emissions from organic soils in Settlements converted from other land use categories, since specific default emission factors for settlements have not been provided in the *2006 IPCC Guidelines* and the *Wetlands Guidelines* and country specific factors based on actual condition in Japan is under investigation, it was assumed that settlements converted from other land use would occur mainly from rice fields, CO<sub>2</sub> emission factor from organic soil in rice field was applied. (see section 6.6.1.).

- **Activity data**

The activity data was organic soils area in settlements within 20 years after conversion. The organic soil area obtained from other lands was estimated in the same way as described in section 6.6.1. This area was also used for estimating CH<sub>4</sub> and N<sub>2</sub>O emissions reported in the CRF “Table 4(II)”.

### c) **Uncertainties and Time-series Consistency**

- **Uncertainty Assessment**

The uncertainties of the parameters and activity data for living biomass and dead organic matter were individually assessed on the basis of field study results, expert judgment, or the default values described in the *2006 IPCC Guidelines*. The uncertainty estimate was 22% for the entire emission from land converted to settlements.

- **Time-series consistency**

Although the methods to estimate the area of forest land converted to other land use are different between FY1990-2004 and post FY2005, as described in section 6.6.2.b)1), time-series consistency for this subcategory is basically ensured.

### d) **Category-specific QA/QC and Verification**

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

### e) **Category-specific Recalculations**

- **Correction in accordance with revision of D area**

Since the D area, which is used for estimating the areas of Settlements converted from forest land were recalculated, carbon stock changes in living biomass, dead organic matter, carbon stock change in mineral soil and CO<sub>2</sub> emissions from organic soils in this category were recalculated for all years.

### f) **Category-specific Planned Improvements**

No improvements are planned.

## 6.10. Other land (4.F.)

Other land consists of land areas that are not included in the other five land-use categories. As concrete examples of other land, the *2006 IPCC Guidelines* indicates bare land, rock, ice, and all land areas that do not fall into any of the five categories. In FY2020, Japan's other land area was about 2.57 million ha, which is equivalent to about 6.8% of the national land. The classification of other land is shown in Table 6-47 below<sup>8</sup>.

Table 6-47 Land included in the other land category

Category	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Other land	kha	2,519.5	2,536.4	2,527.7	2,422.6	2,461.1	2,531.5	2,537.0	2,327.6	2,376.4	2,588.8	2,724.5	2,634.1	2,615.1	2,602.4	2,571.3
Defense Facility Site	kha	139.0	140.0	140.0	140.0	140.0	140.0	140.0	140.0	139.0	139.0	135.0	135.0	135.0	135.0	135.0
Coast	kha	46.0	46.0	46.0	46.0	46.0	46.0	46.0	46.0	46.0	46.0	46.0	46.0	46.0	46.0	46.0
Northern Territories	kha	503.6	503.6	503.6	503.6	503.6	503.6	503.6	503.6	503.6	503.6	503.6	503.6	503.6	503.6	503.6
Wasteland	kha	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Other	kha	1,830.9	1,846.8	1,838.1	1,732.9	1,771.5	1,841.9	1,847.4	1,638.0	1,687.8	1,900.2	2,039.9	1,949.5	1,930.5	1,917.8	1,886.7

The emissions from this category in FY2020 were 243 kt-CO<sub>2</sub> (GHG emissions other than changes in carbon stock are not included in this value.); this represents a decrease of 80.8% compared to FY1990 value and a decrease of 1.3% compared to FY2019.

In this section, other land is divided into two subcategories, "Other land remaining Other land (4.F.1.)" and "Land converted to Other land (4.F.2.)", and describes them separately in the following subsections.

Table 6-48 Emissions and removals resulting from carbon stock changes in other land

Category	Carbon pool	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
4.F. Other land	Total	kt-CO <sub>2</sub>	1,265	1,040	754	253	295	412	316	248	255	271	281	237	289	247	243
	Living Biomass	kt-CO <sub>2</sub>	763	625	440	104	137	250	160	104	114	126	138	101	155	133	128
	Dead Wood	kt-CO <sub>2</sub>	199	161	113	18	39	34	34	29	29	34	34	29	29	16	16
	Litter	kt-CO <sub>2</sub>	96	77	54	9	19	17	17	14	14	17	17	14	14	8	8
	Mineral soil	kt-CO <sub>2</sub>	207	177	146	123	99	111	106	101	98	93	92	93	92	90	92
	Organic soil	kt-CO <sub>2</sub>	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4.F.1. Other land remaining Other land	Total	kt-CO <sub>2</sub>															
	Living Biomass	kt-CO <sub>2</sub>															
	Dead Wood	kt-CO <sub>2</sub>															
	Litter	kt-CO <sub>2</sub>															
	Mineral soil	kt-CO <sub>2</sub>															
	Organic soil	kt-CO <sub>2</sub>															
4.F.2. Land converted to Other land	Total	kt-CO <sub>2</sub>	1,265	1,040	754	253	295	412	316	248	255	271	281	237	289	247	243
	Living Biomass	kt-CO <sub>2</sub>	763	625	440	104	137	250	160	104	114	126	138	101	155	133	128
	Dead Wood	kt-CO <sub>2</sub>	199	161	113	18	39	34	34	29	29	34	34	29	29	16	16
	Litter	kt-CO <sub>2</sub>	96	77	54	9	19	17	17	14	14	17	17	14	14	8	8
	Mineral soil	kt-CO <sub>2</sub>	207	177	146	123	99	111	106	101	98	93	92	93	92	90	92
	Organic soil	kt-CO <sub>2</sub>	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

### 6.10.1. Other land remaining Other land (4.F.1.)

#### a) Category Description

This subcategory deals with carbon stock changes in other land remaining other land during the past 20 years. The land area of this subcategory is determined by subtracting the summed areas of the other five land-use categories from the total national land area shown in the *Statistical Reports on the Land Area by Prefectures and Municipalities in Japan* compiled by the Geospatial Information Authority of Japan. However, carbon stock changes in this subcategory are not considered in accordance with the *2006 IPCC Guidelines*.

<sup>8</sup> The *Defense of Japan* (Ministry of Defense) for "Defense Facility Site", the *Digital national land information* (MLIT) for "Coast" and *Land Survey of Prefectures, Shi, Ku, Machi and Mura* (GSI) for "Northern Territories"

Table 6-49 Areas of other land remaining other land within the past 20 years

Category	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Other land remaining Other land	kha	2,297.1	2,345.7	2,370.3	2,289.9	2,355.4	2,414.3	2,426.0	2,223.4	2,276.1	2,493.6	2,631.1	2,545.4	2,523.8	2,511.9	2,479.7

**b) Category-specific Recalculations**

No recalculations are considered.

**c) Category-specific Planned Improvements**

No improvements are planned.

**6.10.2. Land converted to Other land (4.F.2.)****a) Category Description**

This subcategory deals with carbon stock changes in the land converted to other land within the past 20 years. The land area of this subcategory includes land converted for soil and stone mining, land damaged by natural disasters. “The land used for soil and stone mining activities” is the land which is artificially disturbed and the soil carbon in surface layer are removed and are considered not exist. Therefore, this categorization also takes the consistency of statistical division into consideration. By reading from satellite images to detect the land conversion, “the land used for soil and stone mining activities” is allocated under “Other land”.

The emissions from this subcategory in FY2020 were 243 kt-CO<sub>2</sub>. This represents a decrease of 80.8% compared to FY1990 and a decrease of 1.3% compared to FY2019.

With respect to living biomass, its carbon stock change as a result of land-use conversion from forest land, cropland and grassland to other land were estimated.

With respect to dead organic matter, Japan used the CENTURY-jfos model to estimate carbon stocks in dead organic matter in forest land, and then estimated carbon stock changes in forest land converted to other land. Carbon stock changes in dead organic matter in other subcategories (conversion from cropland and grassland) were reported as “NA”, since dead organic matter pools before and after conversion were assumed to be zero, as described in section 6.6.2.b)2) and 6.7.2.b)2).

With respect to carbon stock changes in soils, carbon stock changes in soils in forest land converted to other land are estimated. Carbon stock changes in soils in cropland and grassland converted to other land are reported as “NA” because it is assumed that the pools of soils before and after conversion are the same.

In addition, the area of wetlands converted to other land and settlements converted to other land cannot be obtained by the current method. Thus, carbon stock changes in these carbon pools were reported as “NO”.

**b) Methodological Issues****1) Carbon stock change in Living Biomass in “Land converted to Other land”****● Estimation Method**

The Tier 2 method was applied as described in section 6.6.2.b)1). Carbon stock changes due to biomass growth in other land were assumed as zero.

## ● Parameters

### ➤ Biomass stock in each Land-Use Category

The values shown in Tables 6-8a and 6-8b are used for the estimation of biomass stock changes upon land-use conversion and subsequent changes in biomass stock due to biomass growth in converted land.

### ➤ Carbon Fraction of dry matter

For carbon fraction of dry matter of forest, average value of broad leaf trees and conifer trees (0.50 t-C/t-d.m.) was applied. The default value (0.47 t-C/t-d.m. for herbaceous biomass in grassland and 0.5 t-C/t-d.m. for the others) was applied for other than forest in accordance with *the 2006 IPCC Guidelines*.

## ● Activity Data

Only the areas converted from forest land and cropland to other land are determined. Since no data were available on the area converted from wetlands and settlements to other land, estimations for those land-use categories could not be made. Instead, they are reported as “IE” since they are included in “Other land remaining Other land”.

It should be noted that the area presented in the CRF “Table 4.F Sectoral background data for land use, land-use change and forestry - Other land” is not the annually converted area in FY2020 but the sum of annually converted areas during the past 20 years.

### ➤ Conversion from Forest Land

See section 6.6.2.b1).

### ➤ Conversion from Cropland

For former rice fields, upland fields, and orchards, the area classified as “other, natural disaster damage” is used according to *the Area Statistics for Cultivated and Commercially Planted Land*.

### ➤ Conversion from Grassland

For former pasture land and grazed meadow land, the area of former pasture land classified as “other, natural disaster damage” (according to *the Area Statistics for Cultivated and Commercially Planted Land*) and the area of former grazed meadow land which is classified as “other, classification unknown” (*the Move and Conversion of Cropland*) are used.

Table 6-50 Area of land converted to other land within the past 1 year

Category	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Land converted to Other land	kha	7.1	7.1	5.2	5.8	2.1	18.8	3.7	1.7	3.8	2.1	3.6	1.3	7.4	6.8	6.2
Forest land converted to Other land	kha	3.6	2.9	2.0	0.3	0.7	0.6	0.6	0.5	0.5	0.6	0.6	0.5	0.5	0.3	0.3
Cropland converted to Other land	kha	2.2	2.6	2.0	4.5	0.9	16.8	2.3	0.8	2.0	1.2	2.7	0.5	5.9	5.6	5.3
Rice field	kha	1.2	1.5	1.6	4.2	0.6	14.9	1.7	0.3	1.3	0.8	2.3	0.3	3.6	3.5	3.9
Upland field	kha	0.7	0.9	0.3	0.2	0.2	1.6	0.5	0.4	0.5	0.4	0.4	0.2	1.8	1.6	1.1
Orchard	kha	0.3	0.3	0.1	0.1	0.1	0.4	0.1	0.1	0.1	0.1	0.1	0.0	0.4	0.4	0.3
Grassland converted to Other land	kha	0.4	0.5	0.2	0.2	0.1	0.8	0.3	0.2	0.3	0.2	0.2	0.1	1.0	0.9	0.6
Wetlands converted to Other land	kha	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Settlements converted to Other land	kha	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE

## 2) Carbon Stock Changes in Dead Organic Matter in “Land converted to Other land”

### ● Estimation Method

Carbon stock changes in dead organic matter in forest land converted to other land were estimated by applying the Tier 2 estimation method as described in section 6.6.2.b2).

- **Parameters**

- **Carbon Stocks in Dead Organic Matter in “Other Land converted from Forest Land”**

The average carbon stocks in dead wood and litter in forest land before conversion are shown in Tables 6-9 and 6-10. It is assumed that carbon stocks become zero immediately after conversion, and are not accumulated after conversion.

- **Activity Data**

The values of annually converted area from each land-use category to other land during the past 20 years are summed up to obtain the total area that is converted to other land during the same time period.

Table 6-51 Area of land converted to other land within the past 20 years

Category	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Land converted to Other land	kha	222.3	190.7	157.4	132.7	105.7	117.2	111.0	104.2	100.3	95.2	93.5	88.7	91.3	90.6	91.6
Forest land converted to Other land	kha	102.4	96.6	85.2	64.2	42.9	39.5	36.9	33.5	30.5	28.2	26.2	23.1	21.0	18.4	16.6
Cropland converted to Other land	kha	55.8	41.1	36.9	38.3	35.1	50.5	51.5	49.7	48.8	47.4	48.6	47.8	52.5	54.5	57.8
Rice field	kha	32.4	20.9	20.3	22.8	22.6	36.9	38.1	37.1	36.8	36.1	37.9	37.3	40.2	40.6	42.9
Upland field	kha	16.1	14.2	12.0	11.5	9.5	10.4	10.3	9.7	9.4	8.8	8.4	8.2	9.7	11.0	11.8
Orchard	kha	7.3	5.9	4.5	4.0	3.0	3.2	3.1	2.9	2.7	2.5	2.3	2.3	2.6	2.9	3.1
Grassland converted to Other land	kha	15.1	12.0	7.3	7.3	6.3	6.8	6.7	6.0	5.6	5.3	5.1	5.0	5.7	6.4	6.8
Wetlands converted to Other land	kha	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Settlements converted to Other land	kha	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE

### 3) Carbon Stock Changes in Soils in “Land converted to Other land”

In this category, carbon stock changes in mineral soils in forest land converted to other land were estimated.

- **Estimation Method**

Carbon stock changes in mineral soils in this category were estimated as same as section 6.6.2.b)3.

- **Parameters**

The parameters described in Table 6-12 were applied to estimating the carbon stock changes in mineral soils in forest land converted to other land.

- **Activity Data**

The areas of forest land converted to other land within 20 years were calculated by summing the annually converted areas during the past 20 years. The areas were shown in Table 6-51.

### c) Uncertainties and Time-series Consistency

- **Uncertainty Assessment**

The uncertainties of the parameters and the activity data for living biomass and dead organic matter were individually assessed on the basis of field study results, expert judgment, or the default values described in the 2006 IPCC Guidelines. The uncertainty was estimated as 18% for the entire emission from the land converted to other land.

- **Time-series Consistency**

Although the methods to estimate the area of forest land converted to other land use are different between FY1990 - 2004 and post FY2005, as described in section 6.6.2.b)1), the time-series consistency for this subcategory is basically ensured.

**d) Category-specific QA/QC and Verification**

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

**e) Category-specific Recalculations**

● **Correction in accordance with revision of D area**

Since the D area, which is used for estimating the areas of Other land converted from forest were recalculated, carbon stock changes in living biomass, dead organic matter and carbon stock change in mineral soils in this category were recalculated for all years.

**f) Category-specific Planned Improvements**

● **Breakdown Analysis of Other Land and Reclassification into Other Land-Use Categories**

A further breakdown analysis of the other land is required, since it may still include some areas that are supposed to be classified into other land-use categories even after the reallocation carried out in this year.

● **Carbon Stock Changes in Living Biomass in “Land converted to Other Land”**

The carbon stock changes in living biomass in land converted to other land were assumed to be zero because of a lack of reference information for other land. However, this assumption may differ from the actual situation. Therefore, the methods used to quantify the carbon stock are being examined.

● **Estimation Method of Soil Carbon Stock Changes in “Forest land, Cropland and Grassland converted to Other Land”**

The estimation method will be considered when new data and information are obtained.

**6.11. Harvested Wood Products (4.G.)**

Harvested Wood Products (HWP) that have been removed from forest through harvest, store carbon in the wood while HWP remain in use, including as housing materials and furniture. Eventually, CO<sub>2</sub> are emitted when HWP are discarded through incineration or decay.

This category deals with annual carbon stock changes in the HWP pool. The production approach is applied to the estimation of HWP. The methodologies according to Land Use, Land-Use Change and Forestry (LULUCF) reporting rules in the Kyoto Protocol are also applied to reporting of LULUCF under the Convention. Therefore, the HWP (such as sawnwood, wooden board, plywood, paper and paperboard) that are produced from domestic HWP from “ikusei-rin forest”, in which forest management practices are implemented in forest land, are subject to estimation. The changes in carbon stock associated with use or disposal of HWP are estimated. The carbon stock changes in the HWP for imports were deducted from the estimation. The net removals (carbon stock changes) from this category in FY2020 were 807 kt-CO<sub>2</sub>; this represents an increase of 79.2% compared to FY1990 and a decrease of 53.3% compared to FY2019. The net removals of this category had been on an increasing trend since FY 2014 due to an increase in the ratio of domestic wood, but decreased in FY 2020. This decrease may be mainly attributed to the decrease in wood production for construction and other uses, due to the effects of the Covid-19 pandemic.



In this section, the HWP pool is divided into three categories: “buildings”, “wood used for other than buildings” and “paper and paperboard”, and reported respectively.

Table 6-52 CO<sub>2</sub> emissions and removals associated with carbon stock changes in the HWP pool

Category		Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Total		kt-CO <sub>2</sub>	-450	1,401	1,765	617	101	2,443	53	304	-898	-1,210	-1,133	-1,490	-1,740	-1,720	-807
Buildings	Total	kt-CO <sub>2</sub>	-555	-926	-58	-842	-1,505	863	-1,511	-810	-1,420	-1,672	-1,555	-1,537	-1,793	-1,696	-1,663
	Sawnwood	kt-CO <sub>2</sub>	-335	-606	361	-356	-777	1,609	-768	20	-613	-829	-611	-565	-807	-619	-634
	Wooden board	kt-CO <sub>2</sub>	-210	-326	-436	-379	-325	-386	-314	-312	-370	-356	-393	-377	-363	-358	-357
	Plywood	kt-CO <sub>2</sub>	-10	6	16	-107	-404	-360	-428	-517	-437	-488	-550	-595	-624	-719	-672
Wood used for other than building	Total	kt-CO <sub>2</sub>	638	1,154	1,395	1,251	971	934	891	740	481	285	135	-34	-79	-168	90
	Sawnwood	kt-CO <sub>2</sub>	954	1,295	1,478	1,485	1,421	1,227	1,313	1,235	1,171	1,095	1,089	1,055	960	877	1,005
	Wooden board	kt-CO <sub>2</sub>	-326	-219	-198	-132	24	4	-98	-112	-93	-86	-113	-115	-85	-85	-9
	Plywood	kt-CO <sub>2</sub>	10	79	115	-102	-475	-297	-324	-383	-597	-724	-842	-973	-953	-960	-906
Paper and paperboard		kt-CO <sub>2</sub>	-533	1,173	429	208	636	646	672	374	41	177	287	80	132	144	765

### 6.11.1. Buildings

#### a) Category Description

This category deals with annual carbon stock changes in sawnwood, wooden board and plywood used in buildings. The net removal (carbon stock changes) from this subcategory in FY 2020 were 1,663 kt-CO<sub>2</sub>; this represents an increase of 199.6% over the FY1990 value and an increase of 1.9% over the FY2019 value.

Note that sawnwood, wooden board and plywood used in buildings are reported in "Sawnwood", "Wood panels" and "Other solid wood products" under "Solid wood" in the CRF tables, respectively.

#### b) Methodological Issues

##### ● Estimation Method

Since sawnwood, wooden board and plywood are mainly used for buildings and their statistics related to the buildings have been compiled with a certain level of accuracy in Japan, the carbon stock changes in these pools are estimated by using the country-specific stock inventory method (Tier 3). Carbon stocks in sawnwood, wooden board and plywood that are used when buildings are constructed are recorded as inflow and those released when the buildings are demolished are recorded as outflow. The net carbon stock changes are estimated by summing the inflow and outflow calculated separately. It means that all the carbon stored in the buildings is immediately oxidized when the buildings are demolished. The estimation equation is as follows:

$$\Delta C_{j,i} = Inflow_{j,i} - Outflow_{j,i}$$

$\Delta C_{j,i}$  : Carbon stock change in subcategory  $j$  of the building HWP pool during year  $i$  [t-C/year]

$Inflow_{j,i}$  : Inflow to subcategory  $j$  of the building HWP pool during year  $i$  [t-C/year]

$Outflow_{j,i}$  : Outflow from subcategory  $j$  of the building HWP during year  $i$  [t-C/year]

$j$  : Subcategories (sawnwood, wooden board, plywood)

$i$  : Year for calculation

$$Inflow_{j,i} = S_{P_{st,i}} \times v_{DP_{j,st,i}} \times f_{DP_{j,i}} \times D_j \times CF_j$$

$Inflow_{j,i}$  : Inflow to subcategory  $j$  of the building HWP pool during year  $i$  [t-C/year]

$S_{P, st, i}$	: Constructed floor area by uses (residential or nonresidential) and by structure type ( $st$ ) during year $i$ [m <sup>2</sup> /year]
$v_{DP, j, st, i}$	: Wood input amount per unit floor area of the building constructed (new construction or extension) by uses (residential or nonresidential) and by structure type ( $st$ ) constructed in year $i$ of subcategory $j$ [m <sup>3</sup> /m <sup>2</sup> ]
$f_{DP, j, i}$	: Ratio of domestic wood to total wood used for construction of subcategory $j$ in year $i$ [%]
$D_j$	: Density of subcategory $j$ (oven dry mass over air dry volume) [t-d.m./m <sup>3</sup> ]
$CF_j$	: Carbon fraction of subcategory $j$ [t-C/t-d.m.]
$j$	: Subcategory (sawnwood, wooden board, plywood)
$i$	: year for calculation
$st$	: Use (residential or nonresidential) and structure type of buildings

$$Outflow_{j,i} = S_{W, st, i} \times v_{DW, j, st, i} \times f_{DW, j, i} \times D_j \times CF_j$$

$Outflow_{j,i}$	: Outflow from subcategory $j$ of the building HWP pool during year $i$ [t-C/year]
$S_{W, st, i}$	: Floor area of demolished by uses (residential or nonresidential) and by structure type ( $st$ ) in year $i$ [m <sup>2</sup> /year]
$v_{DW, j, st, i}$	: Wood input amount per unit floor area in the year $i$ in which the demolished buildings by uses (residential or nonresidential) and by structure type ( $st$ ) were constructed [m <sup>3</sup> /m <sup>2</sup> ]
$f_{DW, j, i}$	: Ratio of domestic wood to total wood used in demolished building of subcategory $j$ during year $i$ [%]
$D_j$	: Density of subcategory $j$ (oven dry mass over air dry volume) [t-d.m./m <sup>3</sup> ]
$CF_j$	: Carbon fraction of subcategory $j$ [t-C/t-d.m.]
$j$	: Subcategory (sawnwood, wooden board, plywood)
$st$	: Use (residential or nonresidential) and structure type of buildings
$i$	: year for calculation

### ● Parameters

#### ➤ Wood input amount per unit floor area of the building constructed ( $v_{DP, j, st, i}$ )

##### - Sawnwood

As for wooden residential buildings, the amount of wood used per unit floor area was obtained from the *Survey on Actual Demand of Construction Labor and Materials* (MLIT). As for non-wood residential buildings, the values of 2013 from the survey conducted by the Forestry Agency of Japan were used, because the data from the *Survey on Actual Demand of Construction Labor and Materials* (MLIT) were available only until 1991. The same values of 2013 were applied from 2014 onwards. The values from 1992 to 2012 were calculated by linear interpolation.

##### - Wooden board

The amount of wooden board by type (particle board, hardboard, medium-density fibreboard and insulating board) and use was calculated by multiplying the total shipment of wooden board by type obtained from the *Yearbook of Current Production Statistics, Mineral Resources and Petroleum Products, Ceramics and building materials Statistics* (METI), by the ratio of the amount of shipped wooden board used for construction, estimated from the Japan Fibreboard and Particleboard Manufacturers Association's statistics. The wood input per unit area was estimated by dividing the

amount of wood calculated above, by the floor area of constructed buildings.

- **Plywood**

The values obtained from the *Survey on Actual Demand of Construction Labor and Materials* (MLIT) were applied. As for the years where data are missing, the values were calculated by linear interpolation.

➤ **Ratio of domestic wood for construction ( $f_{DP,j,i}$ )**

- **Sawnwood**

The ratio of domestic wood for sawnwood by conifer and non-conifer was calculated by dividing the shipment quantity of domestic sawnwood for buildings, by the total amount of shipment quantity of sawnwood for buildings and imported sawnwood.

- **Wooden board**

The amount of shipped wooden board (domestic wood) for buildings by raw material (logs, wood residue in mills and forestry practices and scrap wood) was calculated by multiplying the proportion of raw materials in particle board and fiberboard, by the ratio of domestic wood for each raw material. The ratio of domestic wood for each raw material was estimated, including from the production of domestic wood chips, imported wood chips, and quantity of wood used for wood chips (domestic and imported wood). The ratio of domestic wood for each wooden board type was estimated by dividing the amount of shipped wooden board (domestic wood) above, by the sum of the amount of shipped wooden board for buildings and the amount of imported wooden board for buildings.

- **Plywood**

The ratio of domestic wood for plywood used in constructed buildings was calculated by dividing the production of plywood from domestic wood by the sum of plywood production and imports.

➤ **The amount of wood input per unit floor area of demolished buildings ( $v_{DW,j,st,i}$ ) and the ratio of domestic wood for demolished buildings ( $f_{DW,j,i}$ )**

The amount of wood input per unit floor area of demolished buildings ( $v_{DW,j,st,i}$ ) and the ratio of domestic wood for demolished buildings ( $f_{DW,j,i}$ ) were calculated as the weighted average of the ratio of floor area built in year  $n$  ( $S_{W,st,i(n)}$ ) of the demolished floor area in year  $i$  ( $S_{W,st,i}$ ), respectively to reflect the wood input amount per unit demolished floor area ( $v_{DP,j,i}$ ) or the ratio of domestic wood for construction ( $f_{DP,j,i}$ ) in subcategory  $j$ , as shown in the equations below.

$$v_{DW,j,st,i} = \sum_n \left( \frac{S_{W,st,i(n)}}{S_{W,st,i}} \times v_{DP,j,i(n)} \right)$$

$$f_{DW,j,i} = \sum_n \left( \frac{S_{W,st,i(n)}}{S_{W,st,i}} \times f_{DP,j,i(n)} \right)$$

➤ **Density and carbon fraction**

The default values shown in Table 2.8.1 of the *2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol* (hereafter *KP Supplement*) were applied. Note that the density applied in section 6.11 is the oven dry mass density over air dry volume.

Table 6-53 Default values of density and carbon fraction for the HWP categories

HWP categories		Density [Mg-d.m./m <sup>3</sup> ]	Carbon fraction [Mg-C/Mg-d. m.]
Sawnwood	Coniferous sawnwood	0.45	0.5
	Non-coniferous sawnwood	0.56	0.5
Wood panels (wooden board)	Particle board (PB)	0.596	0.451
	Hardboard (HDF)	0.788	0.425
	Medium-density fireboard (MDF)	0.691	0.427
	Insulating board (other board, low density fiber)	0.159	0.474
Wood panels (plywood)		0.542	0.493

Reference: The *KP Supplement*, Table 2.8.1

Table 6-54 Data used for parameters (Buildings)

	Variable	Reference	Note
1	Shipment quantity of sawlogs (for building) (domestic wood)	<i>Report on Supply and Demand of Lumber</i> (MAFF)	
2	Shipment quantity of sawlogs (for building) (imported wood)	<i>Report on Supply and Demand of Lumber</i> (MAFF)	
3	Quantity of wood input for sawlogs	<i>Report on Supply and Demand of Lumber (the Survey on Lumber)</i> (MAFF)	
4	Imports of sawnwood (coniferous trees)	<i>Trade Statistics of Japan</i> (MOF)	Softwood (coniferous tree) imports are assumed as building materials because imports for building structures cannot be obtained in the statistics.
5	Shipment quantity of wooden board	<i>Yearbook of Current Production Statistics, Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics</i> (METI)	Including own-use
6	Imports of wooden board	<i>Trade Statistics of Japan</i> (MOF)	
7	Imported wood chips	<i>Trade Statistics of Japan</i> (MOF)	
8	Production of domestic wood chips	<i>Report on Supply and Demand of Lumber</i> (MAFF)	
9	Quantity of wood input for wood chips (domestic wood)	<i>Report on Supply and Demand of Lumber</i> (MAFF)	
10	Quantity of wood input for wood chips (imported wood)	<i>Report on Supply and Demand of Lumber</i> (MAFF)	
11	Shipment quantity of wooden board by use	<i>Shipments of wood-based board production</i> by Japan Fiberboard and Particleboard Manufacturers Association	
12	Production of plywood	<i>Report on Supply and Demand of Lumber</i> (MAFF)	
13	Imports of veneer for plywood	<i>Trade Statistics of Japan</i> (MOF)	Calculated by multiplying the rate of veneer for plywood to imports of veneer, by imports of veneer obtained from FAOSTAT
14	Imports of plywood	FAOSTAT (FAO) <i>Trade Statistics of Japan</i> (MOF)	Calculated by subtracting glued-laminated wood and bamboo of plywood by <i>Trade Statistics of Japan</i> from glued-laminated wood by FAOSTAT
15	Quantity of wood input for plywood (domestic wood)	<i>Report on Supply and Demand of Lumber</i> (MAFF)	
16	Quantity of wood input for plywood (imported wood)	<i>Report on Supply and Demand of Lumber</i> (MAFF)	

MIC: Ministry of Internal Affairs and Communications; METI: Ministry of Economy, Trade and Industry; MOF: Ministry of Finance

- **Activity Data**

- **Floor area of construction ( $S_{P_{st,i}}$ )**

The floor area of new construction and extension by use (residential or nonresidential) and by structure in the *Construction Statistics for Housing* and *Construction Statistics for Building* by MLIT was applied.

- **Floor area of demolition ( $S_{W_{st,i}}$ )**

The floor area of demolition was estimated by using the floor area stock in the *Fixed Property Tax Division, Local Tax Bureau (Houses)* by MIC and the floor area of construction described above. The floor area of demolished buildings by use (residential or nonresidential) and by structure in year  $i$  ( $S_{W_{st,i}}$ ) was calculated by subtracting the constructed floor area in  $i$  year ( $S_{P_{st,i}}$ ) from the floor area stock in  $i$  year ( $S_{S_{st,i}}$ ), and subtracting them from the floor area stock in  $i-1$  year ( $S_{S_{st,i-1}}$ ).

$$S_{W_{st,i}} = S_{S_{st,i-1}} - (S_{S_{st,i}} - S_{P_{st,i}})$$

Since the floor area stock and the constructed floor area include the area of extension, the floor area of demolition also includes the floor area of buildings demolished after extension. However, the floor area of renovation has been deducted from the constructed floor area since renovation is not taken into account in the calculation of the amount of wood input per unit floor area of buildings constructed.

- c) **Uncertainties and Time-series Consistency**

- **Uncertainty Assessment**

The uncertainties of carbon stock changes of buildings were assessed based on the uncertainties of the default factors provided in the *KP Supplement* and the uncertainties of existing statistical data. The uncertainty was estimated as 30% for the carbon stock changes in buildings.

- **Time-series Consistency**

Since wood input per unit area was obtained from the *Survey on Actual Demand of Construction Labor and Materials* by the MLIT which is implemented every three years, the data for missing years were calculated by linear interpolation. The time-series consistency for this subcategory is ensured.

- d) **Category-specific QA/QC and Verification**

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on checking the parameters for activity data and emission factors and archiving reference materials. QA/QC activities are summarized in Chapter 1.

- e) **Category-specific Recalculations**

The carbon stock changes were recalculated in accordance with updated activity data for sawnwood and plywood used in buildings from 2017 to 2019 and updated density data in wood boards from 2014 to 2019 in the *Survey of Construction Materials and Labor Demand*, etc. by the Ministry of Land, Infrastructure, Transport and Tourism. See Chapter 10 for impact on trend.

- f) **Category-specific Planned Improvements**

The wood input per unit floor area of buildings constructed may change in the future, through increased use of domestic wood for buildings.

The amount of wood per unit floor area of non-wood residential buildings has not been updated since

2013 when the Forestry Agency's survey was conducted, because that amount had no longer been included in the *Survey on Actual Demand of Construction Labor and Materials* (MLIT) since 1991. If the MLIT statistics are updated, the latest updated values will be used.

For the density of coniferous sawnwood, the default value (0.450) provided in the *KP Supplement* is currently used. Taking into account the availability of domestic statistics, appropriate methods for calculating and implementing country-specific values for this parameter will be considered.

### 6.11.2. Wood used for other than buildings

#### a) Category Description

This category deals with carbon stock changes in sawnwood, wooden board and plywood used in other than buildings. The net emissions from this subcategory in FY2020 were 90 kt-CO<sub>2</sub>, a decrease of 85.8% from FY1990 and an increase of 256 kt-CO<sub>2</sub> from FY2019 when the net removals from this subcategory were 168 kt-CO<sub>2</sub>.

In the CRF tables, this category is reported as "Sawnwood for non-buildings", "Wooden board for non-buildings" and "Plywood for non-buildings" under "Other (please specify)".

#### b) Methodological Issues

##### ● Estimation Method

The carbon stock changes in the HWP pool of this category were estimated as the difference between the HWP pool in the reference year and prior year by using the first-order decay (FOD) function (Tier 2 method) described in the *KP Supplement*. Inflow to the HWP pool during one year was estimated by multiplying the amount of wood used in other than buildings by the ratio of domestic wood of each subcategory (sawnwood, wooden board and plywood) and the carbon conversion factor. The estimation equations are as follows.

$$\Delta C_{j,i} = C_{j,i} - C_{j,i-1}$$

$$C_{j,i} = e^{-k_j} \times C_{j,i-1} + \left[ \frac{(1 - e^{-k_j})}{k_j} \right] \times Inflow_{j,i}$$

$\Delta C_{j,i}$  : Carbon stock change in subcategory  $j$  of the wood used for other than buildings HWP pool during year  $i$  [t-C/year]

$C_{j,i}$  : Carbon stock in subcategory  $j$  of the wood used for other than buildings HWP pool at the beginning of year  $i$  [t-C]

\*  $C_{j,(1900)} = 0$  : Carbon stock in 1900 was assumed to be zero

$k_j$  :  $k_j = \ln(2) / HL_j$

$HL_j$ : half-life in subcategory  $j$  of the wood used for other than buildings HWP pool

$Inflow_{j,i}$  : Inflow to subcategory  $j$  of the wood used for other than buildings HWP pool during year  $i$  [t-C/year]

$j$  : Subcategory (sawnwood, wooden board, plywood)

$i$  : Year for calculation

$$Inflow_{j,i} = V_{P,j,i} \times f_{DP,j,i} \times D_j \times CF_j$$

$Inflow_{j,i}$  : Inflow to subcategory  $j$  of the wood used for other than buildings HWP pool during year  $i$  [t-C/year]

$V_{P,j,i}$  : Amount of wood used in subcategory  $j$  for other than buildings [ $m^3$ /year]

$f_{DP,j,i}$  : Ratio of domestic wood used in subcategory  $j$  for other than buildings during year  $i$  [%]

$D_j$  : Density (oven dry mass over air dry volume) [t-d.m./ $m^3$ ]

$CF_j$  : Carbon fraction [t-C/t-d.m.]

$j$  : Subcategory (sawnwood, wooden board, plywood)

$i$  : Year for calculation

### ● Parameters

#### ➤ Ratio of domestic wood

##### - Sawnwood

The ratio of domestic wood for sawnwood used for other than buildings was calculated by dividing the amount of shipped sawnwood produced from domestic wood by tree species, by the amount of shipment.

##### - Wooden board

The ratio of domestic wood for wooden board production was estimated by multiplying the proportion of each raw material (logs, wood residue in mills and forestry practices and scrap wood) used for particle board and fiberboard, by the ratio of domestic wood for each raw material. The ratio of domestic wood for each raw material was estimated from the production of domestic wood chips, the amount of imported wood chips and the quantity of wood input for wood chips (domestic and imported wood).

##### - Plywood

The ratio of domestic wood for plywood used for other than buildings, was calculated by dividing the amount of input materials from domestic wood for plywood for other than buildings by the sum of the amount of input materials for plywood and imported veneers for plywood (in roundwood-equivalent volume).

#### ➤ Default half-lives

The default half-lives (sawnwood: 35 year, wood panels: 25 year) described in *the KP Supplement* were applied (Table 2.8.2). The default half-lives of wood panels are used for wooden board and plywood.

#### ➤ Density and carbon fraction

The default values used are the same as for the “Buildings” category (section 6.11.1) (See Table 6-53 for the details).

Table 6-55 Data used for parameters (wood used for other than buildings)

	Variable	Reference	Note
1	Shipment quantity of sawnwood (domestic wood for uses other than construction)	<i>Report on Supply and Demand of Lumber</i> (MAFF)	
2	Shipment quantity of wooden board	<i>Yearbook of Current Production Statistics, Mineral Resources and petroleum products, Ceramics and building materials Statistics</i> (METI)	Including own-use
3	Imported wood chips	<i>Trade Statistics of Japan</i> (MOF)	
4	Production of domestic wood chips	<i>Report on Supply and Demand of Lumber</i> (MAFF)	
5	Domestic wood chips (for pulp)	<i>Trends in Pulp Collection</i> by Japan Paper Association	
6	Quantity of wood input for wood chips (domestic wood)	<i>Report on Supply and Demand of Lumber</i> (MAFF)	
7	Quantity of wood input for wood chips (imported wood)	<i>Report on Supply and Demand of Lumber</i> (MAFF)	
8	Imports of plywood (veneer)	<i>Trade Statistics of Japan</i> (MOF)	Calculated by multiplying the rate of veneer for plywood to imports of veneer, by imports of veneer obtained from FAOSTAT
9	Quantity of wood input for plywood (domestic wood)	<i>Report on Supply and Demand of Lumber</i> (MAFF)	
10	Quantity of wood input for plywood (imported wood)	<i>Report on Supply and Demand of Lumber</i> (MAFF)	

METI: Ministry of Economy, Trade and Industry; MOF: Ministry of Finance

### ● Activity Data

Activity data used were the input of sawnwood, volume of wooden board, and production of plywood. The input of sawnwood was estimated by subtracting the shipment quantity of sawnwood for construction from the total shipment quantity of sawnwood in *the Report on Supply and Demand of Lumber* (MAFF). The amount of wooden board was estimated by (1) calculating the volume from the sold area of each of PB, HB, MDF and LDF in the *Yearbook of Current Production Statistics, Mineral Resources and Petroleum Products, Ceramics and Building Materials* (METI); (2) subtracting the volume of sold wooden board for buildings from volumes calculated at (1). The amount of production of plywood was obtained from the *Report on Supply and Demand of Lumber (the Survey on Lumber)* (MAFF). The wood used for buildings is excluded from these activity data, but the wood used for renovations, the floor area of which has been subtracted from that of building construction, is taken into account in this category.

### ➤ Method of tracing back up to 1900

As for wood used for other than buildings, the data were extrapolated backward to 1990 using the equation 12.6 described in section 12.2.3 in *the 2006 IPCC Guidelines*. For the estimated annual rate for industrial round wood production ( $U$ ), the default value of Asia between 1900 and 1961 (0.0217) was used (*2006 IPCC Guidelines*, Table 12.3).

$$V_t = V_{1961} \times e^{[U \times (t-1961)]}$$

$V_t$  : Annual production for other wood use [kt-C/year]

$t$  : Year (1900-1961)

$V_{1961}$  : Annual production for other wood use for the year 1961 [kt-C/year]



$U$  : Estimated continuous rate of change in industrial roundwood consumption for the region that includes the reporting country between 1900 and 1961

### c) *Uncertainties and Time-series Consistency*

#### ● *Uncertainty Assessment*

The uncertainties of carbon stock changes of wood used for other than buildings were assessed based on the uncertainties of the default factors provided in the *KP Supplement* and the uncertainties of statistical data. The uncertainty was estimated as 30% for the carbon stock changes in wood used for other than buildings.

#### ● *Time-series Consistency*

The data before 1961 were extrapolated backward to 1990 using the equation 12.6 described in section 12.2.3 in the *2006 IPCC Guidelines*, and the time-series consistency for this subcategory is ensured. The activity data and any parameter after 1962 used consistent statistics.

### d) *Category-specific QA/QC and Verification*

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on checking the parameters for activity data and emission factors and archiving reference materials. QA/QC activities are summarized in Chapter 1.

### e) *Category-specific Recalculations*

With the updated density data for wooden board from 2014 to 2019 and the updated FAOSTAT data for plywood from 2018 to 2019, carbon stock changes for wooden board and plywood in the wood used for other than buildings for those years were recalculated. See Chapter 10 for impact on trend.

### f) *Category-specific Planned Improvements*

Wood used mainly in the form of roundwood in the civil engineering and construction field is not included in the HWP estimation at present.

## 6.11.3. Paper and paperboard

### a) *Category Description*

This category deals with carbon stock changes in paper and paperboard (including waste paper). The net removals (carbon stock changes) from this subcategory in FY1990 were 533 kt-CO<sub>2</sub>, the net emissions in FY2019 were 144 kt-CO<sub>2</sub>, and the net emissions in FY2020 were 765 kt-CO<sub>2</sub>.

### b) *Methodological Issues*

#### ● *Estimation Method*

The carbon stocks changes in the HWP pool in paper and paperboard were estimated from the difference between the HWP pool in the reference year and prior year in the same way as used in the “wood used for other than buildings” category by using the first order decay (FOD) function (Tier 2 method) described in the *KP Supplement*. Inflow to the HWP pool during one year was estimated by multiplying the amount of production of paper and paperboard, by the ratio of domestic wood for paper and paperboard and the carbon conversion factor. The estimation equations are as follows.

$$\Delta C_i = C_i - C_{i-1}$$

$$C_i = e^{-k} \times C_{i-1} + \left[ \frac{(1 - e^{-k})}{k} \right] \times Inflow_i$$

$\Delta C_i$  : Carbon stock change of paper products HWP pool during year  $i$  [t-C/year]

$C_i$  : Carbon stock in paper products HWP pool at the end of year  $i$  [t-C]

\* $C_{(1900)}=0$ ; Carbon stock in 1900 was assumed to be 0.

$Inflow_i$  : Inflow to the HWP pool in year  $i$  [t-C/year]

$k$  :  $k = \ln(2) / HL$

HL: half-life of the HWP pool: two years

$i$  : year for calculation

$$Inflow_i = PP_{pi} \times f_{DPi} \times D \times CF$$

$Inflow_i$  : Inflow to the HWP pool in year  $i$  [t-C/year]

$PP_{pi}$  : Production of paper and paperboard during year  $i$  [t]

$f_{DPi}$  : Rate of domestic logs for paper and paperboard during year  $i$  [%]

$D$  : Density (oven dry mass over air dry mass)

$CF$  : Carbon fraction [t-C/t-d.m.]

$i$  : year for calculation

## ● Parameters

### ➤ Ratio of domestic wood

The ratio of domestic wood for paper and paperboard was estimated by estimating the amount of domestic production of paper pulp and that of waste paper and waste paper pulp respectively and dividing the amount by the total amount of domestic production of paper and paperboard..

The ratio of domestic wood for paper pulp was estimated by dividing the domestic and imported consumption of paper pulp made from logs and chips, by the total consumption of raw materials in the *Yearbook of current production statistics, Paper, printing, plastic products and rubber products* (METI). Since domestic wood chips in these statistics included chips which were domestically produced from imported wood, the amount of such chips was excluded in the estimation of the ratio of domestic wood for paper pulp, using the input of domestic and imported raw materials for chips, and the ratio of domestic wood for buildings.

The ratios of domestic wood for waste paper and waste paper pulp were estimated by estimating the amount of domestic supply from the production of waste paper in the *Yearbook of current production statistics Paper, printing, plastic products and rubber products* by METI and from the import and export amounts of waste paper in the *Trade Statistics of Japan* by MOF.

Table 6-56 Data used for parameters (Paper and paperboard)

	Variable	Reference	Note
1	Consumption of raw materials for pulp products	<i>Yearbook of Current Production Statistics, Paper, Printing, Plastic Products and Rubber Products Statistics Current Survey of Production</i> (METI)	Used for calculating rate of domestic logs
	Made from domestic wood		
	Logs		
	Chips		
	Chips made from imported wood		
2	Production of waste paper	<i>Yearbook of Current Production Statistics, Paper, Printing, Plastic Products and Rubber Products</i> (METI)	FAOSTAT (Recovered paper)
3	Imports and Exports of waste paper	<i>Trade Statistics of Japan</i> (MOF)	FAOSTAT (Recovered paper)
4	Imports and Exports of paper and paperboard	<i>Trade Statistics of Japan</i> (MOF)	FAOSTAT (Recovered paper)
5	Rate of production of wood chips	<i>Report on Supply and Demand of Lumber</i> (MAFF)	Used for estimating the ratio of domestic wood for pulp production chips
6	Quantity of wood input for wood chips (domestic wood)	<i>Report on Supply and Demand of Lumber</i> (MAFF)	
7	Quantity of wood input for wood chips (imported wood)	<i>Report on Supply and Demand of Lumber</i> (MAFF)	

METI: Ministry of Economy, Trade and Industry; MOF: Ministry of Finance

#### ➤ *Half-life*

The default half-life for paper and paperboard (2 years) described in the *KP Supplement* (Tables 2.8.2) was used.

#### ➤ *Default conversion factors for Paper and paperboard*

The default parameters (oven dry mass over air dry mass: 0.9 t-d.m./t, carbon fraction: 0.386 t-C/t-d.m.) for paper and paperboard described in the *KP Supplement* (Tables 2.8.2) were used.

#### ● *Activity Data*

##### ➤ *Method since 1961*

The amount of domestic production of paper and paperboard used was the sum of domestic pulpwood and chips obtained from the *Yearbook of Current Production Statistics, Paper, Printing, Plastic Products and Rubber Products* (METI). These are the same as the production amount of Paper and Paperboard in FAOSTAT.

##### ➤ *Method of tracing back up to 1900*

For paper and paperboard, the estimation method is the same as for wood used for other than buildings. For detailed information on the equation and the parameters, see section 6.11.2.

#### c) *Uncertainties and Time-series Consistency*

##### ● *Uncertainty Assessment*

The uncertainties of carbon stock changes of paper and paperboard were assessed based on the uncertainties of the default factors provided in the *KP Supplement* and the uncertainties of exiting statistical data.

The uncertainty was estimated as 30% for carbon stock changes in paper and paperboard.

### ● Time-series Consistency

The data before 1961 were extrapolated backward to 1990 using the equation 12.6 described in section 12.2.3 in *the 2006 IPCC Guidelines*, and the time-series consistency for this subcategory is ensured. The activity data and any parameter after 1962 used consistent statistics.

#### d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on checking the parameters for activity data and emission factors and archiving reference materials. QA/QC activities are summarized in Chapter 1.

#### e) Category-specific Recalculations

With the update of FAOSTAT for 2019, carbon stock changes for 2019 were recalculated.

#### f) Category-specific Planned Improvements

No improvements are planned.

## 6.12. Direct N<sub>2</sub>O emissions from N inputs to managed soils (4. (I))

### a) Category Description

This category deals with direct N<sub>2</sub>O emissions from N fertilization in land other than cropland and grassland. Emissions from the application of N fertilizer to forest land was estimated assuming that all fertilizers were synthetic, since the survey by the Forestry Agency showed that the majority of N fertilizers applied to forest land were mineral N fertilizers (synthetic fertilizers). The amount of N fertilizers applied to wetlands or settlements is not individually distinguished, however, their direct N<sub>2</sub>O emissions from those categories were reported as “IE” since all direct N<sub>2</sub>O emissions from all application of N fertilizers except those applied to forest land are estimated and reported in the Agriculture sector. The emissions from N fertilization in other land were reported as “NO” because there were no actual activities involving N fertilizer in other lands. Fertilization to forest land was reported all together in forest land remaining forest land because it was not possible to separate forest land remaining forest land from forest land converted to forest land. The emissions by this subcategory in FY2020 were 0.51 kt-CO<sub>2</sub> eq. This represents a decrease of 38.7% compared to FY1990.

Table 6-57 Direct N<sub>2</sub>O emissions from N fertilization

Category	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Total	kt-N <sub>2</sub> O	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
	kt-CO <sub>2</sub> eq.	0.84	0.72	0.67	0.64	0.56	0.53	0.54	0.56	0.54	0.51	0.51	0.51	0.51	0.51	0.51
Forest land	kt-N <sub>2</sub> O	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Forest land remaining Forest land	kt-N <sub>2</sub> O	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Land converted to Forest land	kt-N <sub>2</sub> O	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Wetlands	kt-N <sub>2</sub> O	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Wetlands remaining Wetlands	kt-N <sub>2</sub> O	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Land converted to Wetlands	kt-N <sub>2</sub> O	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Settlements	kt-N <sub>2</sub> O	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Settlements land remaining Settlements	kt-N <sub>2</sub> O	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Land converted to Settlements	kt-N <sub>2</sub> O	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Other	kt-N <sub>2</sub> O	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

**b) Methodological Issues**● **Estimation Method**

The direct N<sub>2</sub>O emissions from synthetic N fertilization in forest land were estimated by applying Tier 2 estimation method based on decision tree described in the *2006 IPCC Guidelines* because country specific emission factors can be used. The estimation equation was the same as the Agriculture sector.

● **Parameters**

The emission factor (0.62% [kg-N<sub>2</sub>O-N/kg-N<sup>9</sup>]), which was applied to the estimation of N<sub>2</sub>O emissions resulting from application of synthetic N fertilizer (no nitrification inhibitors) to agricultural soils (other crops), was also applied to the estimation of N<sub>2</sub>O emissions from synthetic N fertilization to soils in forest land. For detailed information on the emission factor, see section 5.5.1.1.b) in chapter 5 in this NIR.

● **Activity Data**

Results of surveys from 2006 to 2008 on fertilizer application to soils in forest land by the Forestry Agency of Japan were used as activity data. The amount of synthetic N fertilizer applied to soils in forest land in the years in which the surveyed data did not exist was estimated by multiplying the total amount of synthetic N fertilizer application in *Yearbook of Fertilizer Statistics (Pocket Edition)* by the average percentage of synthetic N fertilizer application to soils in forest land in the period from 2006 to 2008. The average percentage is 0.047% of the total amount of synthetic N fertilizer application.

**c) Uncertainties and Time-series Consistency**● **Uncertainty Assessment**

The uncertainty estimates of N<sub>2</sub>O emissions from N fertilization were 31% by applying the same value as the estimation of the N<sub>2</sub>O emissions from N fertilization in the Agriculture sector.

● **Time-series Consistency**

The emission factor is constant throughout the time series. For activity data, the same sources are multiplied by same ratio throughout the time series. Time-series consistency for this category is ensured.

**d) Category-specific QA/QC and Verification**

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

**e) Category-specific Recalculations**

No recalculations are conducted.

**f) Category-specific Planned Improvements**

No improvements are planned.

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<sup>9</sup> Akiyama et al. (2006)

### 6.13. CH<sub>4</sub> and N<sub>2</sub>O Emissions and Removals from Drainage and Rewetting and Other Management of Organic and Mineral soils (4.(II))

#### a) Category Description

Regarding the CRF-category 4.(II) “emissions and removals from drainage and rewetting and other management of organic and mineral soils”, the CH<sub>4</sub> and N<sub>2</sub>O emissions from drainage and cultivation of organic soils were estimated but removals from rewetting of organic soils nor mineral soils were not included. The estimation status of each land-use category is as follows. The emissions from soil drainage activities in forest land are reported as “NO” because soil drainage activities are not carried out in general in Japan. Among cropland and grassland, N<sub>2</sub>O emissions from cultivation of organic soils in pasture land and CH<sub>4</sub> emissions from rice cultivation in rice fields were reported in the Agriculture sector. As for the estimation of CH<sub>4</sub> emissions in other cropland and grassland in this category, only the emissions from uplands fields are estimated since the emissions from orchards and dilapidated farmland are reported as “NO” because soil drainage activities are not carried out. In the case of grassland, only CH<sub>4</sub> emissions from pasture land are estimated in this category because no farming activities are conducted in grassland other than pasture land (grazed meadow and wild land). As explained in section 6.8.1.b)1), peatlands classified as wetland are reported as "NE" because they are considered to be a minor emission source, while flooded lands and other wetlands are reported as "NA" because the methodologies proposed in the 2006 IPCC Guidelines and the Wetland Guidelines were not applied in Japan. The emissions and removals in the coastal wetland in this category were also reported as "NA" similar to the above. In addition, CH<sub>4</sub> and N<sub>2</sub>O emissions from organic soil drainage activities in settlements converted from other land-use categories were estimated. As there are no sub-categories under "settlements" under the CRF Table, the report was made in the new section, "H. Others".

The emissions by this subcategory in FY2020 were 39.6 kt-CO<sub>2</sub> eq. This represents a decrease of 35.1% compared to FY1990, and a decrease of 0.5 % compared to FY2019.

Table 6-58 CH<sub>4</sub> and N<sub>2</sub>O emissions from drainage of organic soils

Category	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
Total	kt-CO <sub>2</sub> eq.	61.1	53.5	50.0	47.3	45.0	44.1	42.9	42.1	41.9	41.5	40.4	40.2	40.1	39.8	39.6	
CH <sub>4</sub> Total	kt-CH <sub>4</sub>	2.32	2.05	1.92	1.82	1.73	1.70	1.66	1.63	1.62	1.61	1.56	1.56	1.55	1.54	1.54	
	kt-CO <sub>2</sub> eq.	58.0	51.1	48.0	45.5	43.4	42.6	41.5	40.8	40.6	40.2	39.1	38.9	38.8	38.6	38.4	
	Forest land	kt-CH <sub>4</sub>	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Cropland	kt-CH <sub>4</sub>	0.97	0.97	0.99	0.99	0.98	0.97	0.96	0.96	0.95	0.94	0.94	0.94	0.94	0.94	0.94
	Grassland	kt-CH <sub>4</sub>	0.09	0.09	0.09	0.09	0.08	0.10	0.11	0.10	0.11	0.12	0.09	0.09	0.09	0.09	0.09
	Wetlands	kt-CH <sub>4</sub>	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA
		Peat land	kt-CH <sub>4</sub>	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
		Flooded land	kt-CH <sub>4</sub>	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		Other wetlands	kt-CH <sub>4</sub>	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Other (Organic soil in settlements converted from other land-use categories)	kt-CH <sub>4</sub>	1.26	0.99	0.84	0.75	0.67	0.63	0.59	0.58	0.56	0.55	0.54	0.53	0.53	0.52	0.51
N <sub>2</sub> O Total	kt-N <sub>2</sub> O	0.010	0.008	0.007	0.006	0.005	0.005	0.005	0.005	0.004	0.004	0.004	0.004	0.004	0.004	0.004	
	kt-CO <sub>2</sub> eq.	3.02	2.36	2.00	1.78	1.61	1.52	1.41	1.38	1.34	1.31	1.29	1.28	1.26	1.23	1.21	
	Forest land	kt-N <sub>2</sub> O	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Wetlands	kt-N <sub>2</sub> O	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA
		Peat land	kt-N <sub>2</sub> O	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
		Flooded land	kt-N <sub>2</sub> O	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		Other wetlands	kt-N <sub>2</sub> O	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Other (Organic soil in settlements converted from other land-use categories)	kt-N <sub>2</sub> O	0.010	0.008	0.007	0.006	0.005	0.005	0.005	0.005	0.004	0.004	0.004	0.004	0.004	0.004	0.004

## b) Methodological Issues

### ● Estimation Method

As for upland fields, grassland and settlements converted from other land-use categories, CH<sub>4</sub> emissions from drained inland organic soils were estimated by using Tier 1 method (Equation 2.6) described in section 2.2.2.1 in the *Wetlands Guidelines*.

$$CH_{4_{os}} = A_{os} \times [(1 - Frac_{ditch}) \times EF_{CH_4_{land}} + Frac_{ditch} \times EF_{CH_4_{ditch}}]$$

$CH_{4_{os}}$	: Annual CH <sub>4</sub> emissions from drained organic soils [kg-CH <sub>4</sub> ]
$A_{os}$	: Land area of drained organic soils [ha]
$EF_{CH_4_{land}}$	: Emission factors for direct CH <sub>4</sub> emissions from drained organic soil from land surface [kg-CH <sub>4</sub> /ha]
$EF_{CH_4_{ditch}}$	: Emission factors for CH <sub>4</sub> emissions from drainage ditches [kg-CH <sub>4</sub> /ha]
$Frac_{ditch}$	: Fraction of the total area of drained organic soil which is occupied by ditches

N<sub>2</sub>O emissions from drained organic soil in settlements converted from other land-use categories were estimated by using Tier 2 method (Equation 2.7) described in section 2.2.2.2 in the *Wetlands Guidelines*.

$$N_2O-N_{os} = A_{os} \times EF_{os}$$

$N_2O-N_{os}$	: N <sub>2</sub> O-N emissions from drained organic soil [kg-N <sub>2</sub> O-N/yr]
$A_{os}$	: Area of organic soil in settlements converted from other land-use categories [ha]
$EF_{os}$	: N <sub>2</sub> O emission factor form drained organic soil [kg-N <sub>2</sub> O-N/ha/yr]

### ● Parameters

As for upland fields, grassland and Land converted to Settlements, the following emission factors for CH<sub>4</sub> from drained organic soils, emission factors for CH<sub>4</sub> from drainage ditches, and the proportion of ditches to the total area of drained organic soils which were provided by the *Wetlands Guidelines* Table 2.3 and Table 2.4, were applied to the estimation. Regarding to emission factors for N<sub>2</sub>O from settlements converted from other land-use categories, since default emission factors for settlements have not been provided in the *2006 IPCC Guidelines* and the *Wetlands Guidelines*, considering that conversion to settlements mainly occurs in rice fields in Japan, country specific emission factor for rice field was applied.

Table 6-59 CH<sub>4</sub> and N<sub>2</sub>O emission factors for drained organic soils from land surface

Land-use category	Emission factor	Unit	Climate/ vegetation zones
Cropland/Land converted to Settlements	0	kgCH <sub>4</sub> /ha/yr	Cropland, drained, Boreal and Temperate (the <i>Wetlands Guidelines</i> , Table2.3)
Grassland	16	kgCH <sub>4</sub> /ha/yr	Grassland, deep-drained, nutrient-rich, Temperate (the <i>Wetlands Guidelines</i> , Table2.3)
Land converted to Settlements	0.297	kgN <sub>2</sub> O-N/ha/yr	Country specific data (Actual measurement in rice field in Hokkaido)

Table 6-60 CH<sub>4</sub> emission factors for drained organic ditches

Land-use category	Emission factor	Unit	Frac <sub>ditch</sub> (indicative values)	Climate/ vegetation zones
Deep-drained Grassland/ Cropland/Land converted to Settlements	1165	kgCH <sub>4</sub> /ha/yr	0.05	Boreal/ Temperate, Deep drained Grassland, Cropland (Wetlands Guidelines, Table2.3)

- **Activity Data**

For detailed information on the methods of determining the areas of organic soils in upland fields, grassland and settlements converted from other land-use categories, see section 6.6.1. and section 6.7.1.

**c) Uncertainties and Time-series Consistency**

- **Uncertainty Assessment**

The uncertainties for parameters were assessed on the basis of default values described in the *Wetlands Guidelines*. As a result, the uncertainty estimates for the CH<sub>4</sub> emissions from drained inland organic soils were 66%.

- **Time-series Consistency**

The emission factor is constant throughout the time series. For activity data, the same sources are used throughout the time series. Time-series consistency for this category is ensured.

**d) Category-specific QA/QC and Verification**

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

**e) Category-specific Recalculations**

- **Correction in accordance with revision of area estimation**

Since area of deforestation (D area) were revised, CH<sub>4</sub> and N<sub>2</sub>O emissions from this category were recalculated for all years. See Chapter 10 for impact on trend.

**f) Category-specific Planned Improvements**

No improvements are planned.

## **6.14. Direct N<sub>2</sub>O emissions from N mineralization/immobilization associated with loss/gain of soil organic matter resulting from change of land use or management of mineral soils (4.(III))**

**a) Category Description**

The category 4.(III) deals with direct N<sub>2</sub>O emissions from N mineralization or N immobilization associated with loss/gain of soil organic matter resulting from change of land use or management of mineral soils. In accordance with the *2006 IPCC Guidelines*, N immobilization associated with the gain of soil organic matter is not considered, and only N<sub>2</sub>O emissions from mineralization associated with loss of soil organic matter were estimated.

For forest land, the N<sub>2</sub>O emissions from N mineralization associated with loss of soil organic matter resulting from normal forest management of forest land remaining forest land are included in the calculation because soil organic matter increases in land converted to forest land. For cropland, only the emissions from land converted to cropland are included in the calculation because the emissions from cropland remaining cropland are calculated in the Agriculture sector. For grassland, only the emissions from pastures are considered for the calculation because changes of soil organic matter occur only in



pastures among the three subcategories. Changes of soil organic matter were reported collectively as grassland remaining grassland because it is impossible to distinguish between changes resulting from change of land use and changes resulting from management. For wetlands remaining wetlands, settlements and other land remaining other land, N<sub>2</sub>O emissions were reported as “NA” because the decrease in soil carbon stocks does not occur. The emissions from wetlands converted from other land use were reported as “NE” because methodology is not provided. Also, the emissions from land converted to other land were included in the calculation because soil organic matter is lost resulting from change of land use.

The emissions from this subcategory in FY2020 were 148.8 kt-CO<sub>2</sub> eq. This represents a decrease of 10.6% compared to FY1990, and an increase of 0.8 % compared to FY2019.

Table 6-61 Direct N<sub>2</sub>O emissions from N mineralization

Category	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
Total	kt-N <sub>2</sub> O	0.56	0.53	0.50	0.48	0.46	0.46	0.47	0.47	0.47	0.47	0.47	0.48	0.49	0.50	0.50	
	kt-CO <sub>2</sub> eq.	166.4	157.4	148.9	142.1	136.7	138.2	138.9	139.1	139.8	140.4	141.4	143.2	145.6	147.5	148.8	
Forest land	kt-N <sub>2</sub> O	0.40	0.40	0.40	0.41	0.41	0.41	0.41	0.41	0.41	0.42	0.42	0.43	0.43	0.44	0.44	
	Forest land remaining Forest land	kt-N <sub>2</sub> O	0.40	0.40	0.40	0.41	0.41	0.41	0.41	0.41	0.41	0.42	0.42	0.43	0.43	0.44	0.44
	Land converted to Forest land	kt-N <sub>2</sub> O	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cropland	kt-N <sub>2</sub> O	0.08	0.05	0.04	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	
	Land converted to Cropland	kt-N <sub>2</sub> O	0.08	0.05	0.04	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02
Graassland	kt-N <sub>2</sub> O	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	
	Grassland remaining Grassland	kt-N <sub>2</sub> O	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	
	Land converted to Graassland	kt-N <sub>2</sub> O	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	
Wetlands	kt-N <sub>2</sub> O	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	
	Wetlands remaining Wetlands	kt-N <sub>2</sub> O	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
	Land converted to Wetlands	kt-N <sub>2</sub> O	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	
Settlements	kt-N <sub>2</sub> O	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
	Settlements remaining Settlements	kt-N <sub>2</sub> O	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
	Land converted to Settlements	kt-N <sub>2</sub> O	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
Other land	kt-N <sub>2</sub> O	0.08	0.07	0.06	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.04	0.03	0.03	0.03	
	Other land remaining Other land	kt-N <sub>2</sub> O	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
	Land converted to Other land	kt-N <sub>2</sub> O	0.08	0.07	0.06	0.05	0.04	0.04	0.04	0.04	0.04	0.03	0.04	0.03	0.03	0.03	

## b) Methodological Issues

### ● Estimation Method

Equation 11.1 and Equation 11.8 described in session 11.2.1 in Vol.4 of the 2006 IPCC Guidelines is used for estimation.

$$N_2O-N_{direct-N_{Mineral}i} = F_{SOMi} \times EF_i \quad (\text{Equation 11.1, Vol.4 of the 2006 IPCC Guidelines})$$

$$F_{SOMi} = \sum_k \left( \Delta C_{Minerali,k} \times \frac{1}{R_{i,k}} \right) \quad (\text{Equation 11.8, Vol.4 of the 2006 IPCC Guidelines})$$

$$\Delta C_{Minerali,k} = \sum_j \left( c_{ms-lossi,j,k} \times A_{i,j,k} \right)$$

$N_2O-N_{direct-N_{Mineral}}$  : Direct N<sub>2</sub>O emissions from N mineralization as a result of loss of organic matter in mineral soils [kg-N<sub>2</sub>O-N]

$F_{SOM}$  : Annual amount of N mineralized in mineral soils as a result of loss of organic matter in mineral soils [kg-N]

$EF$  : Emission factor for N<sub>2</sub>O emissions per amount of N mineralization [kg-N<sub>2</sub>O-N/kg-N]

$\Delta C_{Mineral}$  : Average annual loss of soil carbon as a result of loss of organic matter in mineral soils [kg-C]

$R$  : C:N ratio for the soil organic matter

$c_{ms-loss}$  : Soil carbon loss per unit area as a result of loss of organic matter in mineral soils [kg-C/ha]

$A$	: Area of Mineral soils with soil carbon loss as a result of loss of soil organic matter [ha].
$i$	: Land use/type of land (forest land remaining forest land, land converted to cropland (rice fields, upland fields, orchards), grassland (pastureland), land converted to other land)
$j$	: Regions (Hokkaido, Tohoku, Kanto, Hokuriku, Tokai/Kinki, Chugoku/Shikoku, Kyushu/Okinawa)
$k$	: Soil type (soil type based on the classification from Yagasaki and Shirato (2014)) considered only for cropland and grassland

For cropland and grassland, the equations above were summarized as follows and set as the  $N_2O$  emission factor per unit area ( $EF_{N_2O-N_{i,j}}$ ) [kg- $N_2O$ -N].

$$\begin{aligned}
 N_2O-N_{direct-N_{Mineral_{i,j}}} &= c_{ms-loss_{i,j,k}} \times A_{i,j,k} \times \frac{1}{R_{i,k}} \times EF_i \\
 &= \left\{ EF_i \times \sum_k \left( c_{ms-loss_{i,j,k}} \times \frac{1}{R_{i,k}} \right) \right\} \times \sum_k (A_{i,j,k}) \\
 &= EF_{N_2O-N_{i,j}} \times A_{i,j}
 \end{aligned}$$

#### ● Parameters

##### ➤ Parameters used for forest land remaining forest land and Land converted to Other land

##### - Soil carbon loss resulting from loss of organic matter in mineral soils in forests land remaining forest land ( $\Delta C_{Mineral}$ )

The change in soil carbon stock per unit area obtained by the Century-jfos model described in 6.5.1.b)2 where the decrease in soil carbon occurred were multiplied by the area.

##### - Soil carbon loss resulting from loss of organic matter in mineral soils on other land converted from other land use ( $\Delta C_{Mineral}$ )

For the amount of soil carbon loss resulting from loss of organic matter in mineral soils in land converted to other land, the amount of loss in carbon stock in mineral soils caused by land-use change obtained in 6.10.2.b)3 was used.

##### - Emissions of $N_2O$ per amount of N mineralization ( $EF_i$ )

The default value [0.01 kg- $N_2O$ -N/kg-N] described in the 2006 IPCC Guidelines was used.

##### - C/N ratio for solids ( $R_i$ )

Country specific value of 11.3 established by MOE (2006) was applied.

##### ➤ Parameters used for cropland (converted from other land use) and grassland

The following parameters were set by Shirato et al. (2021). An overview of the settings is given as below. Note that the same parameters as those used in the agriculture sector are used (See section 5.5.1.5.b).

##### - Soil carbon loss per unit area resulting from loss of organic matter in mineral soil ( $c_{ms-loss_{i,j,k}}$ )

The decomposition amount of soil carbon per unit area not derived from the input of organic matter was calculated by using the Roth C model described in section 6.6.1.b)3) by setting the input of organic matter at zero for the most recent year after giving the long-term normal operation of the models calculating the changes in soil carbon stock for the past years. Calculations were performed for five years from FY2014 to FY2018, taking annual variations into account. The average value for five years

was calculated for each land type, region, and soil type, and this constant value was used as a fixed value in the time series.

- **C/N ratio for solids ( $R_{i,k}$ )**

The 0-30 cm depth data obtained from field surveys conducted in 2015-2018 for each land use and each soil type of cropland were used. The soil types were organized into three groups, and the results of the mean values for each land type are shown in Table 6-62.

Table 6-62 C/N ratio by soil type for each type of land use in cropland and grassland

Soil type	Rice fields	Upland fields	Orchards and tea plantations	Pasture land
Lowland soils	10.9	11.4	11.0	11.6
Andosols	13.5	12.8	13.0	13.9
Other soils	10.8	10.3	10.5	11.4

- **Amount of emission factors of  $N_2O$  per unit area ( $EF_{N_2O-Ni,j}$ )**

The emissions of  $N_2O$  per unit area ( $EF_{N_2O-Ni,j}$ ) in land use and soil type of land ( $i$ ) and region ( $j$ ) were calculated using the  $N_2O$  statistical model of Mu et al. (2009) given by the following equation.

$$EF_{N_2O-Ni,j} = 0.0801 \times e^{0.00722 \times c_{ms-loss_{i,j,k}} \times \frac{1}{R_{i,k}}}$$

However, since the aforementioned statistical model does not take into account for the data of rice fields, the default emission factor for  $N_2O$  per mineralized N in rice fields ( $EF_{IFR}=0.004$ ) listed in Table 1 of section 11.2.1.2 in the 2019 Refinement was applied for rice fields.

The results of the calculations performed by Shirato et.al. (2021) are shown in the table 6-63.

Table 6-63 Emission factors of  $N_2O$  per unit area in each region for each type of land use in cropland and grassland ( $EF_{N_2O-Ni,j}$ )

Region	Rice fields	Upland fields	Orchards and tea plantations		Pasture land
			Orchards	Tea plantations	
Hokkaido	0.244	0.210	0.246	—	0.206
Tohoku	0.269	0.189	0.197	—	0.187
Kanto	0.291	0.166	0.181	0.178	0.178
Hokuriku	0.265	0.167	0.192	0.177	0.199
Tokai-Kinki	0.284	0.172	0.194	0.179	0.195
Chugoku-Shikoku	0.307	0.200	0.190	0.199	0.191
Kyusyu-Okinawa	0.310	0.197	0.181	0.178	0.173

● **Activity Data**

➤ **Mineral soil area with loss of soil carbon resulting from loss of soil organic matter in cropland and grassland (A)**

In cropland and grassland, area of mineral soils in cropland and grassland (pasture land) was used as activity data because soil disturbance caused by land-use change and normal agricultural activities oxidizes the organic matter in mineral soils and causes carbon loss. In pasture land, the area of activity was defined as the mineral soil area multiplied by the renewal rate used in 6.7.1b), because the area where renewal was carried out was considered to be the area where there was actual activity involving soil disturbance.

**c) Uncertainties and Time-series Consistency**● **Uncertainty Assessment**

The uncertainties of emissions/removals for forest land and other land were assessed on the basis of carbon stock change in soil and C:N ratio for the soil organic matter. The uncertainties of parameters described in the *2006 IPCC Guidelines* were used. The uncertainty of emissions/removals for land converted to cropland and grassland were assessed by using the standard deviation for EFs described in Shirato et al.(2021) and by using the standard error for ADs given in the *Statistics of Cultivated and Planted Area*, which are the same as the assessments conducted in Agriculture sector. As a result, the uncertainties in the N<sub>2</sub>O emissions from N mineralization associated with loss of soil organic matter were assessed at -66% to +178%.

● **Time-series Consistency**

The emission factor is constant throughout the time series. For activity data, the same sources are used throughout the time series. Time-series consistency for this category is ensured.

**d) Category-specific QA/QC and Verification**

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

**e) Category-specific Recalculations**● **Changes due to the revision of the method for calculation for cropland and grassland**

The new research results of Shirato et al. (2021) made it possible to use the methodology presented in the *2006 IPCC guidelines* using the carbon loss of soil organic matter. Accordingly, the direct emissions of N<sub>2</sub>O associated with the mineralization of soil organic matter in cropland (Land converted to Cropland) and grassland were recalculated for all years.

● **Correction in accordance with revision of area estimation**

Since area of afforestation and reforestation (AR area) and area of deforestation (D area) were revised and the area of mineral soils are recalculated in cropland and grassland, N<sub>2</sub>O emissions in forest land, cropland, grassland and other land from this category were recalculated for all years. See Chapter 10 for impact on trend.

**f) Category-specific Planned Improvements**

No improvements are planned.

**6.15. Indirect nitrous oxide (N<sub>2</sub>O) emissions from managed soils (4.(IV))****a) Category Description**

This category deals with indirect N<sub>2</sub>O emissions from managed soils. The indirect N<sub>2</sub>O emissions include, N<sub>2</sub>O emissions from N volatilization as NH<sub>3</sub> and NO<sub>x</sub> and deposition of these gases and their products NH<sub>4</sub><sup>+</sup> and NO<sub>3</sub><sup>-</sup> onto soils and the surface of lakes and other waters, and N<sub>2</sub>O emissions from leaching and runoff in regions where these events occur. In Japan, the indirect N<sub>2</sub>O emissions from N fertilization in forest land and the indirect N<sub>2</sub>O emissions from N mineralization associated with loss of soil organic matter were estimated.

The emissions from this category in FY2020 were 42.5 kt-CO<sub>2</sub> eq. This represents a decrease of 19.2% compared to FY1990, and an increase of 1.3% compared to FY2019.

Table 6-64 Indirect N<sub>2</sub>O emissions from managed soils

Category	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Total	kt-N <sub>2</sub> O	0.18	0.16	0.14	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.14	0.14	0.14	0.14
	kt-CO <sub>2</sub> eq.	52.6	46.9	42.4	39.7	37.9	38.3	38.8	39.0	39.3	39.4	39.6	40.3	41.3	42.0	42.5
Atmospheric deposition	kt-N <sub>2</sub> O	0.0007	0.0006	0.0006	0.0005	0.0005	0.0004	0.0005	0.0005	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004
Nitrogen leaching and run-off	kt-N <sub>2</sub> O	0.18	0.16	0.14	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.14	0.14	0.14

## b) Methodological Issues

### 1) N<sub>2</sub>O emission from atmospheric deposition of N volatilized

#### ● Estimation Method

The Tier 1 method described in section 11.2.1.1 in the 2006 IPCC Guidelines is used.

$$N_2O - N_{ATD} = (F_{SN} \times Frac_{GASF}) \times EF_4$$

$N_2O - N_{ATD}$	: Annual amount of N <sub>2</sub> O–N produced from atmospheric deposition of N volatilized [kg N <sub>2</sub> O–N]
$F_{SN}$	: Annual amount of synthetic fertilizer N applied to forest land [kg–N]
$Frac_{GASF}$	: Fraction of synthetic fertilizer N that volatilized as NH <sub>3</sub> and NO <sub>x</sub> [kg–NH <sub>3</sub> –N + NO <sub>x</sub> –N/kg–N]
$EF_4$	: Emission factor for N <sub>2</sub> O emissions from atmospheric deposition of N on soils and water surfaces [kg–N <sub>2</sub> O–N/kg–NH <sub>3</sub> –N+NO <sub>x</sub> –N]

#### ● Parameters

Default values from the 2019 Refinement were used.

#### ➤ Fraction of synthetic fertilizer N that volatilized as NH<sub>3</sub> and NO<sub>x</sub>

0.11 [kg NH<sub>3</sub>–N + NO<sub>x</sub>–N/kg N applied] (Table 11.3 in Vol.4, aggregated)

#### ➤ Emission factor (N volatilization and re-deposition)

0.014 [kg N<sub>2</sub>O–N/kg NH<sub>3</sub>–N + NO<sub>x</sub>–N volatilized] (Table 11.3 in Vol.4, disaggregated, wet climate)

#### ● Activity Data

For amount of synthetic N fertilizer applied to forest land, see section 6.12. in this NIR.

### 2) N<sub>2</sub>O emission from leaching/runoff

#### ● Estimation Method

The Tier 1 method described in section 11.2.2.1 in Vol.4 of the 2006 IPCC Guidelines is used.

$$N_2O - N_{leach} = (F_{SN} + F_{SOM}) \times Frac_{LEACH-H} \times EF_5$$

$N_2O - N_{leach}$	: Annual amount of N <sub>2</sub> O–N produced from leaching and runoff of N additions [kg N <sub>2</sub> O–N]
$F_{SN}$	: Annual amount of synthetic fertilizer N applied to forest land [kg–N]
$F_{SOM}$	: Annual amount of N mineralized in mineral soils associated with loss of soil C from soil organic matter [kg–N]
$Frac_{LEACH-H}$	: Fraction of all N mineralized in managed soils in regions where leaching/runoff occurs that is lost through leaching and runoff [kg–N/kg–N]
$EF_5$	: Emission factor for N <sub>2</sub> O emissions from N leaching and runoff [kg–N <sub>2</sub> O–N]

- **Parameters**

Default values from the *2019 Refinement* were used.

- **Fraction of all N mineralized in managed soils**

0.24 [kg N/kg nitrogen of fertilizer] (Table 11.3 in Vol.4, aggregated)

- **Emission factor (N leaching and runoff)**

0.011 [kg N<sub>2</sub>O-N/(kg N leaching/runoff)] (Table 11.3 in Vol.4, aggregated)

- **Activity Data**

For amount of N fertilizer applied to forest land, see section 6.12. in this NIR. For amount of N mineralization associated with loss of soil organic matter, see section 6.13. in this NIR.

**c) Uncertainties and Time-series Consistency**

The uncertainty of indirect N<sub>2</sub>O emissions from N fertilizer was assessed based on the uncertainty of the emission factor (see the *2006 IPCC Guidelines*, p.11.24) and that of the amount of fertilizer. The uncertainty of indirect N<sub>2</sub>O emissions from N mineralization associated with loss of soil organic matter was 288%, which is the same value with the uncertainty of in direct N<sub>2</sub>O emissions from N mineralization associated with loss of soil organic matter. Consequently, the uncertainty of indirect N<sub>2</sub>O emissions from this category was assessed at -107% to +360%.

- **Time-series Consistency**

The emission factor is constant throughout the time series. For activity data, the same sources are used throughout the time series. Time-series consistency for this category is ensured.

**d) Category-specific QA/QC and Verification**

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

**e) Category-specific Recalculations**

- **Changes due to the revision of the method for calculating N<sub>2</sub>O emissions from N mineralization in cropland and grassland**

Emissions have been recalculated for all years following the revision of the methodology for calculating N<sub>2</sub>O emissions from N mineralization of soil organic matter in cropland and grassland, as indicated in section 6.14.

- **Change the emission factor to be used**

The percentage of N emissions of leaching or runoff and the indirect emission factors for leaching or runoff were changed from the default values in the *2006 IPCC Guidelines* to the default values in the *2019 Refinement*. With this revision, the emissions were recalculated for all years.

- **Correction in accordance with revision of area estimation**

Since area of afforestation and reforestation (AR area) and area of deforestation (D area) were revised and the area of mineral soils are recalculated in cropland and grassland, the indirect N<sub>2</sub>O emissions from managed soils were recalculated for all years (see section 6.14.). See Chapter 10 for impact on trend.

**f) Category-specific Planned Improvements**

No improvements are planned.

**6.16. Biomass burning (4.(V))****a) Category Description**

This category deals with emissions of CH<sub>4</sub>, CO, N<sub>2</sub>O and NO<sub>x</sub> from biomass burning. For the emissions of CO and NO<sub>x</sub>, see Annex 3.

For forest land, the emissions resulting from wildfires in forest land remaining forest land and land converted to forest land are reported in a lump for wildfires in forest land remaining forest land, because the data in the statistics for forest fires include the wildfires occurred in both of the categories. Moreover, controlled burning activities in forests and land conversion from land-use categories other than forest land to forest land are not implemented in Japan because the activities are stringently restricted by the “Waste Management and Public Cleansing Act” and “Fire Service Act”. Hence, the emissions resulting from controlled burning in forest land do not occur and are reported as “NO”.

CH<sub>4</sub> and N<sub>2</sub>O emissions from controlled burning in cropland are estimated for woody biomass burning of pruned branches from orchard. One of the characteristics of Japan’s cropland is intensive management. Under this management style, the occurrences of wildfire are regarded as negligible. CH<sub>4</sub> and N<sub>2</sub>O emissions from wildfires in cropland are reported as “NO”. In addition, CH<sub>4</sub> and N<sub>2</sub>O emissions from controlled burning in grassland are estimated. CH<sub>4</sub> and N<sub>2</sub>O emissions from wildfires in grassland are reported as “NO” for the same reasons as cropland.

CH<sub>4</sub> and N<sub>2</sub>O emissions from wildfires in land other than forest land, cropland and grassland are reported as “NE” because information on wildfires is not enough. CH<sub>4</sub> and N<sub>2</sub>O emissions from biomass burning in Wetlands are reported as “NE” because it can be considered insignificant.

CO<sub>2</sub> emission is not included in this category because it was included in estimation of carbon stock changes.

The emissions by this subcategory in FY2020 were 49.0 kt-CO<sub>2</sub> eq. This represents a decrease of 29.4% compared to FY1990 and a decrease of 6.0% compared to FY2019. These fluctuations are due to less amount of woody biomass burning of pruned branches from orchard over the long run, while, in the short run, inconsistencies of wildfire occurrences also effect it.

Table 6-65 Non-CO<sub>2</sub> emissions from biomass burning

Category	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
Total	kt-CO <sub>2</sub> eq.	69.4	66.8	63.0	62.9	54.9	56.1	51.0	53.0	73.1	54.7	49.2	72.6	49.6	52.1	49.0	
CH <sub>4</sub> Total	kt-CH <sub>4</sub>	1.9	1.8	1.7	1.7	1.4	1.5	1.3	1.3	2.1	1.4	1.2	2.1	1.2	1.3	1.2	
	kt-CO <sub>2</sub> eq.	47.2	45.3	42.2	42.4	35.3	36.5	31.8	33.7	52.3	35.3	30.3	52.0	30.8	33.2	30.3	
	Forest land	kt-CH <sub>4</sub>	0.4	0.4	0.4	0.4	0.2	0.3	0.1	0.2	0.9	0.2	0.1	0.9	0.1	0.2	0.1
	Cropland	kt-CH <sub>4</sub>	1.0	0.9	0.8	0.8	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.6	0.6	0.6	0.6
	Grassland	kt-CH <sub>4</sub>	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	Wetlands	kt-CH <sub>4</sub>	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO
	Settlements	kt-CH <sub>4</sub>	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Other land	kt-CH <sub>4</sub>	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Other	kt-CH <sub>4</sub>	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	N <sub>2</sub> O Total	kt-N <sub>2</sub> O	0.07	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.07	0.06	0.06	0.06	0.07	0.06	0.06
kt-CO <sub>2</sub> eq.		22.1	21.5	20.8	20.5	19.6	19.7	19.2	19.3	20.8	19.4	18.9	20.6	18.8	18.9	18.6	
Forest land		kt-N <sub>2</sub> O	0.0028	0.0028	0.0025	0.0030	0.0013	0.0017	0.0005	0.0011	0.0063	0.0017	0.0004	0.0064	0.0007	0.0014	0.0007
Cropland		kt-N <sub>2</sub> O	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Grassland		kt-N <sub>2</sub> O	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Wetlands		kt-N <sub>2</sub> O	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO
Settlements		kt-N <sub>2</sub> O	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Other land		kt-N <sub>2</sub> O	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Other		kt-N <sub>2</sub> O	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

## b) Methodological Issues

### 1) CH<sub>4</sub> and N<sub>2</sub>O emissions from forest fires

#### ● Estimation Method

For CH<sub>4</sub>, and N<sub>2</sub>O emissions due to biomass burning from forest fires, the Tier 1 method is used in the 2006 IPCC Guidelines.

#### ➤ Forest land

##### - CH<sub>4</sub>

$$bbGHG_f = L_{forest\ fires} \times ER$$

##### - N<sub>2</sub>O

$$bbGHG_f = L_{forest\ fires} \times ER \times NC_{ratio}$$

$bbGHG_f$  : GHG emissions due to forest biomass burning

$L_{forest\ fires}$  : Carbon released due to forest fires [t-C/yr]

$ER$  : Emission ratio (CH<sub>4</sub> : 0.012, N<sub>2</sub>O : 0.007)

$NC_{ratio}$  : Nitrogen Carbon ratio of the biomass

#### ● Parameters

##### ➤ Emission ratio

The following values are applied to emission ratios for non-CO<sub>2</sub> gases due to biomass burning.

CH<sub>4</sub>: 0.012, N<sub>2</sub>O: 0.007 (Default value stated in the *GPG-LULUCF*, Table 3A.1.15)

##### ➤ NC ratio

The following values are applied to NC ratio.

NC ratio: 0.01 (default value stated in the *GPG-LULUCF* p.3.50)



● **Activity Data**

➤ **Forest land**

As activity data in forest land, carbon stock loss due to forest fire is used. Carbon stock loss due to forest fire is estimated by the Tier 3 method in the *2006 IPCC Guidelines*. For each of the national forest land and private forest land, carbon stock loss are calculated from the fire-damaged timber volume multiplied by wood density, the biomass expansion factor and the carbon fraction of dry matter.

$$L_{forest\ fires} = \Delta C_n + \Delta C_p$$

- $L_{forest\ fires}$  : carbon stock loss due to forest fire [t-C/yr]  
 $\Delta C_n$  : carbon stock loss due to fire in national forests [t-C/yr]  
 $\Delta C_p$  : carbon stock loss due to fire in private forests [t-C/yr]

Fire-damaged timber volume is separately estimated for national forests and private forests. With regard to national forests, the timber volume of standing trees damaged due to fires in national forests in the *Handbook of Forestry Statistics* is used. With regard to private forests, the damaged timber volume due to fires is estimated by using the actual damaged area and damaged timber volume by age class (inquiry survey by Forestry Agency). Damaged timber volume for age classes equal to or under 4 is calculated by multiplying the stand volume per unit area of age class equal to or under 4 estimated by the Forestry Status Survey and the NFRDB by loss ratio (ratio of damaged timber volume to stand volume) of damaged timber volumes whose age classes equal to or over 5 in private forests. The loss ratio is assumed to be constant regardless of age classes.

- **National forest, Private forest**

$$\Delta C_{n,p} = Vf_{n,p} \times D_{n,p} \times BET_{n,p} \times CF_{n,p}$$

The values for wood density and biomass expansion factors for national and private forest land are

- $\Delta C_{n,p}$  : Carbon loss due to fire in national forests and private forest [t-C/yr]  
 $Vf_{n,p}$  : Damaged timber volume due to fire in national forests and private forest [m<sup>3</sup>/yr]  
 $D_{n,p}$  : Wood density in national forests and private forest [t-d.m./m<sup>3</sup>]  
 $BET_{n,p}$  : Biomass expansion factor for national forests and private forest  
 $CF$  : Carbon fraction of dry matter [t-C/t-d.m.]

determined as weighted averages using the ratios of intensively managed forests and semi-natural forests.

Table 6-66 Wood density and biomass expansion factors for national and private forests

Type	Wood density [t-d.m./m <sup>3</sup> ]	Biomass expansion factor
National forest	0.49	1.61
Private forest	0.46	1.61

Reference: Based on Forestry Agency data

Table 6-67 Damaged timber volume due to wildfire

Category		Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Damaged timber volume due to disturbance in national forest		m <sup>3</sup>	3,688	1,014	1,599	359	16,091	934	360	279	5,326	2,472	916	75	112	49	275
Damaged timber volume due to disturbance in private forest		m <sup>3</sup>	63,602	68,361	60,228	72,575	15,810	41,537	12,269	26,620	147,989	38,571	8,151	157,051	16,309	34,245	17,235
Ⅳ-5	Actual damaged area	kha	0.29	0.94	0.48	0.35	0.07	0.59	0.10	0.18	0.53	0.22	0.04	0.35	0.09	0.15	0.07
	Damaged timber volume	m <sup>3</sup>	47,390	58,129	54,487	59,235	12,780	40,477	11,566	25,204	137,078	36,693	7,370	153,412	15,148	33,276	15,914
Ⅳ-4	Actual damaged area	kha	0.27	0.51	0.16	0.27	0.06	0.07	0.03	0.04	0.18	0.05	0.02	0.04	0.03	0.02	0.03
	Damaged timber volume	m <sup>3</sup>	16,212	10,232	5,741	13,340	3,030	1,060	703	1,416	10,911	1,878	781	3,639	1,161	969	1,321

Reference: Based on *Handbook of Forestry Statistics* for national forest, and Forestry Agency data for private forest

- **Note**

In Japan, emissions due to biomass burning are estimated separately for national forests and for private forests, because of different reporting procedures in regard to forest fire information. However, forest fires in Japan are covered by a set of data for both national forests and private forests, and the emissions are thus appropriately estimated.

2) **CH<sub>4</sub> and N<sub>2</sub>O emissions from burning of pruned branches from orchard trees**

● **Estimation Method**

For CH<sub>4</sub> and N<sub>2</sub>O emissions due to biomass burning of pruned branches from orchard trees, the estimation method (Equation 2.27, p2.42, Vol.4) described in the *2006 IPCC Guidelines* was applied. The estimation equation is as follows:

$$L_{fire} = W_B \times C_f \times G_{ef} \times 10^{-6}$$

$L_{fire}$	: Amount of greenhouse gas emission from fire [kt- GHG]
$W_B$	: Amount burnt [t-d.m.]
$C_f$	: Combustion factor
$G_{ef}$	: Emission factor [t/kt-d.m.]

● **Parameters**

For the combustion factor, a value of 0.9 which has been used generally in field burning of crop residues in agriculture in Japan is applied. For emission factor, the default emission factors of “Agricultural residue” provided in the *2006 IPCC Guidelines* are used.

Table 6-68 Emission factors [t/kt-d.m.]

Category	CH <sub>4</sub>	N <sub>2</sub> O
Agricultural residue	2.7	0.07

Reference: *2006 IPCC Guidelines*, Vol.4, chp.2, Table 2.5

● **Activity Data (Amount burned)**

The amount burned data was calculated by multiplying the same the cultivation area of the orchard trees as used in the calculation of carbon stock change in 4.B., by the MAFF by dry matter residue weight per unit area (400kg/10a) from the domestic field survey National Institute of Resources (1982), and ratio of burning of pruned branches in field (25%) from the survey result in 2008.

$$W_B = \sum_i (A_i \times E \times 10) \times R$$

$W_B$	: Amount of burning pruned branches from orchard trees [kg-d.m.]
$A$	: Cultivation area of orchard trees [ha]
$E$	: Dry matter residue weight per unit area [kg-d.m./10a]
$R$	: Combustion ratio of pruned branches from orchard trees
$i$	: Type of orchard tree

### 3) CH<sub>4</sub> and N<sub>2</sub>O from biomass burning in Grassland

#### ● Estimation method

For CH<sub>4</sub> and N<sub>2</sub>O emissions due to biomass burning from grassland, the estimation method (Equation 2.27, p2.42, Vol.4) described in the 2006 IPCC Guidelines was applied. The estimation equation is as follows:

$$L_{fire} = A \times M_B \times C_f \times G_{ef} \times 10^{-6}$$

$L_{fire}$	: Amount of greenhouse gas emission from fire [kt-GHG]
$A$	: Area burnt [ha]
$M_B$	: Mass of available fuel for combustion [t-d.m./ha]
$C_f$	: Combustion factor
$G_{ef}$	: Emission factor [t/kt-d.m.]

#### ● Parameters

For the combustion factor, value of 0.9 is applied according to expert judgment that considering survey data on burning of grassland in Japan. For emission factor, the default emission factors of “Savanna and grassland” provided in the 2006 IPCC Guidelines are used.

Table 6-69 Emission factors [t/kt-d.m.]

Category	CH <sub>4</sub>	N <sub>2</sub> O
Savanna and grassland	2.3	0.21

Reference: 2006 IPCC Guidelines, Vol.4, chp.2, Table 2.5

#### ● Activity data

The total mass of fuel available for combustion in grassland is calculated by multiplying area burnt of grassland, by the average amount of dry mass per unit area. There is no comprehensive statistical information or official data relating to burnt area of grassland. However, the area of controlled large-scale burning events on grassland which may affect national GHG emissions is limited in Japan. The area burnt for this estimation is estimated based on the five controlled large-scale burning events exceeding 1,000 ha: Aso, Higashi-Fuji exercise area, Kita-Fuji exercise area, Watarase flood control basin, and Akiyoshidai. The total planned burnt areas of these five events of 24,400ha are used as activity data uniformly over the whole year. For the amount burnt per area unit, value of 10 t-d.m./ha is applied according to expert judgment that considering survey data on burning of grassland in Japan.

### 4) CH<sub>4</sub> and N<sub>2</sub>O emissions from biomass burning in Wetlands

Controlled burning and wildfire occur only at riverside in Wetlands in Japan.

The emissions from biomass burning in Wetland were estimated with Tier 1 methodology (the 2006 IPCC Guidelines, Equation 2.27) with Default EF of All savanna and grassland on Table 2.5 in the 2006 IPCC Guidelines. ‘MB · Cf’ was applied 10.0 t-d.m./ha of All savanna grasslands (mid/late dry season burns) on table 2.4 in the 2006 IPCC Guidelines. (i.e. 1.2 t-CO<sub>2</sub> eq./ha)

From the fire and disaster statistics, 5,500 - 8,000 wildfire occurred on non-forest, agriculture and settlement area per year which included wildfire at riverside. Under the assumption that all these wildfires occurred at riverside, if area burned per a wildfire accounts for more than 11 ha, total emission from this category is classified as “significant” in LULUCF sector in Committee for GHG Emissions Estimation Methods in Japan.

Area of wildfire in forest land in Japan reaches some hundreds ha at the most. Over 10 ha wildfire is regarded as massive fire in Japan. In the view of these facts and uncertainty of parameters, emission in this category was judged as insignificant. Furthermore, the emissions from biomass burning along downstream of Arakawa River at which data on wildfire is available was about 300 t-CO<sub>2</sub> eq. This value applied to estimate the upper limit of applicability of “NE” for being considered insignificant.

**c) Uncertainties and Time-series Consistency**

● **Uncertainly Assessment**

The uncertainties for parameters and activity data related to forest fires were individually assessed on the basis of field studies, expert judgment, or default values described in the *2006 IPCC Guidelines*. Regarding the uncertainties for parameters and activity data related to biomass burning for pruned branches from orchard trees, the uncertainties (CH<sub>4</sub>: 296%, N<sub>2</sub>O: 300%) for crop residues burning in the Agriculture sector were substituted. For the uncertainty for biomass burning from grassland, the uncertainties for parameters and activity data were assessed on the basis of field studies, and default values described in the *2006 IPCC Guidelines* (CH<sub>4</sub>: 56%, N<sub>2</sub>O: 63%). As a result, the uncertainty estimates for the emissions resulting from biomass burning were 79% for CH<sub>4</sub> and 47% for N<sub>2</sub>O, respectively.

● **Time-series Consistency**

Time-series consistency for biomass burning in forest land remaining forest land is ensured by using the same data sources (*Handbook of Forestry Statistics* compiled by the Forestry Agency, and the data provided by the Agency) and the same methodology from 1990 to 2013. Time-series consistency for biomass burning for pruned branches from orchard trees and for grassland is ensured by using the same data sources (*Statistics of Cultivated and Planted Area* by the MAFF.)

**d) Category-specific QA/QC and Verification**

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

**e) Category-specific Recalculations**

Since the estimation methods of cultivation area of orchard trees from 2017 were revised, CH<sub>4</sub> and N<sub>2</sub>O emissions from burning of pruned branches from orchard trees after FY2017 were recalculated.

See Chapter 10 for impact on trend.

**f) Category-specific Planned Improvements**

No improvements are planned.

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## Chapter 7. Waste (CRF sector 5)

### 7.1. Overview of Sector

#### 7.1.1. Overview of Waste Management and Estimation Category

In the waste sector, greenhouse gas (GHG) emissions from treatment and disposal of waste are estimated for solid waste disposal (5.A.), biological treatment of solid waste (5.B.), incineration and open burning of waste (5.C.), wastewater treatment and discharge (5.D.), and other (5.E.)<sup>1</sup> in accordance with treatment processes. Figure 7-1 and Figure 7-2 show the estimation categories of waste/wastewater treatment system and/or waste classification in Japan.

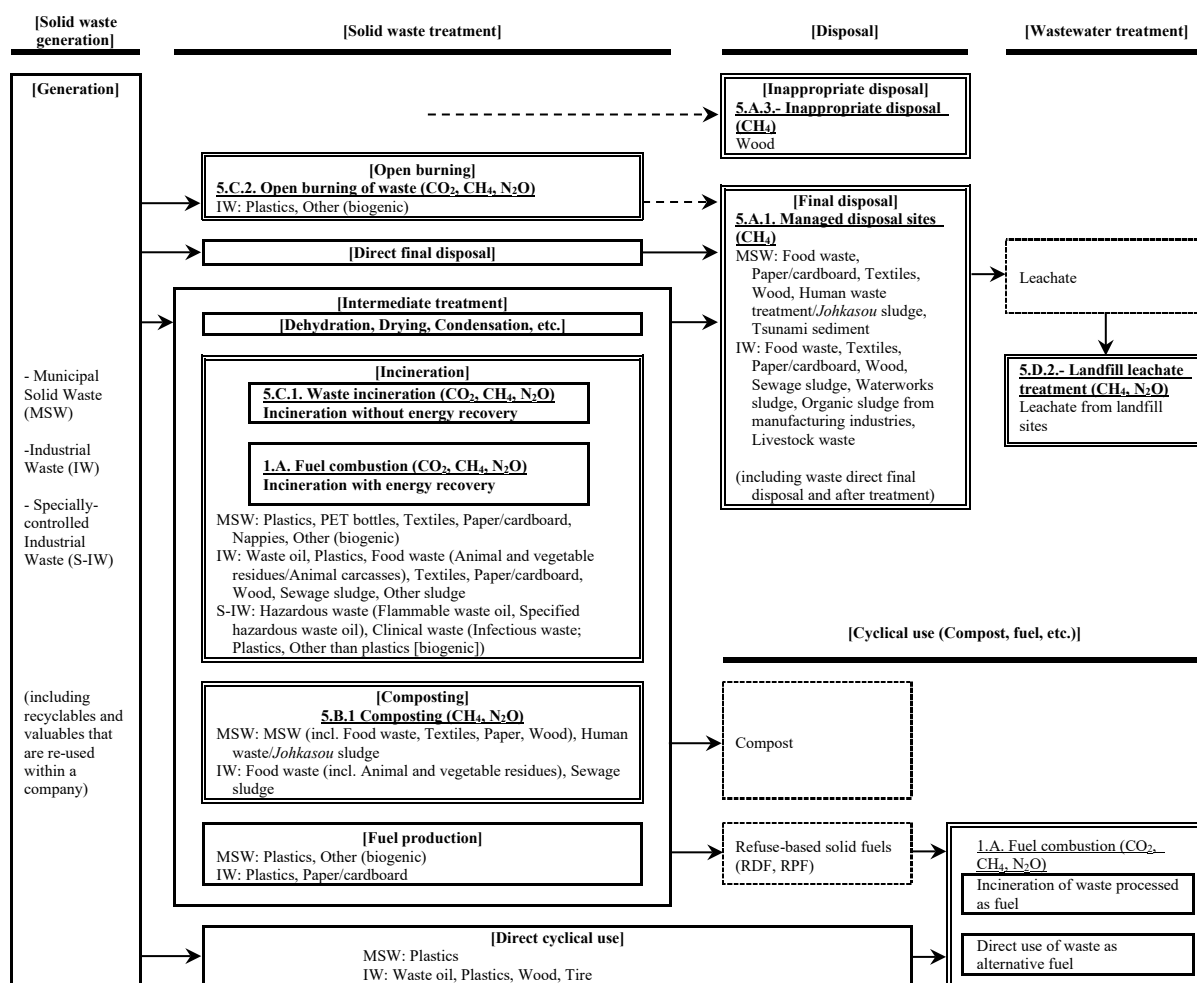


Figure 7-1 Flow chart of solid waste managements and the estimation categories

<sup>1</sup> Data for some emission source categories in the waste sector are complemented by estimation, when statistical data or related data are not available. The methodologies for this estimation are not described in this chapter. For details, refer to the website of MOE, *Committee for the Greenhouse Gases Emissions Estimation Methods* (<http://www.env.go.jp/earth/ondanka/ghg-mrv/committee/>).

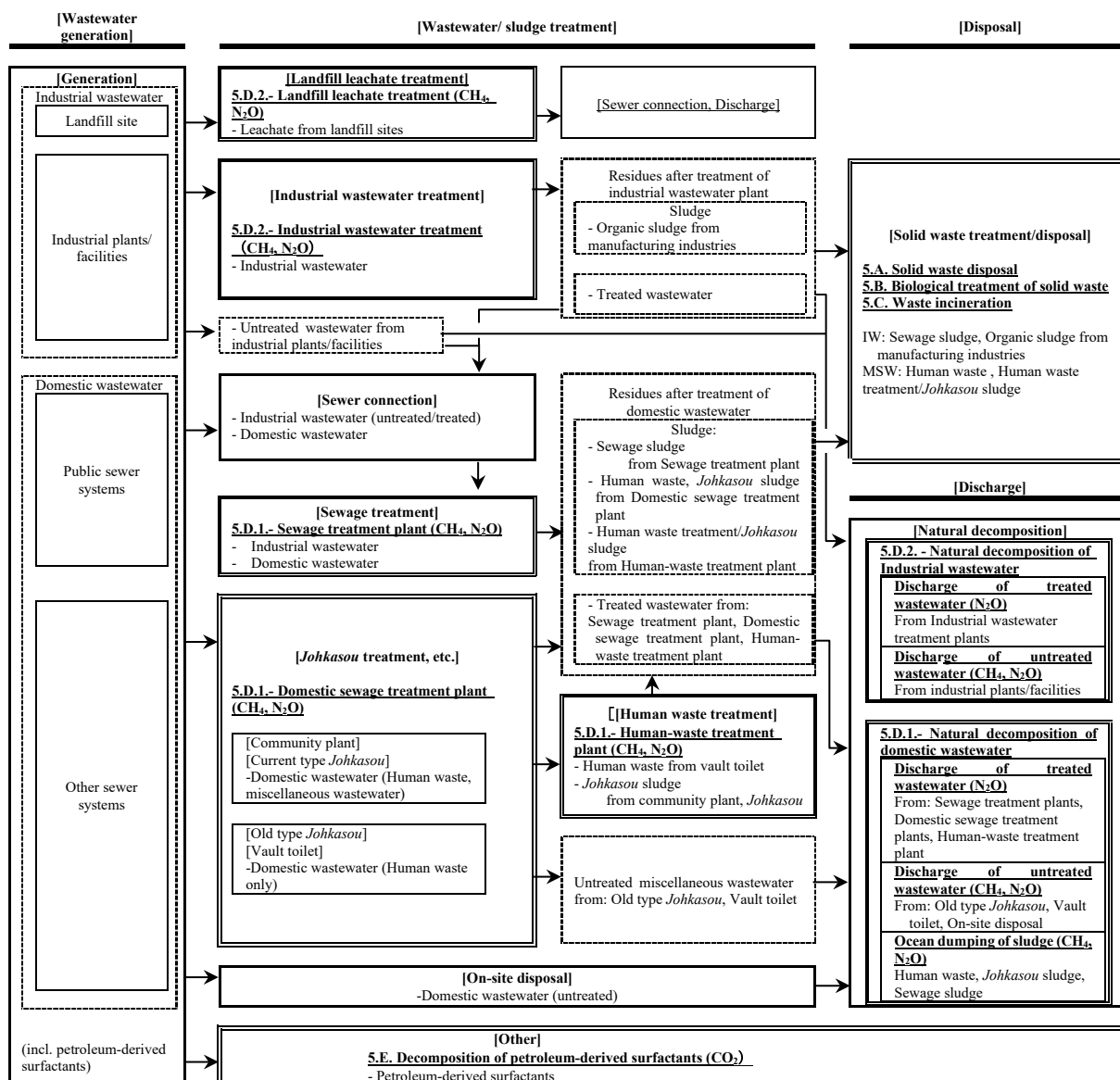


Figure 7-2 Flow chart of wastewater/sludge treatments and the GHG estimation categories

“Waste” to be covered in this sector is the waste as defined in the 2006 IPCC Guidelines. In the case of Japan, the waste does not only include municipal waste and industrial waste as defined by the Waste Management and Public Cleansing Act, but also include recyclables and valuables that are re-used within a company, and are reported in category “7.3.1. Composting (5.B.1)”, “7.4.3.2. Direct Use of Waste as Alternative Fuel (1.A.)”, and “7.4.3.3. Incineration of Waste Processed as Fuel (1.A.)”. Since the waste statistics are compiled separately for municipal waste and industrial waste in Japan, estimation methodologies for many of emission sources in the waste sector are discussed respectively for municipal waste and industrial waste. Emissions from the treatment of disaster waste caused by the Great East Japan Earthquake, which occurred on 11<sup>th</sup> March, 2011, are reported in this sector.

### 7.1.2. Overview of Greenhouse Gas Emissions on Waste Sector

In FY2020, emissions from the Waste sector resulted in 20,186 kt-CO<sub>2</sub> eq. and accounted for 1.8% of Japan’s total GHG emissions (excluding LULUCF). Total emissions had decreased by 31.7% compared

to those of FY1990 and decreased by 0.4% compared to those of FY2019. Breakdown of FY2020 emissions of the Waste sector by category shows that the largest contributor to the emissions is Incineration and Open Burning of Waste (5.C.) (excluding emissions from waste incineration and energy use reported on the energy sector) accounting for 64.0% (a decrease by 6.3% from FY1990) followed by the Wastewater Treatment and Discharge (5.D.) accounting for 18.2% (a decrease by 31.2% compared to FY1990), Solid Waste Disposal (5.A.) accounting for 13.1% (a decrease by 72.1% from FY1990), Other (5.E.) accounting for 3.0% (a decrease by 14.5% from FY1990), and Biological Treatment of Solid Waste (5.B.) accounting for 1.8% (an increase by 50.7% from FY1990). Breakdown of the emissions of the Waste sector by gas shows that the largest contributor to the emissions is CO<sub>2</sub> emissions associated with the incineration/open burning of petroleum-derived waste such as waste plastic and waste oil accounting for 57%, followed by CH<sub>4</sub> emissions from solid waste disposal on land accounting for 13%, N<sub>2</sub>O emissions from wastewater treatment and discharge accounting for 10%.

The changes in GHG emissions from the Waste sector since FY1990 show a trend in a decrease in CH<sub>4</sub> emissions from the solid waste disposal on land associated with a decrease in the amount of disposal of biodegradable waste due to the improvement in recycling rate since the enactment of the Basic Law for Establishing the Recycling-based Society and other recycling laws. Note that while the recycling rate of waste in Japan has increased in FY2018 (15.4%) in comparison with FY1990 (7.4%), the total disposal amount has reduced in FY2018 (13 Mt/year) in comparison with FY1990 (109 Mt/year) (Ministry of the Environment: MOE, 2021b). On the other hand, emissions from the incineration of petroleum-derived waste with energy recovery, emissions from the direct use of petroleum-derived waste as alternative fuel, and emissions from the incineration of petroleum-derived waste processed as fuel, which are accounted for in the Energy sector, have increased along with an increase of waste recycling rate (an increase by 74.9% from FY1990).

### 7.1.3. General Description for Methodological Issues on the Waste Sector

#### ➤ *Estimation Method and Emission Factors*

Japan generally employs country specific methodologies and emission factors in GHG emission estimations on the waste sector. For the category on which sufficient views are not obtained from domestic survey, default methodologies and emission factors in the *2006 IPCC Guidelines* are partially applied. For details, see articles “*b) Methodological Issues*” in each category’s section.

Table 7-1 Summary for methods and emission factors used on waste sector

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO <sub>2</sub>		CH <sub>4</sub>		N <sub>2</sub> O	
	Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor
<b>5. Waste</b>	CS	CS	CS, D, T2, T3	CS, D	CS, D, T2	CS, D
A. Solid waste disposal	NA	NA	T3	CS		
B. Biological treatment of solid waste			T2	CS	T2	CS
C. Incineration and open burning of waste	CS	CS	CS, T2	CS, D	CS, T2	CS, D
D. Wastewater treatment and discharge			CS, D	CS, D	CS, D	CS, D
E. Other	CS	CS	NA	NA	NA	NA

Note:

D: IPCC default, T1: IPCC Tier1, T2: IPCC Tier2, T3: IPCC Tier3, CS: country specific method or EF

#### ➤ *Activity Data*

As activity data in the methodologies on the waste sector, the *Report of the Research on the State of Wide-range Movement and Cyclical Use of Wastes – Volume on Cyclical Use* (Environmental

Regeneration and Material Cycles Bureau of MOE) (hereinafter referred to as the *Cyclical Use of Waste Report*), the *Waste Treatment in Japan* (the same agency of MOE), and the *annual editions of Sewage Statistics – Admin. Ed.* (Japan Sewage Works Association: JSWA) (hereinafter referred to as the *Sewage Statistics*) are mainly referred. Also, various other statistics related on the waste management and provided data from relevant agencies and bodies are used. For details, see articles “*b) Methodological Issues*” in each category’s section.

Note that treatment and disposal amount of disaster wastes since FY2011, when the Great East Japan Earthquake occurred, are surveyed by Environmental Regeneration and Material Cycles Bureau of MOE, and are considered in the activity data to estimate GHG emissions from these sources.

#### 7.1.4. General Assessment Procedure for the Uncertainty on the Waste Sector

The uncertainty of GHG emissions on the waste sector is assessed based on the *2006 IPCC Guidelines* and MOE (2013a). The general assessment procedures are indicated below. For details, see articles “*c) Uncertainties and Time-series Consistency*” in each category’s section.

- **Emission factors**

The uncertainties in emission factors are assessed by using the 95% confidence interval obtained from actual measurement, or by expert judgment. When emission factor is derived from formulas depending on several parameters, the uncertainty is assessed by combining the uncertainties of these parameters using error propagation equation.

- **Activity data**

Regarding the uncertainty for activity data, due to the lack of information on statistical error in quoted references, it is difficult to assess uncertainties based on concrete evidence. Therefore, it is assessed by expert judgment as indicated in the Table 7-2.

Table 7-2 Uncertainty for statistics used for activity data on waste sector

Statistics used for activity data	Range of uncertainty		Justification for assessing the uncertainty
	( - )	( + )	
Municipal waste (Domestic wastewater excl. sewage)	-10%	+10%	In the uncertainty which is provided as default value in the <i>2006 IPCC Guidelines</i> , the value ( $\pm 10\%$ ) in the case where waste weight is measured by truck scale is adopted based on expert judgment.
Industrial waste (Industrial wastewater)	-30%	+30%	In the uncertainty which is provided as default value in the <i>2006 IPCC Guidelines</i> , the value ( $\pm 30\%$ ) “in the case where amount of generated waste is regularly collected” is adopted based on expert judgment.
Specially-controlled industrial waste	-60%	+60%	The twofold higher uncertainty than the value in industrial waste statistics is adopted based on expert judgment.
Valuables (valuable waste)	-30%	+30%	In the uncertainty which is provided as default value in the <i>2006 IPCC Guidelines</i> , the value ( $\pm 30\%$ ) “in the case where amount of generated waste is regularly collected” is adopted based on expert judgment.
Sewage	-5%	+5%	Since the data has collected through complete survey for whole sewage treatment plants in Japan, it is considered that data is accurate enough to reflect the current status. Therefore, the uncertainty is evaluated at 5% based on expert judgment.
Water works	-5%	+10%	Sampling error in the statistics is evaluated at 5% based on expert judgment as well as sewage statistics. However, water works statistics target only water company and supplier of city water which have more than 5001 official water supplied population; sludge generated from small-sized filter plants by private water-supply system is not identified. Therefore, a 5% is added to the upper limit of uncertainty since the population of private water-supply system account for 5% of the total.

- **Emissions**

Since emissions are calculated by formulas, the uncertainty is assessed by combining the uncertainties of emission factors and activity data using error propagation equation.

### 7.1.5. General Recalculations for Emissions from Waste Sector

Most of statistics in Japan are compiled on the basis of Japan's fiscal year (starting on April 1 of the year and ending on March 31 of the following year). Therefore, some process of compiling statistics for the latest fiscal year, which is referred in waste sector inventory, does not complete in time for an inventory compilation.

In such a case, the activity data of previous fiscal year are generally adopted for the latest fiscal year in accordance with the *2006 IPCC Guidelines*, but adoptions of more appropriate estimations are desirable for data of latest fiscal year for the main categories. To obtain such better activity data related to solid waste to be quoted from the *Cyclical Use of Waste Report* (MOE) as main statistics, "the Committee for improvement of the research on cyclical use of waste" organized by Environmental Regeneration and Material Cycles Bureau of MOE, annually prepares preliminary data for the latest year estimated by using economic indexes such as volume/value of shipment of products to be finally disposed of (*Review Report on Improvement of Accuracy and Faster Compilation of Waste Statistics*, MOE). Thus, GHG emissions for the latest fiscal year on the waste sector are estimated by using this preliminary activity data. Consequently, every year, these preliminary data are updated with definite data, and emissions are recalculated in the inventory of its next annual submission.

## 7.2. Solid Waste Disposal (5.A.)

This category covers CH<sub>4</sub> emissions from solid waste disposal on land. For this emission source category, estimation methodologies are discussed separately for municipal waste and industrial waste in accordance with Japan's waste classification system, and emissions are estimated for the sources presented in Table 7-3.

Table 7-3 Categories whose emissions are estimated for solid waste disposal (5.A.)

Category	Waste type		Disposal type	CO <sub>2</sub>	CH <sub>4</sub>				
5.A.1. (7.2.1)	Municipal solid waste	Food waste	Managed disposal sites	Anaerobic/ Semi-aerobic landfill	NO	○			
		Paper/cardboard				○			
		Wood				○			
		Textiles				Natural fiber <sup>1)</sup>	○		
		Sludge				Human waste treatment/ <i>Johkasou</i> sludge	○		
	Tsunami sediment <sup>2)</sup>					○			
	Industrial waste	Food waste <sup>3)</sup>				Animal and vegetable residues, Animal carcasses	Anaerobic/ Semi-aerobic landfill	NO	○
		Paper/cardboard							○
		Wood							○
		Textiles				Natural fiber <sup>1)</sup>			○
		Sludge	Sewage sludge	Digested sewage sludge <sup>4)</sup>	○				
				Other sewage sludge	○				
			Waterworks sludge	○					
			Organic sludge from manufacturing industries	○					
Livestock waste <sup>5)</sup>			○						
5.A.2. (7.2.2)	-		Unmanaged disposal sites	NO	NO				
5.A.3. (7.2.3)	Industrial waste	Wood	Inappropriate disposal <sup>6)</sup> (Anaerobic landfill)	NE	○				

Note:

- 1) Only natural fiber textiles are included in the estimation under the assumption that synthetic fiber waste is not biologically decomposed in landfills.
- 2) Part of tsunami sediment generated by the Great East Japan Earthquake, which occurred on 11<sup>th</sup> March, 2011, is disposed of finally. Since disposed tsunami sediment includes organic matters, CH<sub>4</sub> emissions from this source are estimated using the emission factor for wood by expert judgment.
- 3) Japan's industrial waste classifications of "Animal and vegetable residues" and "Animal carcasses" are aggregated as food waste.
- 4) "Digested sewage sludge" includes sewage sludge landfilled after digested and dehydrated. Because digestion treatment reduces the amount of carbon content biodegraded in sludge decreases, CH<sub>4</sub> emissions are estimated separately by landfilled sewage sludge with and without digestion treatment.
- 5) Although livestock waste is not classified as "sludge" under Japanese law, the emissions from the waste are estimated within the category of sludge since both properties are similar.
- 6) The emissions from wood are currently considered as inappropriate disposal of waste containing biodegradable carbon.
- 7) Since the disposal type for tsunami sediment have not been identified, it is conservatively assumed as anaerobic landfill (MCF=1.0) which derives larger emissions.

Table 7-4 GHG emissions from solid waste disposal (5.A.)

Gas	Category	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020		
CO <sub>2</sub>	5.A.1. Managed waste disposal sites	a. Anaerobic landfill	kt-CO <sub>2</sub>	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO		
		b. Semi-aerobic landfill	kt-CO <sub>2</sub>	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	
	5.A.2. Unmanaged waste disposal sites	kt-CO <sub>2</sub>	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO		
	5.A.3. Uncategorized waste disposal sites	Inappropriate disposal	kt-CO <sub>2</sub>	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	
	Total	kt-CO <sub>2</sub>	NO,NE	NO,NE	NO,NE	NO,NE	NO,NE	NO,NE	NO,NE	NO,NE	NO,NE	NO,NE	NO,NE	NO,NE	NO,NE	NO,NE	NO,NE		
CH <sub>4</sub>	5.A.1. Managed waste disposal sites	a. Anaerobic landfill	MSW	kt-CH <sub>4</sub>	217.8	187.0	145.1	110.1	79.8	74.8	70.1	65.8	62.0	58.0	54.3	51.2	48.1	45.3	42.5
			IW	kt-CH <sub>4</sub>	139.4	134.1	111.3	82.8	58.8	55.6	52.7	49.8	47.0	44.7	42.7	40.8	39.1	37.5	36.1
		b. Semi-aerobic landfill	MSW	kt-CH <sub>4</sub>	18.7	28.0	31.8	34.6	28.8	27.3	26.3	25.6	24.0	23.1	21.4	20.5	19.4	18.1	16.9
			IW	kt-CH <sub>4</sub>	4.1	7.6	11.3	13.2	11.0	10.8	10.8	10.3	9.9	9.5	9.3	9.0	9.0	9.0	
	5.A.2. Unmanaged waste disposal sites	kt-CH <sub>4</sub>	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO		
	5.A.3. Uncategorized waste disposal sites	Inappropriate disposal	kt-CH <sub>4</sub>	0.3	0.8	2.5	2.4	2.2	2.2	2.2	2.1	1.9	1.8	1.9	1.8	1.7	1.7	1.5	
		Total	kt-CH <sub>4</sub>	380.4	357.5	301.9	243.2	180.6	170.7	162.2	154.0	145.2	137.6	129.7	123.6	117.4	111.7	106.2	
		kt-CO <sub>2</sub> eq.	9,510	8,938	7,548	6,080	4,515	4,267	4,054	3,851	3,631	3,441	3,244	3,090	2,934	2,792	2,654		
	Total	kt-CO <sub>2</sub> eq.	9,510	8,938	7,548	6,080	4,515	4,267	4,054	3,851	3,631	3,441	3,244	3,090	2,934	2,792	2,654		

Estimated GHG emissions from solid waste disposal on land are shown in Table 7-4. In FY2020, GHG emissions from this source category are 2,654 kt-CO<sub>2</sub> eq. and accounted for 0.2% of the national total emissions (excluding LULUCF). Emissions from this category decreased by 72.1% compared to the emissions in FY1990. This CH<sub>4</sub> emissions decrease is the result of decrease in the amount of biodegradable waste landfilled due to the increase in the practice of waste incineration to reduce waste volume in Japan.

For the category “managed disposal sites”, while trend in the disposal amount of biodegradable waste has steadily decreased since FY1990, trend in the estimations of CH<sub>4</sub> generated from degradation of waste has relatively slowly decrease due to the time lags derived from long half-lives of waste in the FOD method (e.g. 7 years for half-life of paper/cardboard). Hence trend in the implied emission factors (IEFs) has increased since FY1990. For the category “uncategorized waste disposal sites (inappropriate disposal)”, while trend in the disposal amount irregularly fluctuate year by year since the estimations should consider only disposal amount for revealed matters, trend in CH<sub>4</sub> emissions estimated by FOD method is relatively stable. Hence trend in the IEFs also tend to irregularly fluctuate year by year.

### 7.2.1. Managed Disposal Sites (5.A.1.)

#### a) Category Description

In Japan, part of food waste, paper/cardboard, textiles, wood, and sludge in municipal solid waste (MSW) and industrial waste (IW) is landfilled without incineration; therefore, CH<sub>4</sub> is generated as a result of biodegradation of organic materials from the landfill sites. Because Japanese landfill sites are appropriately managed pursuant to the Waste Management and Public Cleansing Act, the amount of CH<sub>4</sub> emitted from there is reported under this category “Managed Disposal Sites (5.A.1.)”. Emissions of CO<sub>2</sub> from waste incineration at the managed disposal sites are reported as NO, because waste incineration is not implemented at that site in Japan.

#### b) Methodological Issues

##### ● Estimation Method

The revised first order decay (FOD) method given in the *2006 IPCC Guidelines* is applied for its emission estimates since this method assumes the delay time from the deposition of waste to the generation of CH<sub>4</sub>. According to the decision tree indicated in the said guidelines, the revised FOD method with country-specific parameters (Tier 3) is used to estimate emissions from this source. In this method, for consistency with Japan’s domestic estimation method under the *Mandatory GHG Accounting and Reporting System*, emission factors are specifically defined as “CH<sub>4</sub> emissions from biodegradable waste”, and activity data are defined as “the amount of waste biodegraded within the reporting fiscal year”. Note that there are no substantial differences between Japan’s method and that in the *2006 IPCC Guidelines*.

$$E = \left\{ \sum_{i,j} (EF_{i,j} \times A_{i,j}) - R \right\} \times (1 - OX)$$

Where :

$E$  : CH<sub>4</sub> emissions from landfill sites [kg-CH<sub>4</sub>]  
 $EF_{i,j}$  : Emission factor for a biodegradable waste  $i$  (dry basis) that is damped into a landfill site  $j$  without incineration [kg-CH<sub>4</sub>/t]

- $A_{i,j}$  : Amount of a biodegradable waste  $i$  (dry basis) that is damped into a landfill site  $j$  without incineration and is biodegraded within an inventory year) [t]  
 $R$  : Recovered CH<sub>4</sub> in an inventory year [kg-CH<sub>4</sub>]  
 $OX$  : Oxidation factor of CH<sub>4</sub> related to soil cover

### ● Emission Factors

Emission factors are defined as the amount of CH<sub>4</sub> [kg] generated through decomposition of one ton of biodegradable landfill wastes (dry basis) without incineration. They are established by the type of biodegradable waste (i.e., food waste, paper/cardboard, natural fibers, wood, sewage sludge, human waste, waterworks sludge, organic sludge from manufacturing industries and livestock waste) and by the type of landfill site (i.e., anaerobic or semi-aerobic landfill). Emission factors are estimated as indicated below.

$$EF = DOC_i \times DOCF \times MCF_j \times F \times 1000 \times \frac{16}{12}$$

- $DOC_i$  : Fraction of carbon content in a biodegradable waste  $i$   
 $DOCF$  : Fraction of degradable organic carbon dissimilated  
 $MCF_j$  : Methane correction factor in a landfill site  $j$   
 $F$  : Percentages of CH<sub>4</sub> in landfill gas

### ➤ Carbon Content (DOC: Per Dry Weight)

Carbon content per dry weight, which is used as uniform value every year because the property of each waste type does not vary significantly over time, is determined based on MOE (2006b) and MOE (2010) as indicated in Table 7-5 below.

Table 7-5 Carbon content of waste disposed of in managed landfill sites (dry basis)

	Item	Carbon Content	Reference
Municipal solid waste	Food waste	43.4 %	Calculated by taking the averages of carbon contents of MSW provided by Tokyo, Yokohama, Kawasaki, Kobe, and Fukuoka (FY1990-2004) (MOE, 2006b)
	Wood	45.2 %	
	Paper/cardboard	40.8 %	
	Textiles (natural fiber)	45.0 %	Calculated by taking a weighted average of carbon content estimated based on the constituent of each natural fiber type (cotton, wool, silk, linen, and recycled textiles) by the domestic demand of natural fibers (FY1990-2004) (MOE, 2006b)
	Human waste treatment /Johkasou sludge	40.0 %	Substituted the value for “Other sewage sludge”
	Tsunami sediment	4.5 %	Calculated by multiplying the fraction of organic matter in tsunami sediment by the fraction of carbon contents in the organic matter; assuming the fraction of organic matter in tsunami sediment finally disposed of is 10%, and 45.2% of fraction of carbon content for wood is substituted for tsunami sediment by expert judgment
Industrial waste	Food waste	43.4 %	Substituted the carbon content of MSW for that of IW because its properties are similar to those of MSW.
	Wood	45.2 %	
	Paper/cardboard	40.8 %	
	Digested sewage sludge	30.0 %	Expert judgment based on Fujimoto (2000), Fujishima et al. (2004), Oshima et al. (1986) and Tanaka et al. (1980)
	Other sewage sludge	40.0 %	Expert judgment based on domestic researches (MOE, 2006b)
	Waterworks sludge	6.0 %	Average values of survey results conducted at 23 water purification plants (MOE, 2010)
	Organic sludge from manufacturing industries	45.0 %	Value for paper industry is substituted because it generates the largest amount of organic sludge finally disposed of. Estimated based on the carbon content of cellulose because the main constituent of organic sludge generated is paper sludge (MOE, 2006b)
Livestock waste	40.0 %	Substituted the value for “Other sewage sludge”	



➤ **Fraction of degradable organic carbon dissimilated (DOCF)**

Fraction of degradable organic carbon dissimilated for the biodegradable waste is set at 50% based on Ito (1992).

➤ **Methane Correction Factor (MCF)**

- **Anaerobic landfill sites**

For Methane Correction Factor of anaerobic landfill sites ( $MCF_{an}$ ), default values of 1.0 given in the 2006 IPCC Guidelines is used.

- **Semi-aerobic landfill sites**

For Methane Correction Factor of semi-aerobic landfill sites in ideal condition ( $MCF_{semi}$ ) default values of 0.5 given in the 2006 IPCC Guidelines is used. However, semi-aerobic landfill site in Japan is in an anaerobic condition when the outflow port of leachate collection system is swamped, the system is full of water, it holds retaining of leachate, or leachate collection/gas extraction system is not properly extend. Considering these inappropriate management conditions of the leachate collection system at landfill sites, a country-specific parameter is defined as “percentage of open outflow port of leachate collection system” and used for the estimation; the methane correction factor of semi-aerobic landfill site in actual condition ( $MCF_{semi,act}$ ) is estimated for municipal solid waste disposal sites and industrial waste disposal sites, respectively, as follows:

$$MCF_{semi,act} = \{P \times MCF_{semi} + (1 - P) \times MCF_{an}\}$$

$MCF_{semi,act}$  : Methane correction factor of semi-aerobic landfill sites in actual condition

$MCF_{semi}$  : Methane correction factor of semi-aerobic landfill sites in ideal condition (0.5)

$MCF_{an}$  : Methane correction factor of anaerobic landfill sites (1.0)

$P$  : Percentage of open outflow port of leachate collection system in a reporting year

Where,

$$P = W' / W$$

$W'$  : Disposal amount in a reporting year at semi-aerobic landfill sites in ideal condition, where open outflow port of leachate collection system [for municipal solid waste: t, for industrial waste: m<sup>3</sup>]

$W$  : Disposal amount in a reporting year at whole semi-aerobic landfill sites [for municipal solid waste: t, for industrial waste: m<sup>3</sup>]

To evaluate  $W'$  and  $W$  for municipal solid waste, the condition of open outflow port and disposal amount in each semi-aerobic landfill sites provided in the *state of municipal waste treatment survey* are used. For industrial waste, those data in each semi-aerobic landfill sites indicated in a result of questionnaire survey by Environmental Regeneration and Material Cycles Bureau of MOE, are used.

Table 7-6 Percentage of open outflow port of leachate collection system at semi-aerobic landfill sites for municipal solid waste and industrial waste

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Municipal solid	%	64.7	64.7	64.7	64.7	69.1	71.2	71.2	69.7	71.9	70.3	73.2	71.2	70.5	71.8	71.8
Industrial waste	%	84.3	84.3	84.3	84.3	88.2	85.6	85.6	85.6	85.6	85.6	85.6	85.6	85.6	85.6	85.6

➤ **Proportions of CH<sub>4</sub> in Generated Gas (F)**

Default value (50%) given in the 2006 IPCC Guidelines is used.

➤ **Emission Factor (EF)**

Emission factors calculated by methodologies above are shown in Table 7-7.

Table 7-7 Emission factors by type of biodegradable waste and by treatment

Item		Anaerobic landfill [kg-CH <sub>4</sub> /t]	Semi-aerobic landfill [kg-CH <sub>4</sub> /t]
Municipal solid waste	Food waste	145	72
	Paper/cardboard	136	68
	Textiles (natural fiber)	150	75
	Wood	151	75
	Human waste treatment/ <i>Johkasou</i> sludge	133	67
	Tsunami sediment	15	NA
Industrial waste	Food waste	145	72
	Paper/cardboard	136	68
	Textiles (natural fiber)	150	75
	Wood	151	75
	Digested sewage sludge	100	50
	Other sewage sludge	133	67
	Waterworks sludge	20	10
	Organic sludge from manufacturing	150	75
Livestock waste	133	67	

Note: Emission factors for semi-aerobic landfill on above table indicate the values in the ideal condition of semi-aerobic landfill. (MCF=0.5).

### ● Activity Data

Out of the amount of waste landfilled without incineration (dry basis), the amount of waste degraded within the reporting year is calculated by multiplying the amount of waste remaining in landfills at the end of the previous reporting year by the methane generation rate constant for waste landfilled. The amount of biodegradable MSW and IW are determined by type of waste and landfill site.

The amount of waste landfilled in each fiscal year is calculated by multiplying the amount of biodegradable waste landfilled (wet basis) by the percentage of landfill site by the type of site (wet basis), and subtracting the water content by each type of waste. Activity data are estimated going back as far as FY1954, when the Public Cleansing Law (now the Waste Management and Public Cleansing Act) was enforced.

$$A_{i,j}(T) = W_{i,j}(T-1) \times (1 - e^{-k_i})$$

$$W_{i,j}(T) = W_{i,j}(T-1) \times e^{-k_i} + w_{i,j}(T)$$

$A_{i,j}(T)$  : Amount of waste  $i$  degraded in site  $j$  in the calculated year (year  $T$ ) (activity data: dry basis) [t (dry)]

$W_{i,j}(T)$  : Amount of waste  $i$  remaining in site  $j$  in year  $T$  (dry basis) [t (dry)]

$w_{i,j}(T)$  : Amount of waste  $i$  landfilled into site  $j$  in year  $T$  (dry basis) [t (dry)]

$k_i$  : Methane generation rate constant of waste  $i$  [1/year]

Where,

$$w_{i,j}(T) = w_{i,wet}(T) \times S_j \times (1 - u_i)$$

$$k_i = \ln(2)/H_i$$

$w_{i,wet}(T)$  : Amount of waste  $i$  landfilled in year  $T$  (wet basis) [t (wet)]

$S_j$  : Percentage of landfill site structure type  $j$  [%]

$u_i$  : Percentage of water content in waste  $i$  [%]

$H_i$  : Decomposition half-life of waste  $i$  (the time taken by landfilled waste  $i$  to reduce in amount by half) [year]

### ➤ Amount of Biodegradable Waste Disposed of in Landfills

Table 7-8 shows the annual amount of biodegradable waste landfilled (dry basis) in Japan.

Table 7-8 Annual amount of biodegradable waste disposed of in landfills  
(Total amount of anaerobic and semi-aerobic landfilling)

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
MSW																
Food waste	kt (dry)	424	272	196	78	30	27	22	21	18	16	13	13	13	10	9
Paper/ cardboard	kt (dry)	1,140	859	698	492	311	294	260	226	182	142	125	97	102	63	56
Textiles (natural fiber)	kt (dry)	59	46	34	67	3	5	4	3	3	3	2	1	1	1	1
Wood	kt (dry)	363	200	155	81	40	36	31	65	27	22	21	18	19	13	10
Human waste treatment/ <i>Johkasou</i> sludge	kt (dry)	78	51	46	47	20	14	15	10	8	7	8	9	12	12	11
Tsunami sediment <sup>1)</sup>	kt (dry)	NO	NO	NO	NO	NO	9	10	29	NO	NO	NO	NO	NO	NO	NO
IW																
Food waste	kt (dry)	65	177	109	45	22	23	30	11	15	12	13	14	14	18	18
Paper/ cardboard	kt (dry)	102	125	137	89	31	37	32	16	17	12	15	11	29	24	25
Textiles (natural fiber)	kt (dry)	4	16	15	17	7	10	7	6	10	11	11	9	7	10	11
Wood	kt (dry)	465	490	235	230	145	149	106	111	116	124	110	129	129	126	130
Digested sewage sludge	kt (dry)	59	50	31	11	3	5	5	4	5	3	3	3	4	3	3
Other sewage sludge	kt (dry)	219	185	114	42	17	34	22	11	12	12	12	10	10	7	7
Waterworks sludge	kt (dry)	199	166	146	66	67	67	67	67	67	67	67	67	67	67	67
Organic sludge from manufacturing industry	kt (dry)	328	154	69	48	31	39	27	17	14	13	11	12	12	12	12
Livestock waste	kt (dry)	12	12	11	11	11	11	9	12	13	13	13	12	13	13	13

Note:

1) Disposal amount of tsunami sediment has increased in FY2013 compared to FY2012, since disaster waste by the 2011 earthquake has massively treated in FY2013 due to the activation of disaster restoration service. The final disposal of this tsunami sediment has finished in FY2013; therefore, the amount is accounted as 0 kt/year from FY2014 onward.

As indicated in Table 7-9, for the references for the amount of biodegradable waste landfilled by waste type, the *Cyclical Use of Waste Report* (MOE), and the *Sewage Statistics* (JSWA) are used.

The amount of biodegradable waste landfilled is estimated going back as far as FY1954, when the Public Cleansing Law (now the Waste Management and Public Cleansing Act) was enforced. The statistical survey of landfilling began in 1980s, and in the case that historical data on the amount of biodegradable waste landfilled are unavailable (primarily prior to FY1980), the data of the most current year available (primarily the data of FY1980) are applied. For the years where the data are unavailable even after FY1980, interpolated values are applied. For details, see Table 7-9.

Table 7-9 Overview of data for the amount of biodegradable waste disposed of in landfill

Waste type		Reference	Detail	Historical data	
Municipal solid waste	Food waste	<i>Cyclical Use of Waste Report</i> (MOE)	- Amount directly landfilled - Amount landfilled after intermediate treatment.  * Fraction of natural fiber content in total waste textiles is calculated by using the fraction of natural fiber products in total textile products, which is determined by taking the ratio of the annual domestic demand for synthetic textiles to that of all textiles indicated in the <i>Textile Handbook</i> (Japan Chemical Fibers Association) and the <i>Yearbook of Textiles and Consumer Goods Statistics</i> (METI).	- Estimated by interpolation for some fiscal years, - Substituted FY1980 value for the years prior to FY1980	
	Paper/cardboard				
	Wood				
	Textiles (natural fiber) *				
	Human waste treatment/ <i>Johkason</i> sludge	(Direct final disposal)	<i>Waste Management in Japan</i> (MOE)	Calculated by multiplying the amount of human waste sludge in “other treatment” (volume basis) by the weight-conversion factor (1.0 kg/L)	Substituted FY1978 value for the years prior to FY1978
		(Final disposal after treatment)	<i>Cyclical Use of Waste Report</i> (MOE)	Amount landfilled after intermediate treatment, excluding ash after incineration	For the years prior to FY1998, estimated by using the amount of direct final disposal human waste sludge
Tsunami sediment		<i>Waste Treatment in Japan</i> (MOE)	Direct final disposal of “Tsunami sediment”	Disposed from FY2011	
Industrial waste	Food waste (Animal and vegetable residues, Animal carcasses)	<i>Cyclical Use of Waste Report</i> (MOE)	- Amount directly landfilled - Amount landfilled after intermediate treatment, excluding ash after incineration by using reference data  * All textiles in industrial waste are considered to consist of natural fiber due to the Waste Management and Public Cleansing Act	- Estimated by interpolation for some fiscal years, - Substituted FY1980 value for the years prior to FY1980	
	Paper/cardboard				
	Wood				
	Textiles (natural fiber) *				
	Digested sewage sludge		Data provided by MLIT	Compiled and provided by MLIT	- For some fiscal years, estimated by interpolation - Substituted FY1985 value for the years prior to FY1985
	Other sewage sludge		<i>Sewage Statistics</i> (JSWA)	Total amount of sewage sludge excluding the amount of digested sewage sludge	- For some fiscal years, estimated by interpolation - For the years from FY2015 onward, estimated with the data from <i>Follow-up Action Result of the Voluntary Action Plan on the Environment</i> (Japan Business Federation) and the <i>Report on the State of Industrial Waste Generation and Treatment Survey</i> (MOE) - For the years prior to FY1998, estimated with the data from <i>Follow-up Action Result of the Voluntary Action Plan on the Environment</i> (Japan Business Federation) - Substituted FY1990 value for the years prior to FY1990
	Waterworks sludge		<i>Waterworks Statistics</i> (Japan Water Works Association)	Estimated by “Total amount of soil disposed” and “landfilled percentage” of each purification plant	Substituted FY1980 value for the years prior to FY1980
	Organic sludge from manufacturing industries	Paper industry	Data provided by Japan Paper Association, Japan Technical Association of the Pulp and Paper Industry	Total amount of organic sludge landfilled for paper industry	Substituted FY1989 value for the years prior to FY1989
		Chemical industry	<i>Survey of generation status of industry-specific by-products (industrial waste and recyclable waste)</i> (METI), etc.	Total amount of organic sludge landfilled for chemicals industry and food manufacturing industry	- For some fiscal years, estimated by interpolation - For the years from FY2015 onward, estimated with the data from <i>Follow-up Action Result of the Voluntary Action Plan on the Environment</i> (Japan Business Federation) and the <i>Report on the State of Industrial Waste Generation and Treatment Survey</i> (MOE) - For the years prior to FY1998, estimated with the data from <i>Follow-up Action Result of the Voluntary Action Plan on the Environment</i> (Japan Business Federation) - Substituted FY1990 value for the years prior to FY1990
		Food manufacturing industry			
Livestock waste		Survey conducted by MOE	—	Substituted FY1980 value for the years prior to FY1980	

Note:

METI: Ministry of Economy, Trade and Industry, MLIT: Ministry of Land, Infrastructure, Transport and Tourism.

### ➤ *Percentage of Water Content in Waste*

In Japan, activity data are estimated on a dry basis because the carbon content of waste can be identified more precisely. The percentages of water content by each type of waste to estimate activity data on a dry basis and their sources are given in Table 7-10. In order to estimate the CO<sub>2</sub> emissions for the category “Incineration and Open Burning of Waste (5.C.)” as well as this source category, dry basis activity are used for the same reason.

Table 7-10 Percentage of water content in waste disposed of in managed landfill sites

Items		Intermediate treatment	Water content	Reference	
Municipal solid waste	Food waste	Untreated	75%	Water percentage of food waste in the <i>Cyclical Use of Waste Report</i> (MOE)	
		Treated	30%	Specified by considering material flow	
	Paper/cardboard	(Unseparated)	20%	Expert judgment	
	Wood	(Unseparated)	45%	Expert judgment	
	Textiles (natural fiber)	(Unseparated)	20%	Expert judgment	
	Human waste treatment/ <i>Johkasou</i> sludge	Untreated	85%	Moisture content standard of landfill standard (sludge) specified by enforcement ordinance of the Waste Management and Public Cleansing Act	
		Treated	70%	Expert judgment	
Tsunami sediment	(Unseparated)	45%	Substituted the value for wood by expert judgment		
Industrial solid waste	Food waste	Untreated	75%	Water percentage of food waste in <i>Cyclical Use of Waste Report</i> (MOE)	
		Treated	Specific to each FY	Specified by considering material flow	
	Paper/cardboard	(Unseparated)	15%	Expert judgment	
	Wood	(Unseparated)	45%	Expert judgment	
	Textiles (natural fiber)	(Unseparated)	15%	Expert judgment	
	Sewage sludge	Digested sewage sludge	(Unseparated)	Specific to each disposal site	Average water content of “delivered or final disposal sludge” in the <i>Sewage Statistics</i> (JSWA)
		Other sewage sludge	(Unseparated)		
	Waterworks Sludge	(Unseparated)	Not specified	Activity data on a dry basis are provided by the data sources	
	Organic sludge from manufacturing industries	Paper industries	(Unseparated)	Not specified	Reference of Clean Japan Center Survey
		Chemical industries	(Unseparated)	57%	
	Food manufacturing	(Unseparated)	77%		
Livestock waste	Untreated		83.1%	Japan Livestock Technology Association (2002)	
	Treated		70%	Expert judgment	

### ➤ *Percentages of Landfill Sites by Site Structure Type*

#### - *Percentages of MSW Landfill Sites by Site Structure Type*

Among the Japan’s MSW disposal sites listed in the section “Facility by Type (Final Disposal Sites)” of the *Annual editions of Results of Study on Municipal Solid Waste Disposal* (Environmental Regeneration and Material Cycles Bureau of MOE) (hereinafter referred to as the *Results of Study on MSW Disposal*), landfill sites which have leachate treatment facilities and subsurface containment structures are regarded as semi-aerobic landfill sites, and the percentage of their total landfill capacity [m<sup>3</sup>] is defined as the percentage of semi-aerobic landfill disposal volume.

Since the percentages of semi-aerobic landfill sites for the period FY1996 and before are not available, they are determined as indicated below:

- For the period FY1997 and after, they are determined based on actual data.
- For the period FY1977 and before, all the landfill sites including all the sea area landfills are considered to be anaerobic landfill sites since semi-aerobic landfill technology started in FY1977.
- For the period FY1977-1996, they are estimated by linear interpolation using actual data of FY1997 based on expert judgment.

- **Percentages of IW Landfill Sites by Site Structure Type**

The percentages of landfill sites by site structure type for IW are determined as follows:

- For the period FY2008 and after, they are determined based on the *Survey of Industrial Waste Treatment Facilities* (MOE).
- For the period FY1977 and before, all the landfill sites including all the sea area landfills are considered to be anaerobic landfill sites since semi-aerobic landfill technology started in FY1977.
- For the period FY1990-2007, they are estimated by using the total amount of waste landfilled and the actual data of waste deposited of in semi-aerobic landfill sites in FY2008.
- For the period FY1977-1989, they are estimated by linear interpolation using the data of FY1990 based on expert judgment.

Table 7-11 Percentages of landfill sites by site structure

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
<b>MSW</b>																
Anaerobic landfill	%	74.2	64.2	54.4	43.5	36.1	38.7	33.1	39.9	28.4	28.8	29.1	35.4	30.6	31.8	31.8
Semi-aerobic landfill	%	25.8	35.8	45.6	56.5	63.9	61.3	66.9	60.1	71.6	71.2	70.9	64.6	69.4	68.2	68.2
<b>IW</b>																
Anaerobic landfill	%	90.2	81.1	66.4	48.3	47.0	36.7	28.5	30.0	35.0	37.7	33.4	29.5	24.3	24.3	24.3
Semi-aerobic landfill	%	9.8	18.9	33.6	51.7	53.0	63.3	71.5	70.0	65.0	62.3	66.6	70.5	75.7	75.7	75.7

➤ **Decomposition Half-life**

Decomposition half-life is the time taken for 50% of waste landfilled in a certain year to be degraded from its initial mass. Conducting several actual measurements at the Central Breakwater Landfill Site in metropolitan Tokyo, the largest managed landfill for MSW in Japan at the time, Ito (1992) obtained a set of half-lives. Assuming this research was on a representative managed disposal site in Japan for temperate/boreal wet climate, the half-lives in his research for food waste, paper/cardboard, textiles (natural fiber), and wood are applied as country specific parameters (3, 7, 7, and 36 years respectively). Because no relevant research have been obtained to identify a country specific half-life for the sludge, the default value of 3.7 years provided in the spreadsheets attached to the *2006 IPCC Guidelines* is applied. The half-life for wood is used for the half-life of tsunami sediment as a substitute by expert judgment.

Table 7-12 Decomposition half-life for biodegradable waste

Item		Half-life [year]	Reference
Food waste <sup>1)</sup>		3	Ito (1992)
Paper/cardboard		7	
Textiles (natural fiber)		7	
Wood <sup>2)</sup>		36	
Sludge	Tsunami sediment	36	The half-life of wood is applied by expert judgment.
	Human waste treatment/ <i>Johkasou</i> sludge	3.7	<i>2006 IPCC Guidelines</i>
	Digested sewage sludge		
	Other sewage sludge		
	Waterworks sludge		
	Organic sludge from manufacturing		
	Livestock waste		
Digested sewage sludge <sup>3)</sup>			

Note:

- 1) Ito (1992) identified the half-life for food waste that is shorter than the default value (4 years) for temperate/wet climate zone of the *2006 IPCC Guidelines*. This is considered to be the reason for that food waste in Japan is more rapidly degraded than theoretical waste the IPCC guidelines assume, since Japan's climate is warmer and more humid than typical temperate/wet climate assumed by the IPCC guidelines (MOE, 2006b).

- 2) Ito (1992) identified the half-life for wood that is longer than the default value (23 years) for temperate/wet climate zone of the 2006 IPCC Guidelines. This is considered to be the reason for that meanwhile the IPCC default value covers wood and straw waste, the Japan's country specific parameter does only wood (MOE, 2006b).
- 3) Although livestock waste is not sludge on the "Wastes Disposal and Public Cleansing Act", the IPCC default half-life for sewage sludge is adopted as that of livestock waste since livestock waste has similar property of sewage sludge.

➤ **Delay Time**

Delay time is the time lag from when the waste is landfilled until when the decomposition actually occurs. As no knowledge is obtained for making it possible to set a delay time specific to Japan, the default value (6 months) given in the 2006 IPCC Guidelines is used.

Table 7-13 Amount of biodegraded waste decomposed in each year (Activity data)

		Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
a. Anaerobic landfill	Municipal solid waste	Food waste	kt (dry)	358	278	172	99	44	37	32	27	23	19	16	14	12	10	9
		Paper/cardboard	kt (dry)	1,042	913	724	545	393	367	343	319	297	274	252	232	213	196	179
		Textiles (natural fiber)	kt (dry)	54	48	38	31	23	21	19	18	16	15	13	12	11	10	9
		Wood	kt (dry)	186	186	179	167	155	152	149	147	144	142	139	137	134	132	129
		Human waste treatment/ Johkasou sludge	kt (dry)	96	66	44	29	17	16	14	12	11	10	8	7	7	6	6
		Tsunami sediment	kt (dry)	NO	NO	NO	NO	NO	NO	NO	0.2	0.4	1	1	1	1	1	1
	Industrial waste	Food waste	kt (dry)	69	102	117	74	32	28	24	21	17	15	12	11	9	8	7
		Paper/cardboard	kt (dry)	137	138	121	99	74	68	63	58	53	49	44	41	37	34	32
		Textiles (natural fiber)	kt (dry)	22	16	15	12	10	9	8	8	7	7	7	6	6	6	5
		Wood	kt (dry)	224	261	258	247	232	228	225	221	218	214	211	208	205	201	198
		Digested sewage sludge	kt (dry)	59	52	38	22	10	9	8	7	6	5	4	4	3	3	3
		Other sewage sludge	kt (dry)	221	196	144	83	39	34	30	26	22	19	17	15	13	11	9
		Waterworks sludge	kt (dry)	180	165	127	85	51	48	44	40	36	34	33	31	29	27	25
		Organic sludge from manufacturing industry	kt (dry)	326	252	149	86	42	38	34	29	25	22	19	16	14	12	11
Livestock waste	kt (dry)	11	11	9	7	6	6	5	5	5	5	5	5	5	4	4	4	
b. Semiaerobic landfill	Municipal solid waste	Food waste	kt (dry)	70	94	90	81	45	39	35	31	27	24	21	19	17	15	13
		Paper/cardboard	kt (dry)	119	191	232	262	248	243	237	231	222	214	203	192	180	170	158
		Textiles (natural fiber)	kt (dry)	6	10	12	18	16	15	14	13	12	11	10	9	8	8	7
		Woods	kt (dry)	10	16	21	25	26	26	26	26	26	26	26	26	26	25	25
		Human waste treatment/ Johkasou sludge	kt (dry)	14	18	20	22	17	16	15	14	13	12	10	10	9	9	9
	Industrial waste	Food waste	kt (dry)	4	15	36	39	23	21	19	20	17	16	14	13	12	12	12
		Paper/cardboard	kt (dry)	6	12	21	31	35	33	32	31	29	28	26	24	23	23	22
		Textiles (natural fiber)	kt (dry)	1	1	2	4	5	5	5	5	5	5	5	5	5	5	6
		Wood	kt (dry)	6	15	20	27	34	35	36	37	37	38	39	39	40	42	43
		Digested sewage sludge	kt (dry)	3	6	9	8	5	5	4	4	4	4	4	3	3	3	3
		Other sewage sludge	kt (dry)	13	23	33	32	20	18	19	18	17	15	14	13	12	11	10
		Waterworks sludge	kt (dry)	12	20	30	36	37	37	38	39	41	41	41	42	43	44	45
		Organic sludge from manufacturing industry	kt (dry)	20	27	28	31	22	21	22	22	20	18	16	15	14	13	12
		Livestock waste	kt (dry)	1	1	2	4	5	5	6	6	6	7	7	7	7	8	8

Note: The declining trend in the amount of biodegraded waste is affected by the improvement of waste reduction that causes the decrease of landfilled waste.

➤ **Amount of CH<sub>4</sub> recovered from Landfills**

In order to reduce the amount of organic matter content and CH<sub>4</sub> emissions at landfill sites, certain intermediate treatments and landfill methods have been conducted; CH<sub>4</sub> recovery from landfills is not very common practice in Japan. CH<sub>4</sub> recovery from landfilled MSW for the purpose of electric power generation implemented at the Tokyo Metropolitan Inner Landfill Site for the Central Breakwater Landfill Site is the sole practice example in Japan. For IW, there is no practice of CH<sub>4</sub> recovery from landfills implemented in Japan. Because CO<sub>2</sub> emitted from the combustion of recovered CH<sub>4</sub> is of biogenic-origin, it is not included in the total emissions.

$$R = r \times f \times 16/22.4/1000$$

- $R$  : Amount of CH<sub>4</sub> recovered in landfill [g]  
 $r$  : Amount of recovered landfill gas used for electric power generation [m<sup>3</sup> N]  
 $f$  : Ratio of CH<sub>4</sub> to recovered gas

- **The amount of recovered landfill Gas used for electric power generation in the Central Breakwater Landfill Site**

The amount of recovered gas used for electric power generation is provided by the Waste Disposal Management Office of Tokyo.

- **Fraction of CH<sub>4</sub> to the recovered gas**

The fraction of CH<sub>4</sub> to recovered landfill gas in the Central Breakwater Landfill Site has been annually provided since FY2005 by the Waste Disposal Management Office of Tokyo. The fraction for the years prior to FY2005 are determined based on the hearing conducted with the Waste Disposal Management Office of Tokyo: 60% for FY1987, when the recovery of landfill gas was started; 40% for FY1996; interpolated for FY1988 through FY1995; The FY1996 value is used for FY1997 through FY2004.

Table 7-14 Amount of CH<sub>4</sub> used at landfill sites in Japan

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Amount of landfill gas use	km <sup>3</sup> N	1,985	2,375	2,372	140	1,266	1,032	1,681	1,734	1,612	1,565	1,488	NO	NO	NO	NO
CH <sub>4</sub> ratio	%	53.3	42.2	40.0	48.5	43.8	51.2	49.5	44.9	41.0	39.2	40.2	NA	NA	NA	NA
Amount of CH <sub>4</sub> use	km <sup>3</sup> N	1,059	1,003	949	68	555	528	832	779	661	613	598	NO	NO	NO	NO
CH <sub>4</sub> unit conversion	Gg-CH <sub>4</sub>	0.76	0.72	0.68	0.05	0.40	0.38	0.59	0.56	0.47	0.44	0.43	NO	NO	NO	NO

Note: The trend of landfill gas use significantly depends on the operation of the only power plant at the Central Breakwater Landfill Site. The operation of the power plant has stopped since the beginning of CY2017.

➤ **CH<sub>4</sub> Oxidation Factor Related by Landfill Cover Soil**

Based on law enforcement ordinances and local government ordinances, daily, intermediate and final soil coverings are practiced in the managed final disposal sites for MSW and IW in Japan. Therefore, the default oxidation factor for managed landfill sites (0.1) is used in accordance with the 2006 IPCC Guidelines.

c) **Uncertainties and Time-series Consistency**

● **Uncertainties**

The uncertainties in emission factors for municipal solid waste and industrial waste on the category are assessed by combining the uncertainties in carbon content, fraction of degradable organic carbon dissimilated, percentages of CH<sub>4</sub> in landfill gas, methane correction factor (*MCF*), and oxidation factor evaluated by using the 95% confidence interval obtained from actual measurement, or by expert judgment.

Regarding the uncertainty for activity data for this sector, due to the lack of information on statistical error in quoted references, it is difficult to assess uncertainties based on concrete evidence. Therefore, it is assessed by expert judgment as indicated in the Table 7-2. Details of the uncertainty assessment on this category are shown in the Table 7-15.



Table 7-15 Uncertainty assessment by waste type on the category “managed disposal sites (5.A.1.)”

Item	GHGs	Emission /removal factor uncertainty		Activity data uncertainty		Emission /removal uncertainty		The method of evaluating uncertainty in emission factor	The method of evaluating uncertainty in activity data	The method of evaluating uncertainty in emissions/removals	
		(-)	(+)	(-)	(+)	(-)	(+)				
Municipal waste	Food waste	CH <sub>4</sub>	-47%	+47%	-10%	+10%	-48%	+48%	The uncertainties in emission factors are evaluated by combining the 95% confidence interval of actual measurement data of carbon content, the uncertainty in fraction of degradable organic carbon dissimilated and proportion of methane in generated gas based on expert judgment, and the uncertainty in default value of MCF and oxidation factor provided by the 2006 IPCC Guidelines, by using the formula for propagation of errors. (Method 1)	The uncertainty in municipal waste statistics based on expert judgment is applied.	Combined by using the formula for propagation of errors.
	Paper/cardboard	CH <sub>4</sub>	-47%	+47%	-10%	+10%	-48%	+48%			
	Textiles (natural fiber)	CH <sub>4</sub>	-47%	+47%	-10%	+10%	-48%	+48%			
	Wood	CH <sub>4</sub>	-47%	+47%	-10%	+10%	-48%	+48%			
	Human waste treatment/ Johkasou sludge	CH <sub>4</sub>	-49%	+49%	-10%	+10%	-50%	+50%			
	Tsunami sediment	CH <sub>4</sub>	-47%	+47%	-10%	+10%	-48%	+48%			
Industrial waste	Food waste	CH <sub>4</sub>	-47%	+47%	-30%	+30%	-56%	+56%	The uncertainty is evaluated by using method 1.	The uncertainty in industrial waste statistics based on expert judgment is applied.	Combined by using the formula for propagation of errors.
	Paper/cardboard	CH <sub>4</sub>	-47%	+47%	-30%	+30%	-56%	+56%			
	Textiles (natural fiber)	CH <sub>4</sub>	-47%	+47%	-30%	+30%	-56%	+56%			
	Wood	CH <sub>4</sub>	-47%	+47%	-30%	+30%	-56%	+56%			
	Sewage sludge	CH <sub>4</sub>	-49%	+49%	-5%	+5%	-49%	+49%	The uncertainty in emission factor is evaluated by using method 1. The uncertainty of carbon content in the method is evaluated based on expert judgment.	The uncertainty in sewage statistics based on expert judgment is applied.	
	Waterworks sludge	CH <sub>4</sub>	-51%	+51%	-5%	+10%	-51%	+52%	The uncertainty is evaluated by using method 1.	The uncertainty in the waterworks statistics based on expert judgment is applied.	
	Organic sludge from manufacturing industries	CH <sub>4</sub>	-58%	+58%	-30%	+30%	-65%	+65%	The uncertainty in emission factor is evaluated by using method 1. The uncertainty of carbon content in the method is evaluated by expert judgment.	The uncertainty in industrial waste statistics based on expert judgment is applied.	
Livestock waste	CH <sub>4</sub>	-51%	+51%	-30%	+30%	-59%	+59%	The uncertainty in emission factors is evaluated by using method 1. For the carbon content in the method, the uncertainty provided by the 2006 IPCC Guidelines as default value is applied.			
Methane recovery	CH <sub>4</sub>	-10%	+10%	-10%	+10%	-14%	+14%	The uncertainty of Methane concentration in recovered gas is evaluated based on expert judgment.	The uncertainty in municipal waste statistics based on expert judgment is applied.	Combined by using the formula for propagation of errors.	

### ● Time-series Consistency

Although some activity data in FY1990 and thereafter are not available, they are estimated by using the methods described in “Activity data” to develop consistent time-series data. The emissions are calculated in a consistent manner.

**d) Category-specific QA/QC and Verification**

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

**e) Category-specific Recalculations**

By revising the carbon contents of paper/cardboard in industrial waste, CH<sub>4</sub> emissions for whole time series were recalculated. By updating the statistical data, emissions for whole time series were recalculated. For detail, see the section “7.1.5. General Recalculations for Emissions from Waste Sector”. See Chapter 10 for impact on trend.

**f) Category-specific Planned Improvements**

For future inventories, long-term efforts on further scientific investigations will be made to identify country-specific parameters (e.g. fraction of degradable organic carbon dissimilated for each type of biodegradable waste and country-specific half-life for sludge at final disposal sites).

**7.2.2. Unmanaged Waste Disposal Sites (5.A.2.)****a) Category Description**

Because landfill sites in Japan are appropriately managed pursuant to the Waste Management and Public Cleansing Act, there are no unmanaged waste disposal sites in Japan. Therefore, the emissions from this source category are reported as “NO”.

**7.2.3. Uncategorized Waste Disposal Sites (5.A.3.)****7.2.3.1. Inappropriate Disposal (5.A.3.-)****a) Category Description**

In Japan, the definition of “inappropriate disposal” is waste disposal violating the Waste Management and Public Cleansing Act (illegal dumping and other forms of improper disposal on lands or areas other than landfill sites). Activities in the category of inappropriate disposal are identified as 1) illegal dumping, and 2) revealed matter; both are irregular events. The ratio of the amount of inappropriate waste disposal is quite small comparing to the one of appropriate waste disposal. Although these inappropriate disposal lands or areas generally satisfy the conditions of managed disposal sites defined in the *2006 IPCC Guidelines*, CH<sub>4</sub> emissions from inappropriate disposal are reported under “Uncategorized waste disposal sites (5.A.3.)”.

Very few fires are observed in inappropriate landfill sites, and they may be emitting fossil-fuel derived CO<sub>2</sub>. However, since actual data are not available, the emissions from the fires at inappropriate landfill sites are reported as “NE”.

## b) Methodological Issues

### ● Estimation Method

Wood and paper/cardboard are the wastes containing biodegradable carbon and being inappropriately disposed without incineration; however, only wood is the subject for the estimation, because the residual amount of paper/cardboard should be very small.

In a similar manner for the “Managed Disposal Sites (5.A.1.)”, a FOD method with Japan’s country-specific parameters is used for the estimation. Emissions are estimated by multiplying the amount of wood (dry basis) degraded in a reporting year by an emission factor. Since the condition of CH<sub>4</sub> emissions from inappropriate disposal is unidentified, it is regarded as almost the same as for the anaerobic landfill.

### ● Emission Factor

Adopting 1.0 of methane correction factor for anaerobic decomposition and 45.2% of fraction of carbon content in wood, the same emission factor as shown in Table 7-7 is used for the anaerobic disposal sites for “wood emissions from managed disposal sites”.

### ● Activity Data

Activity data (dry basis) is obtained by subtracting the water content from the residual amount of inappropriately disposed wood (wet basis) and multiplied by methane generation rate constant. The amount of inappropriately disposed wood is provided by “Wood (Construction and Demolition)” in the *Study on Residual Amounts of Industrial Waste from Illegal Dumping and other Sources* (Environmental Regeneration and Material Cycles Bureau, MOE). The percentage of water content and the methane generation rate constant used for estimating emissions from wood in managed disposal sites are also used for this source.

Table 7-16 Inappropriately disposed wood to be degraded in each estimation year (Activity data)

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Activity data	kt (dry)	2.3	5.5	16.3	16.3	14.7	14.5	14.5	13.7	12.8	12.2	12.3	12.0	11.6	11.4	10.0

## c) Uncertainties and Time-series Consistency

### ● Uncertainties

The uncertainties in emission factor and activity data are evaluated by using the same methods that are used for “Managed Disposal Sites (5.A.1.)”. Details of the uncertainty assessment on this category are shown in the Table 7-17.

Table 7-17 Uncertainty assessment on the category “inappropriate disposal sites (5.A.3.-)”

Item	GHGs	Emission /removal factor uncertainty		Activity data uncertainty		Emission /removal uncertainty		The method of evaluating uncertainty in emission factor	The method of evaluating uncertainty in activity data	The method of evaluating uncertainty in emissions/removals
		(-)	(+)	(-)	(+)	(-)	(+)			
Inappropriately disposed waste	CH <sub>4</sub>	-42%	+41%	-60%	+60%	-74%	+73%	The uncertainty in emission factor for wood is substituted, since the source for estimation is assumed to be wood.	The twofold higher uncertainty than the value in industrial waste statistics is applied based on expert judgment.	Combined by using the formula for propagation of errors.

● **Time Series Consistency**

Because data on inappropriate disposal are available only since FY2002, activity data prior to FY2002 are estimated. The emissions are calculated in a consistent manner.

**d) Category-specific QA/QC and Verification**

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

**e) Category-specific Recalculations**

Due to the removals of inappropriate disposal, revelations of past inappropriate disposal, and etc., the amount of identified inappropriate disposal in the past has been updated annually. Due to the changes in the amount of inappropriate disposal, emissions from FY2009 onward were recalculated. See chapter 10 for impact on trend.

**f) Category-specific Planned Improvements**

For future inventories, long-term efforts on further scientific investigations will be made to identify country-specific parameters.

### 7.3. Biological Treatment of Solid Waste (5.B.)

In this category, CH<sub>4</sub> and N<sub>2</sub>O emissions from biological treatment of solid waste are calculated. The target categories are shown in Table 7-18.

Table 7-18 Categories whose emissions are estimated for biological treatment of solid waste (5.B.)

Category	Waste type		Treatment type	CH <sub>4</sub>	N <sub>2</sub> O	
5.B.1. (7.3.1)	Municipal solid waste	Food waste	Composting	○	○	
		Paper/cardboard				
		Textiles				
		Wood (garden and park waste)				
	Human waste/ <i>Johkasou</i> sludge	○				○
	Industrial waste	Food waste (animal and vegetable residues, other food waste)				○
	Sewage sludge	○	○			
5.B.2. (7.3.2)	-		Anaerobic digestion	NE	NO	

Estimated GHG emissions from this category are shown in Table 7-19. In FY2020, emissions from this source category are 354 kt-CO<sub>2</sub> eq. and accounted for 0.03% of the national total emissions (excluding LULUCF). The emissions from this source category had increased by 50.7% compared to those in FY1990. This emission increase is primarily due to the enhancement of effective utilization of waste as recycled resources. While Japan adopts country-specific emission factors (wet basis) in this category, due to low variation in time series of waste composition for composting, the IEFs for whole category are stable (approximately 2.8 kg-CH<sub>4</sub>/t [dry] and 0.78-0.79 kg-N<sub>2</sub>O/t [dry]).

Table 7-19 GHG emissions from biological treatment of solid waste (5.B.)

Gas	Category	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
CH <sub>4</sub>	5.B.1. Composting	Municipal solid waste	kt-CH <sub>4</sub>	0.1	0.0	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.1	
		Human waste/ <i>Jokasou</i> sludge	kt-CH <sub>4</sub>	NO	NO	NO	0.004	0.02	0.01	0.02	0.02	0.02	0.03	0.03	0.02	0.02	0.02	0.02
		Industrial waste	kt-CH <sub>4</sub>	2.1	2.1	2.1	3.7	3.6	3.9	3.9	3.9	3.8	3.9	3.9	3.4	3.4	3.1	3.1
	5.B.2. Anaerobic digestion at biogas facilities		kt-CH <sub>4</sub>	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
		Total	kt-CH <sub>4</sub>	2.2	2.1	2.2	3.8	3.7	4.1	4.1	4.0	4.0	4.1	4.1	3.6	3.6	3.3	3.3
		kt-CO <sub>2</sub> eq.	54	53	54	95	93	102	101	100	100	102	103	90	89	82	82	
N <sub>2</sub> O	5.B.1. Composting	Municipal solid waste	kt-N <sub>2</sub> O	0.02	0.01	0.01	0.02	0.03	0.04	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.03
		Human waste/ <i>Jokasou</i> sludge	kt-N <sub>2</sub> O	NO	NO	NO	0.001	0.005	0.004	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
		Industrial waste	kt-N <sub>2</sub> O	0.59	0.59	0.59	1.05	1.00	1.10	1.10	1.09	1.08	1.10	1.11	0.96	0.95	0.88	0.87
	5.B.2. Anaerobic digestion at biogas facilities		kt-N <sub>2</sub> O	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
		Total	kt-N <sub>2</sub> O	0.61	0.60	0.61	1.07	1.04	1.15	1.14	1.12	1.12	1.14	1.15	1.00	0.99	0.92	0.91
		kt-CO <sub>2</sub> eq.	181	179	181	319	309	342	338	335	333	340	343	298	296	274	272	
Total			kt-CO <sub>2</sub> eq.	235	233	235	414	402	444	440	435	433	441	446	388	385	356	354

### 7.3.1. Composting (5.B.1)

#### a) Category Description

Part of the MSW and industrial waste generated in Japan is composted, and CH<sub>4</sub> and N<sub>2</sub>O generated in that process are emitted from composting facilities. Emissions from composting of livestock waste are reported under “5.3. Manure management (3.B)” in the agriculture sector.

#### b) Methodological Issues

##### ● Estimation Method

Emissions are calculated by taking the amount of organic waste composted, which is obtained from the statistical information available in Japan, and multiplying it by country-specific emission factors. The calculation method is the same for both CH<sub>4</sub> and N<sub>2</sub>O emissions.

$$E = \sum_i EF_i \times A_i$$

$E$  : Amount of CH<sub>4</sub> or N<sub>2</sub>O emissions generated by composting organic waste [kg-CH<sub>4</sub>], [kg-N<sub>2</sub>O]

$EF_i$  : Emission factor for organic waste  $i$  (wet basis) [kg-CH<sub>4</sub>/t], [kg-N<sub>2</sub>O/t]

$A_i$  : Amount of composted organic waste  $i$  (wet basis) [t]

##### ● Emission Factor

Country-specific emission factors obtained from actual measurements at 9 facilities in summer and winter by MOE (2018a) are adopted (MOE, 2018b).

Table 7-20 GHG emission factors for composting (5.B.1) (wet basis)

Waste type		CH <sub>4</sub> emission factor [kg-CH <sub>4</sub> /t]	N <sub>2</sub> O emission factor [kg-N <sub>2</sub> O/t]	Note
MSW	Wood (garden and park waste)	0.35	0.0015	Low degradable
	Food waste	0.96	0.27	
	Paper/cardboard			
	Textiles			
Human waste/ <i>Jokkasou</i> sludge		0.96	0.27	High degradable
IW	Food waste (animal and vegetable residues, other food waste)			
	Sewage sludge			

Note: Each composting facility in which actual measurement was conducted treats different type of waste respectively. According to the study, the emission factors for the facilities composting wood (garden and park waste) are lower than those for the facilities composting of food waste, human waste, *jokkasou* sludge and sewage sludge. Although only one facility solely composts park and garden waste among facilities treated in this study, the expert acknowledged the significantly lower CH<sub>4</sub> and N<sub>2</sub>O emissions from composting process for only garden and park waste by considering obviously lower degradability of garden and park waste than that of sludge and food waste. Hence based on these actual

measurement, CH<sub>4</sub> and N<sub>2</sub>O emission factors for composting distinguished by waste type, such as low degradable and high degradable waste, are defined and applied in the category 5.B.1 composting (MOE 2018b) as shown in Table 7-20.

Since management practice in Japanese composting facilities includes turning over compost regularly or blowing air into the lower part of fermentation tanks to keep aerobic conditions, the country-specific CH<sub>4</sub> emission factors are lower than the default value in the 2006 *IPCC Guidelines*.

### ● Activity Data

Activity data for the category composting (5.B.1) are obtained from the references shown on the Table 7-21.

Table 7-21 References of activity data for composting (5.B.1)

Waste type		Reference	Note
MSW	Food waste	- <i>Waste Treatment in Japan</i> (MOE)	Amount of MSW treated at waste composting facilities indicated in the <i>Waste Treatment in Japan</i> (MOE), is disaggregated by using MSW composition treated at high-rate composting facilities provided in the <i>Cyclical Use of Waste Report</i> (MOE).
	Paper/cardboard		
	Textiles	- <i>Cyclical Use of Waste Report</i> (MOE)	
	Wood (garden and park waste)		
Human waste/ <i>Johkasou</i> sludge		<i>Waste Treatment in Japan</i> (MOE)	-
IW	Food waste (animal and vegetable residues, other food waste)	<i>Review Report on Improvement of Accuracy and Faster Compilation of Waste Statistics</i> (MOE)	This category includes; - Animal and vegetable residues generated by food and beverage manufacturing. - Food waste including valuables other than the above: although it falls under the category other than industrial waste in the Waste Management and Public Cleansing Act, it is included in industrial waste because of its source and properties.
	Additives (e.g. wood, etc.)	Expert judgment	Estimated by using additive ratio of 30% in food waste, derived from expert judgment referring to the <i>Cyclical Use of Waste Report</i> (MOE).
	Sewage sludge	<i>Sewage Statistics</i> (JSPA)	-
	Additives (e.g. wood, etc.)	Data provided by MLIT	-

Activity data (wet basis) obtained is shown on the Table 7-22.

Table 7-22 Amounts of composted waste (Activity data: wet basis)

Item		Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
MSW	Food waste	kt (wet)	35	20	29	66	117	143	120	121	115	122	134	141	133	131	124
	Paper/cardboard	kt (wet)	28	16	23	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Textiles	kt (wet)	3	2	2	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Wood	kt (wet)	8	5	4	33	48	41	40	45	60	60	85	84	83	75	71
Total		kt (wet)	74	42	58	99	165	184	160	166	175	182	219	225	216	206	195
Human waste/ <i>Johkasou</i> sludge		kt (wet)	NO	NO	NO	4	17	15	21	19	25	35	30	21	21	23	22
IW	Food waste	kt (wet)	2,063	2,063	2,063	3,747	3,564	3,923	3,920	3,883	3,861	3,923	3,973	3,439	3,417	3,164	3,150
	Sewage sludge	kt (wet)	118	126	135	147	144	168	145	136	139	140	129	105	103	84	84
Total		kt (wet)	2,180	2,189	2,198	3,894	3,708	4,091	4,065	4,019	4,000	4,063	4,102	3,543	3,520	3,249	3,234

### c) Uncertainties and Time-series Consistency

#### ● Uncertainties

The uncertainties in emission factors are evaluated according to the survey for EFs (MOE, 2018a). As for the uncertainty in activity data, since valuables account for much of activity data in biological treatment, the uncertainty of valuables indicated in Table 7-2 is adopted for that of activity data based on expert judgment. Details of the uncertainty assessment on this category are indicated in the Table 7-23.

Table 7-23 Uncertainty assessment on the category “composting (5.B.1.)”

Item	GHGs	Emission /removal factor uncertainty		Activity data uncertainty		Emission /removal uncertainty		The method of evaluating uncertainty in emission factor	The method of evaluating uncertainty in activity data	The method of evaluating uncertainty in emissions/removals
		(-)	(+)	(-)	(+)	(-)	(+)			
Composting	CH <sub>4</sub>	-79%	+79%	-30%	+30%	-84%	+84%	The uncertainty is evaluated according to the survey for the EFs (MOE, 2018a)	The uncertainty in valuables based on expert judgment is applied since AD mostly consists of valuables.	Combined by using the formula for propagation of errors.
	N <sub>2</sub> O	-167%	+167%	-30%	+30%	-170%	+170%			

### ● *Time-series Consistency*

Since the amount of composted animal and plant residues generated by food manufacturing and food waste other than those for FY1990-2000 are unavailable, the data for FY2001 are used for those years. Since the data of the amount of additives (e.g. wood, etc.) to be added to sewage sludge treated at composting facilities for FY1990-1995 are unavailable, those data are estimated by multiplying the sewage sludge for FY1990-1995 by the ratio of additives for FY1996; thus, time series consistency in emission estimates has been ensured.

### d) *Category-specific QA/QC and Verification*

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

### e) *Category-specific Recalculations*

By updating the statistical data, emissions in FY2019 were recalculated. For detail, see the section “7.1.5. General Recalculations for Emissions from Waste Sector”. See Chapter 10 for impact on trend.

### f) *Category-specific Planned Improvements*

The implementation of emission estimates from domestic and commercial composting machine will be further considered. Because this kind of research could not be completed in a short period of time, a long-term effort on scientific investigations will be necessary.

## 7.3.2. Anaerobic Digestion at Biogas Facilities (5.B.2.)

### a) *Category Description*

#### ● *Biogas facilities in Japan*

As biogas facilities to be considered in this category, anaerobic digestion equipment at sewage treatment plants, biogas facilities for municipal waste, and biogas facilities for industrial waste are operated in Japan.

#### ➤ *Anaerobic digestion equipment for sewage sludge at sewage treatment plants*

JSWA (2009) states that, digestion tanks for sludge at sewage treatment plants should be kept airtight to prohibit explosions and odors caused by biogas leakage. It also states that unutilized digestion gas from such equipment should be combusted in views of safety and climate change mitigation. In addition, Japan estimates CH<sub>4</sub> and N<sub>2</sub>O emissions from sludge thickening tank and dehydration room by using

emission factors considering whole treatment system including these processes; CH<sub>4</sub> and N<sub>2</sub>O emissions from this source stated in the *2006 IPCC Guidelines* are included in “5.D.1. domestic wastewater”.

➤ ***Biogas facilities for municipal waste***

MOE (2008) states that fermentation equipment at biogas facilities for municipal waste should be kept airtight. It also states that biogas from such equipment should be combusted by the excess gas combustion system and discharged safely when the facilities cannot supply biogas to consumers in emergencies or maintenances.

➤ ***Biogas facilities for industrial waste***

Although biogas facilities for industrial waste are not controlled by the guidelines such as for these for municipal waste, operators ought to keep airtight at the facilities in their installations as a safety measure.

● ***Emission estimates***

Biogas facilities in Japan for municipal waste and industrial waste are leaking small amounts of CH<sub>4</sub>. By assuming 2% of the leakage fraction of biogas produced in a facility (a consideration of actual situation of the CH<sub>4</sub> emission) and 60% of the CH<sub>4</sub> concentration in biogas (the *JARUS Reference System for Information of Biomass Recycling Technology*, The Japan Association of Rural Resource Recycling Solutions), the CH<sub>4</sub> emissions from this source category were tentatively estimated as 1.4 [kt-CO<sub>2</sub> eq. per year] at a maximum. Hence the emissions from this source category are reported as “NE” which stands for “considered insignificant” guided by the decision tree on the Figure A5-2 of Annex 5.

Assumed to be negligible in accordance with the *2006 IPCC Guidelines*, N<sub>2</sub>O emission from this source category are reported as “NO”.



## 7.4. Incineration and Open Burning of Waste (5.C.)

In Japan, waste disposed of has been reduced in volume primarily by incineration. Emissions from waste incineration are categorized into different types as shown in Table 7-24. CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O emissions from “7.4.1. Waste Incineration (without Energy Recovery) (5.C.1.)” and “7.4.2. Open Burning of Waste (5.C.2.)” are reported under this category.

Table 7-24 Categories whose emissions are estimated for waste incineration and open burning (5.C.)

Category	Waste type		Category to be allocated to CRF	Treatment type	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	
5.C.1 (7.4.1)	Municipal solid waste (7.4.1.1)	Plastics	Fossil-fuel derived plastics	Non-biogenic/MSW	Incinerator -continuous -semi-continuous -batch type  Gasification melting furnace	○	○ <sup>2)</sup>	○ <sup>2)</sup>
			Biomass-based plastics	Biogenic/MSW		NA <sup>1)</sup>		
		PET bottles	Fossil-fuel derived PET bottles	Non-biogenic/MSW		○		
			Biomass-based PET bottles	Biogenic/MSW		NA <sup>1)</sup>		
		Paper/ cardboard	Fossil-fuel derived fraction	Non-biogenic/MSW		○		
			Biogenic fraction	Biogenic/MSW		NA <sup>1)</sup>		
		Nappies	Fossil-fuel derived fraction	Non-biogenic/MSW		○		
			Biogenic fraction	Biogenic/MSW		NA <sup>1)</sup>		
		Textiles	Synthetic textiles	Non-biogenic/MSW		○		
			Natural fiber	Biogenic/MSW		NA <sup>1)</sup>		
	Other (Biogenic)		Biogenic/MSW	NA <sup>1)</sup>				
	Industrial waste (7.4.1.2)	Waste oil	Fossil-fuel derived oil	Non-biogenic/ Fossil liquid waste	Incinerator          Various types of incinerations <sup>5)</sup>	○	○	○
			Animal and vegetable oil	Biogenic/ Non- fossil liquid waste		NA <sup>1)</sup>	○	○
		Plastics	Fossil-fuel derived plastics	Non-biogenic/ISW		○	○	○
			Biomass-based plastics	Biogenic/ISW		NA <sup>1)</sup>	IE <sup>3)</sup>	IE <sup>3)</sup>
		Food waste [Animal and vegetable residues/animal carcasses]		Biogenic/ISW		NA <sup>1)</sup>	○	○
		Paper/ cardboard	Fossil-fuel derived fraction	Non-biogenic/ISW		○	IE <sup>4)</sup>	IE <sup>4)</sup>
			Biogenic fraction	Biogenic/ISW		NA <sup>1)</sup>	○	○
		Wood		Biogenic/ISW		NA <sup>1)</sup>	○	○
		Textiles	Synthetic textiles	-		IE <sup>3)</sup>	IE <sup>3)</sup>	IE <sup>3)</sup>
			Natural fiber	Biogenic/ISW		NA <sup>1)</sup>	○	○
	Sludge	Sewage sludge	Biogenic/Sludge	NA <sup>1)</sup>	○	○		
		Other than sewage sludge	Biogenic/Sludge	NA <sup>1)</sup>	○	○		
	Specially-controlled industrial waste (7.4.1.3)	Hazardous waste (Waste oil)	Flammable waste oil	Non-biogenic/ Hazardous waste	Incinerator	○	○	○
			Specified hazardous industrial waste oil	Non-biogenic/ Hazardous waste		○	○	○
		Infectious waste	Plastics (Fossil-fuel derived)	Non-biogenic/ Clinical waste		○	○	○
			Other (except plastics)	Biogenic/ Clinical waste		NA <sup>1)</sup>	○	○
5.C.2 (7.4.2)	Municipal solid waste (7.4.2.1)		-	Open burning	NO	NO	NO	
	Industrial waste (7.4.2.2)	Plastics (Fossil-fuel derived)	Non-biogenic/ISW		○	○	○	
		Other (Biogenic)	Biogenic/ISW		NA <sup>1)</sup>	IE <sup>6)</sup>	IE <sup>6)</sup>	

Note:

- 1) CO<sub>2</sub> emissions from the incineration of biomass-derived waste are not included in the total emissions in accordance with the 2006 IPCC Guidelines; instead it is estimated as a reference value and reported under “Biogenic” in Table 5.C of the CRF.
- 2) CH<sub>4</sub> and N<sub>2</sub>O emissions from incineration of municipal solid waste in bulk are estimated by each incineration type and reported under “Non-biogenic/MSW” in Table 5.C of the CRF.
- 3) Included in fossil-fuel derived plastics in industrial solid waste (ISW)
- 4) Included in biogenic fraction of paper/cardboard
- 5) For details of incineration types for sewage sludge, see section 7.4.1.2.
- 6) CH<sub>4</sub> and N<sub>2</sub>O emissions from open burning of industrial solid waste in bulk are reported under “Non-biogenic/ISW”.

Also, waste incineration includes the following practices of waste used as raw material or fuel:

- Waste Incineration with Energy Recovery (1.A.) (See section 7.4.3.1.)

- Direct Use of Waste as Alternative Fuel (1.A.) (See section 7.4.3.2.)
- Incineration of Waste Processed as Fuel (1.A.) (See section 7.4.3.3.)

In accordance with the 2006 IPCC Guidelines, estimated emissions from the sources listed above are allocated to Energy sector (Category 1) as “7.4.3. Waste Incineration and Energy Use (Reported on Energy Sector) (1.A.)”. For details of reporting category on energy sector, see Table 7-26.

In order to avoid double-counting or any other confusion, emissions from the categories indicated in Table 7-24, Table 7-25 and Table 7-26 with or without energy use are estimated collectively under the waste sector, thus the estimation methodology for these categories are provided in this section.

Table 7-25 Waste types whose emissions are estimated for  
“Waste Incineration and Energy Use (Reported on Energy Sector) (1.A.)”

Category	Waste type		Fuel type on energy sector to be allocated to CRF	Treatment type	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O
1.A.4. (7.4.3.1) <sup>7)</sup>	MSW	Plastics	Fossil-fuel derived plastics	Other fossil fuels	○	○ <sup>2)</sup>	○ <sup>2)</sup>
			Biomass-based plastics	Biomass <sup>8)</sup>	NA <sup>1)</sup>		
		PET bottles	Fossil-fuel derived PET bottles	Other fossil fuels	○		
			Biomass-based PET bottles	Biomass <sup>8)</sup>	NA <sup>1)</sup>		
		Paper/cardboard	Fossil-fuel derived fraction	Other fossil fuels <sup>9)</sup>	○		
			Biogenic fraction	Biomass	NA <sup>1)</sup>		
		Nappies	Fossil-fuel derived fraction	Other fossil fuels	○		
			Biogenic fraction	Biomass	NA <sup>1)</sup>		
	Textiles	Synthetic textiles	Other fossil fuels	○			
		Natural fiber	Biomass	NA <sup>1)</sup>			
	Other (biogenic)		Biomass	NA <sup>1)</sup>			
	IW	Waste oil	Fossil-fuel derived oil	Other fossil fuels	○	○	○
			Animal and vegetable oil	Biomass	NA <sup>1)</sup>	○	○
		Plastics	Fossil-fuel derived plastics	Other fossil fuels	○	○	○
			Biomass-based plastics	Biomass <sup>8)</sup>	NA <sup>1)</sup>	IE <sup>3)</sup>	IE <sup>3)</sup>
		Food waste [Animal and vegetable residues/animal carcasses]		Biomass	NA <sup>1)</sup>	○	○
		Paper/cardboard	Fossil-fuel derived fraction	Other fossil fuels <sup>9)</sup>	○	IE <sup>4)</sup>	IE <sup>4)</sup>
			Biogenic fraction	Biomass	NA <sup>1)</sup>	○	○
		Wood		Biomass	NA <sup>1)</sup>	○	○
				Biomass	NA <sup>1)</sup>	○	○
Textiles		Synthetic textiles	–	IE <sup>5)</sup>	IE <sup>5)</sup>	IE <sup>5)</sup>	
		Natural fiber	Biomass	NA <sup>1)</sup>	○	○	
Sludge		Sewage sludge	–	NO	NO	NO	
	Other than sewage sludge	Biomass	NA <sup>1)</sup>	○	○		
Specially-controlled industrial waste		–	IE <sup>5)</sup>	IE <sup>5)</sup>	IE <sup>5)</sup>		
1.A.1./ 1.A.2./ 1.A.4. (7.4.3.2) <sup>7)</sup>	MSW	Plastics	Fossil-fuel derived plastics	Other fossil fuels	○	○	○
			Biomass-based plastics	Biomass <sup>8)</sup>	NA <sup>1)</sup>	IE <sup>3)</sup>	IE <sup>3)</sup>
	PET bottles		–	NO	NO	NO	
	IW	Waste oil	Fossil-fuel derived oil	Other fossil fuels	○	○	○
			Animal and vegetable oil	Biomass	NA <sup>1)</sup>	○	○
		Plastics	Fossil-fuel derived plastics	Other fossil fuels	○	○	○
			Biomass-based plastics	Biomass <sup>8)</sup>	NA <sup>1)</sup>	IE <sup>3)</sup>	IE <sup>3)</sup>
	Wood		Biomass	NA <sup>1)</sup>	○	○	
Waste tire	Fossil-fuel derived fraction		Other fossil fuels	○	○	○	
		Biogenic fraction	Biomass <sup>8)</sup>	NA <sup>1)</sup>	IE <sup>6)</sup>	IE <sup>6)</sup>	
1.A.1./ 1.A.2. (7.4.3.3) <sup>7)</sup>	Refuse Derived Fuel (RDF)	Fossil-fuel derived fraction	Other fossil fuels	○	○	○	
		Biogenic fraction	Biomass <sup>8)</sup>	NA <sup>1)</sup>	IE <sup>6)</sup>	IE <sup>6)</sup>	
	Refuse Paper and Plastic Fuel (RPF)	Fossil-fuel derived fraction	Other fossil fuels	○	○	○	
		Biogenic fraction	Biomass <sup>8)</sup>	NA <sup>1)</sup>	IE <sup>6)</sup>	IE <sup>6)</sup>	

Note:

- 1) CO<sub>2</sub> emissions from the incineration of biomass-derived waste are not included in the total emissions; instead it is estimated as a reference value and reported as “Biomass” fuel in the CRF tables.
- 2) CH<sub>4</sub> and N<sub>2</sub>O emissions from incineration of municipal solid waste in bulk are estimated by each incineration type and reported as “Other fossil fuels” in the CRF tables.
- 3) Included in fossil-fuel derived plastics in ISW
- 4) Included in biogenic fraction of paper/cardboard
- 5) Included in “Specially-controlled industrial waste” incineration without energy recovery

- 6) Included in the fossil-fuel derived fraction
- 7) For details of categories to be reported in the CRF, see Table 7-26.
- 8) For the biomass fraction in solid waste, etc. such as plastics, waste tire, RPF and RDF, it is difficult to distinguish the activity data on calorie basis for energy sector from the fossil-fuel derived fraction since there are no appropriate way to decompose calorimetric data of mixed solid waste. Hence, the activity data is reported as “IE”, and is included in “other fossil fuels”.
- 9) For the fossil-fuel derived fraction in “paper/cardboard”, it is difficult to distinguish the activity data on calorie basis for energy sector from the biogenic fraction. Hence, the activity data is reported as “IE”, and is included in “biomass”.

Table 7-26 Reporting categories for waste incineration and energy use emissions  
(reported in the energy sector) (1.A.)

Treatment type	Waste type	Application breakdown	Major application	Reporting category on the energy sector	CO <sub>2</sub> <sup>2)</sup>	CH <sub>4</sub>	N <sub>2</sub> O	
Waste incineration with energy recovery	MSW	(Unclassified)	Waste incineration with energy recovery	1.A.4.a. Commercial/institutional	○	○	○	
	Industrial waste				○	○	○	
Direct use of waste as alternative fuel	MSW	Plastics	Liquefaction	Fuel	1.A.2.g. Other	○	○	○
			Blast furnace reducing agent	Reducing agent in blast furnace	1.A.2.a. Iron and steel	○	NO <sup>3)</sup>	NO <sup>3)</sup>
			Coke oven chemical feedstock	Raw material in coke oven	1.A.1.c. Manufacture of solid fuels and other energy industries	○	IE <sup>4)</sup>	NO <sup>5)</sup>
			Gasification	Fuel	1.A.2.g. Other	○	NE <sup>6)</sup>	NE <sup>6)</sup>
	Industrial waste	Waste oil	(Unclassified)	Fuel	1.A.2.g. Other	○	○	○
						Plastics	Blast furnace reducing agent	Blast furnace reducing agent
		Chemical industry	boiler fuel	1.A.2.c. Chemicals	○		○	○
		Paper industry	boiler fuel	1.A.2.d. Pulp, paper and print	○		○	○
		Cement burning	Cement burning	1.A.2.f. Non-metallic minerals	○		○	○
		Automobile manufacturer	boiler fuel	1.A.2.g. Other	○		○	○
		Liquefaction	Fuel	1.A.2.g. Other	○		○	○
		Gasification	Fuel	1.A.2.g. Other	○		NE <sup>6)</sup>	NE <sup>6)</sup>
		Wood	(Unclassified)	Fuel	1.A.2.g. Other		NA	○
		Waste tire	(Unclassified)	Cement burning	Cement burning	1.A.2.f. Non-metallic minerals	○	○
	Boiler			Fuel	1.A.2.g. Other	○	○	○
	Iron manufacture			Raw materials in iron manufacturing	1.A.2.a. Iron and steel	○	NO <sup>3)</sup>	NO <sup>3)</sup>
	Gasification			Fuel in iron manufacturing	1.A.2.a. Iron and steel	○	○	○
	Metal refining			Fuel in metal refining	1.A.2.b. Non-ferrous metals	○	○	○
	Tire manufacture			Fuel in tire manufacturing	1.A.2.c. Chemicals	○	○	○
	Paper manufacture			Fuel in paper manufacturing	1.A.2.d. Pulp, paper and print	○	○	○
Incineration of waste processed as fuel	Refuse-derived fuel (RDF)	(Unclassified)	Fuel use (including power generation)	1.A.2.g. Other <sup>1)</sup>	○	○	○	
	Refuse Paper and Plastic fuel (RPF)	Petroleum product manufacturer	boiler fuel	1.A.1.b. Petroleum refining	○	○	○	
Chemical industry		boiler fuel	1.A.2.c. Chemicals	○	○	○		
Paper industry		Fuel use in paper manufacturing	1.A.2.d. Pulp, paper and print	○	○	○		
Cement manufacturer		Cement burning	1.A.2.f. Non-metallic minerals	○	○	○		

Note:

- 1) Emissions from power generation and heat supply excluding in-house use should be included in the category 1.A.4.a. However, they are reported in the category 1.A.2.g., because the actual circumstances are not understood at the moment.
- 2) CO<sub>2</sub> emissions from the incineration of biomass-derived fraction are not included in the total emissions; instead it is estimated as a reference value and reported as “Biomass” fuel in the CRF tables. For detail, see Table 7-25 .
- 3) Blast furnace gas generated from steel industry is entirely recovered.
- 4) These emissions are included in “solid fuels” in same category 1.A.1.c.
- 5) N<sub>2</sub>O is likely not produced since the atmosphere in coke oven is normally at least 1,000 degree Celsius, and reducing.
- 6) Considering that small fraction of these sources is combusted as alternative fuel but these are mostly used to obtain feedstock for ammonia productions, the emissions are not estimated.

Estimated GHG emissions from waste incineration (category 5.C.) are shown in Table 7-27. In FY2020, emissions from waste incineration are 12,909 kt-CO<sub>2</sub> eq. and accounted for 1.1% of the national total

emissions (excluding LULUCF). The emissions from this source category decreased by 6.3% compared to those in FY1990. For the period FY1990-1997, CO<sub>2</sub> emissions increased as the practice of intermediate treatment by waste incineration increased in order to decrease the total volume of waste landfilled. From FY2001 onwards, as the use of waste as raw material or fuel has been replacing the incineration of fossil-origin waste for intermediate treatments, and these CO<sub>2</sub> emissions which used to be allocated to the waste sector is now allocated to the Energy sector, CO<sub>2</sub> emission estimates from the waste sector decreased. The trend in the IEFs of CO<sub>2</sub> for this category is basically stable and range from 2.58 to 2.70 [t-CO<sub>2</sub>/t-waste (wet)]. On the other hand, N<sub>2</sub>O emissions increased compared to FY1990 level due to the increase in sewage sludge incineration practice for the period FY1990-1997. From FY2005 onward, N<sub>2</sub>O emissions from this source decreased because the practice of high temperature incineration of sewage sludge increased.

Table 7-27 GHG emissions from waste incineration and open burning (5.C.)

Gas	Category		Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020			
CO <sub>2</sub>	5.C.1. Waste incineration	Municipal solid waste	Plastics <sup>1)</sup>	kt-CO <sub>2</sub>	3,981	3,973	4,067	2,384	1,637	1,878	2,036	2,121	1,751	1,926	1,281	1,266	1,547	1,605	1,485		
			PET bottles <sup>1)</sup>	kt-CO <sub>2</sub>	289	289	366	202	131	158	142	161	178	184	118	116	178	192	187	187	
			Paper/cardboard <sup>1)</sup>	kt-CO <sub>2</sub>	590	610	588	488	426	465	449	451	420	436	287	253	320	311	303	311	
			Nappies <sup>1)</sup>	kt-CO <sub>2</sub>	153	180	162	171	195	210	199	211	206	224	153	145	185	181	181	181	
		Industrial waste	Synthetic textiles <sup>1)</sup>	kt-CO <sub>2</sub>	540	568	440	446	591	535	431	451	410	521	319	307	332	350	329	329	
			Waste oil <sup>1)</sup>	kt-CO <sub>2</sub>	3,670	4,366	4,799	4,270	4,128	3,966	4,430	3,652	3,990	3,324	3,856	3,699	3,740	3,400	3,548	3,548	
			Plastics <sup>1)</sup>	kt-CO <sub>2</sub>	2,131	4,539	4,380	4,332	3,785	3,183	3,447	3,942	3,391	3,770	3,708	3,884	3,960	3,755	3,851	3,851	
			Paper/cardboard <sup>1)</sup>	kt-CO <sub>2</sub>	41	86	87	39	34	23	37	17	14	12	12	13	12	1	1	1	
			Specially-controlled industrial waste	Flammable waste oil <sup>1)</sup>	kt-CO <sub>2</sub>	698	1,036	1,526	1,402	1,143	815	784	796	782	692	816	652	772	930	974	974
				Specified hazardous industrial waste oil <sup>1)</sup>	kt-CO <sub>2</sub>	19	28	41	38	42	44	25	55	124	149	131	95	101	102	106	106
	5.C.2. Open burning (Industrial waste plastics) <sup>1)</sup>	Total	kt-CO <sub>2</sub>	5.1	5.1	1.4	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.2	0.2	0.2		
			kt-CO <sub>2</sub> eq.	12,318	16,009	16,884	14,208	12,507	11,729	12,317	12,198	11,719	11,664	11,093	10,825	11,626	11,358	11,491	11,491		
	CH <sub>4</sub>	5.C.1. Waste incineration	Municipal solid waste <sup>2)</sup>	kt-CH <sub>4</sub>	0.5	0.4	0.4	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0		
				Waste oil <sup>2)</sup>	kt-CH <sub>4</sub>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Industrial waste			Plastics <sup>2)</sup>	kt-CH <sub>4</sub>	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
			Food waste <sup>3)</sup>	kt-CH <sub>4</sub>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
			Paper/cardboard <sup>2)</sup>	kt-CH <sub>4</sub>	0.0	0.0	0.0	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
			Wood <sup>3)</sup>	kt-CH <sub>4</sub>	0.1	0.1	0.1	0.4	0.2	0.2	0.2	0.3	0.2	0.2	0.2	0.3	0.3	0.2	0.3		
			Natural fiber <sup>3)</sup>	kt-CH <sub>4</sub>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
			Sludge (sewage sludge/ other) <sup>3)</sup>	kt-CH <sub>4</sub>	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
Specially-controlled industrial waste			Flammable waste oil <sup>1)</sup>	kt-CH <sub>4</sub>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
			Specified hazardous industrial waste oil <sup>1)</sup>	kt-CH <sub>4</sub>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
		Infectious waste (plastics) <sup>1)</sup>	kt-CH <sub>4</sub>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
		Infectious waste (except plastics) <sup>3)</sup>	kt-CH <sub>4</sub>	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
5.C.2. Open burning (Industrial waste) <sup>2)</sup>		Total	kt-CH <sub>4</sub>	1.1	1.2	0.8	0.7	0.5	0.4	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4			
			kt-CO <sub>2</sub> eq.	28	29	21	18	12	11	11	12	10	10	9	10	11	10	10			
N <sub>2</sub> O	5.C.1. Waste incineration	Municipal solid waste <sup>2)</sup>	kt-N <sub>2</sub> O	1.03	1.05	0.98	0.52	0.46	0.49	0.46	0.47	0.43	0.47	0.30	0.28	0.34	0.34	0.33			
			Waste oil <sup>2)</sup>	kt-N <sub>2</sub> O	0.02	0.02	0.02	0.10	0.09	0.09	0.10	0.08	0.09	0.08	0.09	0.08	0.09	0.08	0.08		
		Industrial waste	Plastics <sup>2)</sup>	kt-N <sub>2</sub> O	0.15	0.32	0.31	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02		
			Food waste <sup>3)</sup>	kt-N <sub>2</sub> O	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02		
			Paper/cardboard <sup>2)</sup>	kt-N <sub>2</sub> O	0.01	0.01	0.01	0.02	0.02	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00		
			Wood <sup>3)</sup>	kt-N <sub>2</sub> O	0.06	0.10	0.06	0.14	0.08	0.07	0.08	0.10	0.08	0.08	0.07	0.09	0.09	0.08	0.09		
			Natural fiber <sup>3)</sup>	kt-N <sub>2</sub> O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
			Sewage sludge <sup>3)</sup>	kt-N <sub>2</sub> O	2.65	3.94	4.86	5.48	4.16	4.17	4.22	4.25	3.92	4.16	3.69	4.07	4.11	4.20	3.97		
		Specially-controlled industrial waste	Other sludge <sup>3)</sup>	kt-N <sub>2</sub> O	0.89	0.92	0.94	0.22	0.19	0.19	0.16	0.18	0.17	0.16	0.16	0.18	0.17	0.17	0.18		
			Flammable waste oil <sup>1)</sup>	kt-N <sub>2</sub> O	0.00	0.00	0.01	0.03	0.02	0.02	0.02	0.02	0.02	0.01	0.02	0.01	0.02	0.02	0.02		
	Specified hazardous industrial waste oil <sup>1)</sup>		kt-N <sub>2</sub> O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01			
	Infectious waste (plastics) <sup>1)</sup>		kt-N <sub>2</sub> O	0.01	0.02	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
	5.C.2. Open burning (Industrial waste) <sup>2)</sup>	Total	kt-N <sub>2</sub> O	4.83	6.40	7.23	6.59	5.08	5.09	5.11	5.15	4.77	5.03	4.40	4.78	4.88	4.94	4.72			
			kt-CO <sub>2</sub> eq.	1,438	1,908	2,156	1,963	1,515	1,518	1,523	1,535	1,423	1,498	1,312	1,423	1,453	1,473	1,408			
Total				kt-CO <sub>2</sub> eq.	13,783	17,946	19,060	16,189	14,033	13,258	13,851	13,745	13,153	13,172	12,414	12,258	13,090	12,840	12,909		

Note:

- 1) Include fossil-fuel derived component only.
- 2) Include both fossil-fuel derived component and biogenic component.
- 3) Include biogenic component only.

CO<sub>2</sub> emissions from the incineration of biomass-derived waste (including biomass-based plastics and waste animal and vegetable oil) is not included in the total emissions in accordance with the 2006 IPCC Guidelines; instead, it is estimated as a reference value and reported under "Biogenic" in Table 5.C of the CRF.

For reference, the GHG emissions from waste incineration for energy purpose and with energy recovery are shown in Table 7-28. In FY2020, the emissions from waste incineration including these sources are 32,400 kt-CO<sub>2</sub>, and it accounts for 2.8% of Japan's total GHG emissions (excluding LULUCF). The emissions from this source's category had increased by 29.9% compared to those in FY1990.

Table 7-28 Total GHG emissions from incineration of waste (reference value) including emissions from waste incineration for energy use and energy recovery

Gas	Category		Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020		
CO <sub>2</sub>	5.C. Waste Incineration and open burning (without energy recovery) <sup>1)</sup>		kt-CO <sub>2</sub>	12,318	16,009	16,884	14,208	12,507	11,729	12,317	12,198	11,719	11,664	11,093	10,825	11,626	11,358	11,491		
	I.A. Fuel combustion	Waste Incineration with Energy Recovery	MSW	Plastics <sup>1)</sup>	kt-CO <sub>2</sub>	4,625	4,982	6,376	5,151	3,312	3,516	4,272	4,199	3,686	3,572	4,191	4,560	4,142	4,492	4,156
				PET bottles <sup>1)</sup>	kt-CO <sub>2</sub>	336	363	573	436	264	295	298	318	375	342	386	418	475	536	524
				Paper/cardboard <sup>1)</sup>	kt-CO <sub>2</sub>	686	765	922	1,055	861	870	941	893	885	808	939	911	857	870	848
			Nappy <sup>1)</sup>	kt-CO <sub>2</sub>	178	226	253	369	395	392	417	417	434	415	502	522	494	507	505	
			Synthetic textiles <sup>1)</sup>	kt-CO <sub>2</sub>	627	713	689	964	1,196	1,002	905	894	862	967	1,045	1,106	887	981	921	
			IW	Waste oil <sup>1)</sup>	kt-CO <sub>2</sub>	21	30	28	109	176	170	105	152	175	169	176	117	123	134	140
		Plastics <sup>1)</sup>		kt-CO <sub>2</sub>	31	66	188	307	581	687	731	607	677	898	836	830	817	983	1,008	
		Paper/cardboard <sup>1)</sup>		kt-CO <sub>2</sub>	0.1	0.7	1.0	0.6	2.1	4.3	5.6	1.6	1.7	1.4	1.3	1.2	1.0	0.0	0.1	
		Direct Use of Waste as Alternative Fuel	MSW	Plastics <sup>1)</sup>	kt-CO <sub>2</sub>	NO	NO	94	522	464	444	475	239	232	270	259	273	224	228	212
				Waste oil <sup>1)</sup>	kt-CO <sub>2</sub>	3,592	4,193	4,150	5,215	4,778	4,733	4,952	4,796	4,592	5,015	4,678	4,680	5,079	5,328	5,473
	IW		Plastics <sup>1)</sup>	kt-CO <sub>2</sub>	55	450	1,238	1,835	1,741	1,818	1,890	2,180	2,094	2,240	2,366	2,485	2,571	2,530		
	Incineration of Waste Processed as Fuel	RDF <sup>1)</sup>	kt-CO <sub>2</sub>	34	40	151	423	387	396	391	393	394	366	365	364	367	322	321		
		RPF <sup>1)</sup>	kt-CO <sub>2</sub>	NO	11	46	684	1,171	1,226	1,274	1,342	1,317	1,354	1,445	1,461	1,477	1,451	1,410		
	Total			kt-CO <sub>2</sub>	23,030	28,303	31,850	31,549	28,937	28,181	29,853	29,298	28,546	28,972	29,153	29,470	30,120	30,735	30,485	
	CH <sub>4</sub>	5.C. Waste Incineration and open burning (without energy recovery) <sup>2)</sup>		kt-CH <sub>4</sub>	1.1	1.2	0.8	0.7	0.5	0.4	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	
		I.A. Fuel combustion	Waste Incineration with Energy Recovery	MSW <sup>2)</sup>	kt-CH <sub>4</sub>	0.5	0.5	0.6	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
					Waste oil <sup>2)</sup>	kt-CH <sub>4</sub>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Plastics <sup>2)</sup>					kt-CH <sub>4</sub>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
IW				Food waste <sup>3)</sup>	kt-CH <sub>4</sub>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				Paper/cardboard <sup>2)</sup>	kt-CH <sub>4</sub>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				Wood <sup>3)</sup>	kt-CH <sub>4</sub>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Use of Waste as Alternative Fuel			MSW	Plastics <sup>2)</sup>	kt-CH <sub>4</sub>	NO	NO	0.0	0.0	0.0	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
				Waste oil <sup>2)</sup>	kt-CH <sub>4</sub>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			IW	Plastics <sup>2)</sup>	kt-CH <sub>4</sub>	0.0	0.0	0.0	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3
				Wood <sup>3)</sup>	kt-CH <sub>4</sub>	1.8	1.8	2.2	2.9	4.2	4.4	4.5	4.8	5.2	5.0	4.9	5.2	5.0	5.5	5.8
Incineration of Waste Processed as Fuel		Waste Tire <sup>2)</sup>	kt-CH <sub>4</sub>	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
		RDF <sup>2)</sup>	kt-CH <sub>4</sub>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
RPF <sup>2)</sup>		kt-CH <sub>4</sub>	NO	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
		kt-CO <sub>2</sub> eq.	3.5	3.6	3.8	4.0	5.0	5.2	5.3	5.6	6.1	5.8	5.7	6.1	5.9	6.4	6.7			
Total			kt-CO <sub>2</sub> eq.	86	89	95	99	126	130	133	141	152	145	143	152	149	159	167		
N <sub>2</sub> O		5.C. Waste Incineration and open burning (without energy recovery) <sup>2)</sup>		kt-N <sub>2</sub> O	4.83	6.40	7.23	6.39	5.08	5.09	5.11	5.15	4.77	5.03	4.40	4.78	4.88	4.94	4.72	
		I.A. Fuel combustion	Waste Incineration with Energy Recovery	MSW <sup>2)</sup>	kt-N <sub>2</sub> O	1.19	1.32	1.53	1.13	0.93	0.91	0.97	0.93	0.91	0.86	0.99	1.00	0.92	0.94	0.91
	Waste oil <sup>2)</sup>				kt-N <sub>2</sub> O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	Plastics <sup>2)</sup>				kt-N <sub>2</sub> O	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.01
	IW			Food waste <sup>3)</sup>	kt-N <sub>2</sub> O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
				Paper/cardboard <sup>2)</sup>	kt-N <sub>2</sub> O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
				Wood <sup>3)</sup>	kt-N <sub>2</sub> O	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
	Direct Use of Waste as Alternative Fuel		MSW	Plastics <sup>2)</sup>	kt-N <sub>2</sub> O	0.01	0.01	0.00	0.00	0.00	NO	NO	NO	NO	NO	NO	NO	NO	NO	
				Waste oil <sup>2)</sup>	kt-N <sub>2</sub> O	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	
			IW	Plastics <sup>2)</sup>	kt-N <sub>2</sub> O	0.03	0.02	0.03	0.02	0.05	0.04	0.04	0.04	0.05	0.05	0.05	0.06	0.06		
				Wood <sup>3)</sup>	kt-N <sub>2</sub> O	0.02	0.02	0.03	0.03	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.06		
	Incineration of Waste Processed as Fuel	Waste Tire <sup>2)</sup>	kt-N <sub>2</sub> O	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02				
		RDF <sup>2)</sup>	kt-N <sub>2</sub> O	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01				
	RPF <sup>2)</sup>	kt-N <sub>2</sub> O	NO	0.00	0.00	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03					
		kt-CO <sub>2</sub> eq.	1,817	2,323	2,644	2,336	1,842	1,845	1,866	1,869	1,758	1,817	1,669	1,786	1,793					
	Total			kt-CO <sub>2</sub> eq.	24,933	30,715	34,589	33,984	30,905	30,156	31,852	31,308	30,455	30,934	30,965	31,408	32,061	32,714	32,400	

Note:

- 1) Include fossil-fuel derived component only.
- 2) Include both fossil-fuel derived component and biogenic component.
- 3) Include biogenic component only.

## 7.4.1. Waste Incineration (without Energy Recovery) (5.C.1.)

### 7.4.1.1. Municipal Solid Waste (5.C.1.-)

#### a) Category Description

This category covers the emissions from incineration of municipal solid waste without energy recovery. Emissions of CO<sub>2</sub> are reported under either “Biogenic, Municipal solid waste (MSW)” or “Non-biogenic, Municipal solid waste” in accordance with the waste type as indicated in the Table 7-24. Emissions of CH<sub>4</sub> and N<sub>2</sub>O are estimated for each type of furnace. The data used for the estimation on MSW incineration cannot distinguish biogenic-origin wastes and non-biogenic origin wastes. Therefore, total emissions including biogenic-origin ones are reported altogether under “Non-biogenic, Municipal solid waste”.

#### b) Methodological Issues

##### 1) CO<sub>2</sub>

##### ● Estimation Method

Emissions of CO<sub>2</sub> from this emission source are calculated based on Japan’s country-specific emission factors, the volume of waste incinerated (dry basis) and the percentage of municipal waste treated at the municipal incineration facilities that are accompanied by energy recovery, in accordance with the decision tree in the *2006 IPCC Guidelines* (Volume 5, Page 5.9, Fig. 5.1). In order to estimate CO<sub>2</sub> emissions from the incineration of fossil-fuel derived waste<sup>2</sup>, emissions from fossil-fuel derived fraction in bottles made from polyethylene terephthalate (PET bottles), plastics other than PET bottles (herein after referred to “plastics”), synthetic textiles, paper/cardboard and nappies in municipal solid waste are estimated.

$$E = \sum_i EF_i \times A_i \times (1 - R)$$

$E$  : CO<sub>2</sub> Emissions from the incineration of municipal solid waste type  $i$  [kg-CO<sub>2</sub>]

$EF_i$  : Emission factor for the incineration of waste type  $i$  (dry basis) [kg-CO<sub>2</sub>/t]

$A_i$  : Volume of waste type  $i$  incinerated (dry basis) [t]

$R$  : Percentage of municipal solid waste incinerated at facilities with energy recovery

##### ● Emission Factor

##### ➤ Equation

In accordance with the *2006 IPCC Guidelines*, the emission factor is calculated as follows.

$$EF_i = CF_i \times FCF_i \times OF \times 44/12$$

$EF_i$  : Emission factor for the incineration of waste type  $i$  (dry basis) [kg-CO<sub>2</sub>/t]

$CF_i$  : Carbon content in waste type  $i$  (dry basis) [%]

$FCF_i$  : Fossil-fuel derived fraction in carbon in waste type  $i$  [%]

$OF$  : Oxidation factor [%]

<sup>2</sup> CO<sub>2</sub> emissions from the incineration of food waste, biogenic fraction of paper/cardboard, natural fiber textiles, wood and biomass-based plastics are reported as the reference figures of “Biogenic Municipal solid waste”. Estimation methods for their emissions are the same as those for emissions from the incineration of fossil-fuel derived waste.

➤ **Carbon Content (CF)**

The carbon contents in MSW by waste type are shown in the following table.

Table 7-29 Carbon content of each waste type in MSW (CF: dry basis)

Item	Carbon content	Reference
Plastics	76.8 %	Survey for the fraction and carbon content in each plastic material composition in MSW generated by each of domestic 14 cities (MOE, 2020b)
PET bottles	62.1 %	Averaged value of the data obtained from actual measurements at domestic 10 cities (MOE, 2020b)
Synthetic textiles	63.0 %	Weighted average of carbon content by each type of synthetic textile (MOE, 2006b)
Paper/cardboard	40.8 %	Averaged value of the data obtained from actual measurements at domestic 14 cities (MOE, 2020b)
Nappies	56.0 %	Estimated based on an interview survey of <i>Japan Hygiene Products Industry Association</i> (MOE, 2021a)

➤ **Fossil-fuel derived fraction in carbon in waste (FCF)**

- **Synthetic textiles, Paper/cardboard, Nappies**

The fossil-fuel derived fractions in carbon in synthetic textiles, paper/cardboard and nappies in MSW are shown in the following table.

Table 7-30 Fossil-fuel derived fraction in carbon in synthetic textiles, paper/cardboard and nappies in MSW (FCF)

Item	Fossil-fuel derived fraction in carbon	Reference
Synthetic textiles	100%	Assumed that all is fossil-fuel derived by expert judgement
Paper/cardboard	9.6%	Based on research of present Modern Carbon (pMC) from <sup>14</sup> C in the waste measured by Accelerator Mass Spectrometer (ASTM D6866) (MOE, 2020b)
Nappies	59%	Estimated based on an interview survey of <i>Japan Hygiene Products Industry Association</i> (MOE, 2021a)

Note: Fossil-fuel derived carbon in paper/cardboard incinerated comes from loading materials, colorant, strength agents, adhesive, ink, laminate film, and other additives added at paper manufacturing or processing.

- **Plastics, PET bottles**

Fossil-fuel derived fraction in carbon in plastics and PET bottles are estimated based on biomass-based plastic content in those items. Note that “biomass-based plastics” is a general term for plastics using the biomass as raw material, including bio composite plastics and plastic-like material. Fossil-fuel derived fraction in plastics is estimated as follows.

$$FCF_i(T) = 1 - \frac{BPW_i(T)}{PW_i(T)}$$

$FCF_i(T)$  : Fossil-fuel derived fraction in plastic  $i$  (MSW plastics, MSW PET bottles, IW plastics) in FY  $T$  [%]

$BPW_i(T)$  : Amount of biogenic fraction in plastic  $i$  (MSW plastics, MSW PET bottles, IW plastics) in FY  $T$  [t (dry)]

$PW_i(T)$  : Amount of plastic  $i$  (MSW plastics, MSW PET bottles, IW plastics) generation in FY  $T$ , excluding impurities [t (dry)]

Amount of MSW plastics, MSW PET bottles and IW plastics generation in FY  $T$  ( $PW_{msw}(T)$ ) are obtained from the *Cyclical Use of Wastes Report*. Amount of biogenic fraction in MSW plastics, MSW PET bottles and IW plastics in FY  $T$  ( $BPW_i(T)$ ) are calculated by following equation.

$$BP_i(T) = \sum_t^T \sum_j (BP_{j,t} \times DP_{j,t} \times B_j \times W_{i,j,t}(T) \times DW_i(T))$$

$BP_{j,t}$  : Amount of biomass-based plastics product  $j$  production in FY  $t$  [t (dry)]

$DP_{j,t}$  : Share of domestic shipments of biomass-based plastics product  $j$  in FY  $t$  [%]

$B_j$  : Biogenic fraction of biomass-based plastics product  $j$  [%]

$W_{i,j,t}(T)$  : Probability that biomass-based plastic product  $j$ , which was produced in FY  $t$ , is disposed of as plastic  $i$  (MSW plastics, MSW PET bottles, IW plastics) in FY  $T$  after use [%]

$DW_i(T)$  : Fraction of plastic  $i$  (MSW plastics, MSW PET plastic, IW plastics) treated domestically in FY  $T$  [%]

For the amount of biomass-based plastic products production ( $BP_{j,t}$ ), the share of domestic shipments ( $DP_{j,t}$ ), and the biogenic fraction ( $B_j$ ) are obtained from a survey by the Japan Society of Biomass Industries and Japan BioPlastics Association. Note that the survey distinguishes final products made of bio-based resin by type (e.g. bio-PE, bio-PET, PLA, etc.) and by use (e.g. wrapping material, containers, daily use products, LCD, etc.).

The survey also provides the supplied amount of bio-based resin as intermediate products of bio-PE, bio-PET and PLA. By subtracting the amount of bio-based resin in final products identified above from the supplied amount of intermediate products by each bio-based resin type, unidentified amount of final products ( $BP$ ) in the survey are also estimated as resin amounts. The shares of domestic shipments ( $DP$ ) and the biogenic fractions ( $B$ ) for those unidentified final products are given by an expert judgement.

A part of bio-PET resin in PET bottles, one of a bio-based resin widely used in Japan, are recovered after use, materially recycled as final products such as bottle or other commodities, and disposed/incinerated finally. In such a circumstance, amount of biogenic fraction in MSW PET bottles ( $BPW_{MSW\ PET\ bottles}(T)$ ) are identified by considering disposal amount of bio-based resin not only after first use in products but also after use in recycled products. The amount of recycled bio-PET resin in each product are estimated by considering data of material recycled plastics after bottle use provided by the *Annual Report on PET Bottle Recycling* (the Council for PET Bottle Recycling).

The probability that is disposed of as MSW ( $W_{i,j,t}(T)$ ) is estimated by the expert judgement.

Fractions of MSW plastics and IW plastics treated domestically in FY  $T$  ( $DW_i(T)$ ) are assumed as 100% for plastics other than PET bottles since the export status are not clear. The parameters for PET bottles are obtained from *Annual report on PET bottle recycling* (Table 7-31).

Table 7-31 Fraction of waste plastic treated domestically ( $DW$ )

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Plastics in MSW	%	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
PET bottle in MSW	%	48.6	48.6	48.6	48.6	47.5	50.5	50.9	51.6	57.1	52.0	54.4	59.6	61.7	62.8	69.1
Plastics in IW	%	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Fossil-fuel derived fractions in plastics calculated by methodologies above are shown in Table 7-32.

Table 7-32 Fossil-fuel derived fraction in waste plastics ( $FCF$ )

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Plastics in MSW	%	100.0	100.0	100.0	99.6	99.4	99.3	99.4	99.3	99.1	99.0	98.9	99.0	98.9	98.6	98.1
PET bottle in MSW	%	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.8	99.8	99.8	99.7	99.7	99.7	99.7	99.6
Plastics in IW	%	100.0	100.0	100.0	100.0	99.9	99.8	99.7	99.7	99.6	99.6	99.6	99.8	99.8	99.9	99.9



➤ **Oxidation Factor**

Taking into account Japan's circumstances, the default value of 100% indicated in the *2006 IPCC Guidelines* is used.

➤ **Emission Factor**

Emission factors calculated by methodologies above are shown in Table 7-33.

Table 7-33 Fossil-fuel derived CO<sub>2</sub> Emission factors for MSW incineration (dry basis)

Item	Unit	Emission factor	Note
Plastics	kg-CO <sub>2</sub> /t	2,816	In case of $FCF=1$
PET bottles	kg-CO <sub>2</sub> /t	2,277	
Synthetic textiles	kg-CO <sub>2</sub> /t	2,310	–
Paper/cardboard	kg-CO <sub>2</sub> /t	144	–
Nappies	kg-CO <sub>2</sub> /t	1,220	–

● **Activity Data**

As basic information to estimate activity data, the amount of plastic, PET bottles distinguished from plastics, textiles and paper/cardboard incinerated are obtained from the *Cyclical Use of Wastes Report*. Note the reported amounts of plastic including PET bottles potentially include biomass-based plastics. The details of activity data estimations are shown as follows.

➤ **Plastics, PET bottle**

The activity data for CO<sub>2</sub> emissions from the incineration of plastics and PET bottles in MSW on a dry basis are calculated by following equation.

$$A_i = MSW_i \times (1 - u_i) \times (1 - F_{impurity,i})$$

$A_i$  : Activity data for plastics or PET bottles in MSW incinerated (dry basis) [t (dry)]

$MSW_i$  : Amount of plastics or PET bottles in MSW incinerated (wet basis) [t (wet)]

$u_i$  : Percentage of water content in plastics or PET bottles in MSW [%]

$F_{impurity,i}$  : Fraction of impurities adhered to plastics or PET bottles in MSW [%]

- **Percentage of water content in plastics ( $u$ )**

The percentage of water contents in plastics and PET bottles in MSW are shown in following table.

Table 7-34 Percentage of water contents in plastics and PET bottles in MSW

Item	Water content	Reference
Plastics	26.1 %	Based on the surveys at domestic 13 cities (MOE, 2020b)
PET bottles	8.4 %	Based on the surveys at domestic 9 cities (MOE, 2020b)

- **Fraction of impurities adhered to plastics ( $F_{impurity}$ )**

In many cases, some residual impurities such as biogenic food waste are adhered to the wastes categorized as plastics in investigation for MSW composition. Activity data of plastics incinerated are defined as the amount of plastics from which those impurities are subtracted. Fraction of impurities adhered to plastics are shown in the table below.

Table 7-35 Fraction of impurities adhered to plastics and PET bottles in MSW

Item	Fraction of impurities adhered	Reference
Plastics	11.9%	Based on the surveys at domestic 14 cities (MOE, 2020b)
PET bottles	0%	Expert judgement (MOE, 2020b)

### ➤ **Synthetic textiles**

The activity data of synthetic textiles in MSW is estimated by disaggregating the amount of textiles in MSW incinerated (wet basis) by using the fraction of waste synthetic textiles in the total waste textiles, and subtracting the water content in textiles (percentage of water content: 20%; see also Table 7-10).

$$A_{\text{textiles}} = MSW_{\text{textiles}} \times (1 - u_{\text{textiles}}) \times F_{\text{synthetic}}$$

$A_{\text{textiles}}$  : Activity data for incineration of synthetic textiles (MSW) incinerated (dry basis) [t (dry)]

$MSW_{\text{textiles}}$  : Amount of textiles incinerated (wet basis) [t (wet)]

$u_{\text{textiles}}$  : Percentage of water content in textiles [%]

$F_{\text{synthetic}}$  : Fraction of synthetic fiber content in total waste textiles [%]

### - **Fraction of Synthetic Textiles in Total Waste Textiles ( $F_{\text{synthetic}}$ )**

Fraction of synthetic textiles content in total textiles contained in the MSW is calculated by using the amount of fiber based final consumption by each fiber type provided by the Japan Chemical Fibers Association.

$$F_{\text{synthetic}} = (C_{\text{synthetic}} + 0.4 \times C_{\text{semisynthetic}}) / C_{\text{total fiber}}$$

$C_{\text{synthetic}}$  : Amount of domestic final consumption of synthetic textiles (dry basis) [t (dry)]

$C_{\text{semisynthetic}}$  : Amount of domestic final consumption of semisynthetic textiles (dry basis) [t (dry)]

$C_{\text{total fiber}}$  : Amount of domestic final consumption of total textiles (dry basis) [t (dry)]

Note: Most semisynthetic textile for domestic use consists of acetate fiber derived from acetylcellulose, and its synthetic fraction by weight is assumed as 40% by expert judgement.

Table 7-36 Fraction of synthetic textiles in textiles

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Fraction of synthetic textile	%	52.2	52.9	55.3	54.4	59.4	61.8	62.0	62.2	62.9	65.3	63.9	65.6	64.5	63.6	61.4

### ➤ **Paper/cardboard**

The activity data of paper/cardboard in MSW is estimated by subtracting the water content (percentage of water content: 20%; see also Table 7-10) in paper/cardboard from the amount of paper/cardboard in MSW incinerated (wet basis). Since the item of paper/cardboard in the *Cyclical Use of Wastes Report* includes nappies, for activity data, activity data of nappies incinerated are subtracted from the amount of paper/cardboard incinerated.

$$A_{\text{paper}} = MSW_{\text{paper}} \times (1 - u_{\text{paper}}) - A_{\text{nappy}}$$

$A_{\text{paper}}$  : Activity data for incineration of paper/cardboard (MSW) incinerated (dry basis) [t (dry)]

$MSW_{\text{paper}}$  : Amount of paper/cardboard incinerated [t (wet)]

$u_{\text{paper}}$  : Percentage of water content in paper/cardboard [%]

$A_{\text{nappy}}$  : Activity data of nappies incinerated (dry basis) [t (dry)]

### ➤ Nappies

Although nappies in Japan's municipal waste is generally classified into paper or textiles, the incinerated amount is not clearly distinguished from these categories.

#### - Prior to FY2004

Based on expert judgement, the amount of domestic production of nappies is applied as the activity data for nappy incinerated prior to FY2004.

The amount of domestic production of nappies is derived from the reported amount of nappies for adult and infant (dry basis) on the *JHPIA news* published by Japan Hygiene Products Industry Association.

#### - FY 2005 onward

The amount of nappies incinerated for FY2005 onward are estimated by following equation based on MOE (2020a), as the amount of nappy consumption.

$$A_{nappy} = \sum_i WT_i \times N_i \times PN_i \times 365/10^6$$

$A_{nappy}$  : Activity data of nappies incinerated (amount of nappy consumption: dry basis) [t (dry)]

$WT_i$  : Weight of nappy  $i$  (for adult or child) per piece (dry basis) [t (dry)]

$N_i$  : Number of nappy  $i$  (for adult or child) consumed per person and day [piece/person/day]

$PN_i$  : Number of nappy  $i$  (for adult or child) users [person]

Properties of each parameter in the estimation are as shown in following table.

Table 7-37 Parameters in estimation of amount of nappy consumption

Item	User	Volume	Reference
Weight of nappy per piece ( $WT$ )	Adult	292g (outer cover [84g×1] and inner pads [52g×4])	MOE (2020a)
	Child	30g	
Number of nappies consumed per person per day ( $N$ )	Adult	1 piece (a set of 1 outer cover and 4 inner pads) /person/day	MOE (2020a)
	Child	5 pieces/person/day	
Number of nappy user ( $PN$ )	Adult	$PN_{adult} = \sum_a P_a \times (PS_{1/2,a} \times 0.2 + PC_{1/2,a} \times 0.64)$ <p> <math>P_a</math> : Population in age-group <math>a</math>  <math>PS_{1/2, a}</math> : Fraction of Requiring support 1 or 2 in age-group <math>a</math>  <math>PC_{1/2, a}</math> : Fraction of Requiring long-term care 1 or 2 in age-group <math>a</math> </p>	Equations: MOE (2020a)  $P_a$ : Current Population Estimates (MIC)
	Child	$PN_{child} = P_{0-3} \times 0.9$ <p> <math>P_{0-3}</math> : Population in age from 0 to 3 </p>	$PS_{1/2, a}, PC_{1/2, a}$ : Status report of Long-Term Care Insurance System (MHLW)

Note: MIC: Ministry of Internal Affairs and Communications, MHLW: Ministry of Health, Labour and Welfare

### ➤ Activity data

Activity data calculated by methodologies above is shown in Table 7-38.

Table 7-38 Activity data to estimate CO<sub>2</sub> emissions from MSW incinerated (dry basis)

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Plastics	kt (dry)	3,056	3,180	3,708	2,686	1,769	1,929	2,254	2,261	1,949	1,971	1,964	2,091	2,042	2,197	2,041
PET bottles	kt (dry)	275	286	412	280	173	199	193	211	244	232	222	236	288	321	313
Synthetic textile	kt (dry)	505	555	489	610	774	665	579	582	551	644	591	612	528	576	541
Paper/cardboard	kt (dry)	8,885	9,583	10,523	10,751	8,964	9,303	9,682	9,366	9,092	8,662	8,541	8,106	8,204	8,224	8,014
Nappy	kt (dry)	272	333	340	442	483	493	505	515	525	524	537	546	556	564	562

● **Percentage of Municipal Waste Incinerated at Municipal Incineration Facilities for Energy Recovery**

Percentage of municipal waste that is incinerated at municipal incineration facilities with energy recovery stands for the one being incinerated at the facilities actually supply electricity or heat outside of them. These values are obtained from the *State of Municipal Waste Treatment Survey* (MOE).

Table 7-39 Percentage of municipal solid waste incinerated at incineration facilities with energy recovery

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
With off-field power generation or heat utilization	%	53.7	55.6	61.1	68.4	66.9	65.2	67.7	66.4	67.8	65.0	76.6	78.3	72.8	73.7	73.7
Without off-field power generation or heat utilization	%	46.3	44.4	38.9	31.6	33.1	34.8	32.3	33.6	32.2	35.0	23.4	21.7	27.2	26.3	26.3

2) **CH<sub>4</sub>**

● **Estimation Method**

CH<sub>4</sub> emissions from incinerator are estimated by multiplying the amount of MSW (wet basis) by incinerator method by each emission factor. CH<sub>4</sub> emissions from gasification melting furnace are estimated by multiplying the amount of MSW (wet basis) incinerated in gasification melting furnace by emission factors. Emissions from MSW with energy recovery are subtracted from the total emissions from this source and allocated to the waste sector.

$$E = \sum_i (EF_i \times A_i) \times (1 - R)$$

$E$  : CH<sub>4</sub> emission from the incineration of MSW [kg-CH<sub>4</sub>]

$EF_i$  : Emission factor for incineration method  $i$  (or furnace type  $i$ ) (wet basis) [kg-CH<sub>4</sub>/t]

$A_i$  : Amount of incinerated MSW by incineration method  $i$  (or furnace type  $i$ ) (wet basis) [t]

$R$  : Percentage of MSW incinerated at facilities with energy recovery

● **Emission Factor**

➤ **Incinerator**

In order to implement countermeasures against dioxins, the renovations, repairs, or rebuilding of incineration facilities took place in the latter half of 1990 through the first half of 2000 in Japan. There have been some improvements made in CH<sub>4</sub> emission factors from the facilities renovated or rebuilt in FY2000 and later, compared to the values obtained before then (MOE, 2010). Therefore, based on the survey (MOE, 2010) and expert judgment, for the CH<sub>4</sub> emission factors for incinerator by incinerator type (stoker furnace and fluidized bed incinerator) and incineration method (continuous incinerator, semi-continuous incinerator, and batch type incinerator) for the period FY2001 and before (MOE, 2006b), and from FY2002 onward (MOE, 2010), respectively, different values are used. All the emission factors are established based on actual measurement survey.

In order to apply activity data based on the amount of incineration by incineration method, emission factors are established by incineration method (continuous incinerator, semi-continuous incinerator, and batch type incinerator) using the weighted average of fraction of the amount of incineration by incinerator type for each fiscal year. The Correction taking into account CH<sub>4</sub> concentrations in the atmosphere is not made to these emission factors.

### ➤ Gasification Melting Furnace

Different emission factor is used for each furnace type (shaft furnace, fluidized bed, and rotary kiln) (MOE, 2010). Also, in order to apply activity data based on the total amount of incineration, emission factors are determined by taking the weighted average of the amount of incineration by gasification melting furnace type for each year.

Table 7-40 CH<sub>4</sub> emission factors by type of incineration method (MSW)

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Continuous incinerator	g-CH <sub>4</sub> /t	8.2	8.2	8.3	2.6	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.6	2.6	2.6
Semi-continuous incinerator	g-CH <sub>4</sub> /t	69.6	69.6	75.1	19.9	20.9	20.8	21.1	20.9	21.1	20.7	20.4	20.5	20.9	20.5	20.5
Batch type incinerator	g-CH <sub>4</sub> /t	80.5	80.5	84.1	13.2	11.6	11.6	11.6	11.7	11.7	11.8	11.8	10.9	10.9	11.0	11.0
Gasification melting furnace	g-CH <sub>4</sub> /t	NA	NA	5.6	6.9	7.0	7.0	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9

Reference: MOE (2000), MOE (2010), the *Waste Treatment in Japan* (MOE), Ishikawa Prefecture et al. (1991-1997), Japan Society for Atmospheric Environment: JSAE (1996), Ueno et al. (1992)

### ● Activity Data

The activity data for CH<sub>4</sub> emissions for incinerator and gasification melting furnace are estimated by multiplying the amount of MSW incinerated (wet basis) provided in the *Cyclical Use of Waste Report* (MOE) (publicized reports and the most current data from the reports prior to publication) by the fraction of incineration by incineration method of incinerator or gasification melting furnace provided by the *Waste Treatment in Japan* (MOE).

Table 7-41 Amount of incineration of MSW by incineration method (Activity data)

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Continuous incinerator	kt (wet)	26,215	29,716	32,749	32,246	27,603	27,892	28,702	28,246	27,360	27,364	26,961	26,883	26,877	27,266	26,431
Semi-continuous incinerator	kt (wet)	4,810	5,455	5,882	4,047	2,968	2,932	2,849	2,827	2,524	2,349	2,164	2,072	1,894	1,849	1,792
Batch type incinerator	kt (wet)	5,643	4,328	3,131	1,562	1,078	1,057	1,061	970	867	842	744	693	660	625	606
Gasification melting furnace	kt (wet)	NO	NO	370	2,397	3,605	3,857	4,122	4,098	4,161	4,328	4,423	4,599	4,739	4,889	4,739

### 3) N<sub>2</sub>O

#### ● Estimation Method

N<sub>2</sub>O emissions from incinerator are estimated by multiplying the amount of MSW (wet basis) by incinerator method by each emission factor. N<sub>2</sub>O emissions from gasification melting furnace are estimated by multiplying the amount of MSW (wet basis) incinerated in gasification melting furnace by emission factors. Emissions from MSW with energy recovery are subtracted from the total emissions from this source and allocated to the waste sector.

$$E = \sum_i (EF_i \times A_i) \times (1 - R)$$

$E$  : N<sub>2</sub>O emission from the incineration of MSW [kg-N<sub>2</sub>O]

$EF_i$  : Emission factor for incineration method  $i$  (or furnace type  $i$ ) (wet basis) [kg-N<sub>2</sub>O / t]

$A_i$  : Amount of incinerated MSW by incineration method  $i$  (or furnace type  $i$ ) (wet basis) [t]

$R$  : Percentage of MSW incinerated at facilities with energy recovery

## ● Emission Factor

### ➤ Incinerator

Same as for CH<sub>4</sub> emissions estimation, for the N<sub>2</sub>O emission factors for incinerator by type and by incineration method, different values are used for the period FY2001 and before (MOE, 2006b), and from FY2002 onward (MOE, 2010), respectively. In order to apply activity data based on the amount of incineration by incineration method, emission factors are established by incineration method (continuous incinerator, semi-continuous incinerator, and batch type incinerator) using the weighted average of fraction of the amount of incineration by incinerator type for each fiscal year calculated based on the *Waste Treatment in Japan* (MOE).

### ➤ Gasification Melting Furnace

Different emission factor is used for each furnace type (shaft furnace, fluidized bed, and rotary kiln) (MOE, 2010). In order to apply the activity data based on the total amount of incineration, emission factors are established by taking the weighted average of the amount of incineration by gasification melting furnace type for each year calculated based on the *Waste Treatment in Japan* (MOE).

Table 7-42 N<sub>2</sub>O emission factors by incineration types (MSW)

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Continuous incinerator	g-N <sub>2</sub> O/t	58.8	58.8	59.1	37.9	38.0	38.0	38.0	38.0	38.1	38.1	38.1	37.9	37.8	37.9	37.9
Semi-continuous incinerator	g-N <sub>2</sub> O/t	56.8	56.8	57.3	71.5	73.2	73.1	73.4	73.1	73.5	72.8	72.3	72.5	73.2	72.5	72.5
Batch type incinerator	g-N <sub>2</sub> O/t	71.4	71.4	74.8	76.0	76.2	76.2	76.2	76.2	76.2	76.2	76.2	76.3	76.3	76.3	76.3
Gasification melting furnace	g-N <sub>2</sub> O/t	NA	NA	16.9	12.0	11.5	11.9	11.7	11.7	12.0	12.2	12.5	12.1	12.4	12.3	12.3

Reference: MOE (2006b), MOE (2010), *Waste Treatment in Japan* (MOE), Ishikawa Prefecture et al. (1991-1997), JSAE (1996), Ueno et al. (1992)

## ● Activity Data

The activity data for CH<sub>4</sub> emissions from incinerators and gasification melting furnaces are also applied for the activity data for N<sub>2</sub>O emission from them.

### c) Uncertainties and Time-series Consistency

#### ● Uncertainties

The uncertainties in CO<sub>2</sub> emission factors are evaluated by using the 95% confidence interval of carbon content data in plastics. The uncertainties in CH<sub>4</sub> and N<sub>2</sub>O emission factors are evaluated by using the 95% confidence interval in the actual measurement on the surveys for emissions factors. As for the uncertainties in activity data, the uncertainties in municipal solid waste data indicated in Table 7-2 are applied. Details of the uncertainty assessment on this category are indicated in the Table 7-43 and Table 7-44.

Table 7-43 Uncertainty assessment for municipal solid waste on the category “waste incineration (5.C.1.-)”  
(CO<sub>2</sub>)

Item	GHGs	Emission /removal factor uncertainty		Activity data uncertainty		Emission /removal uncertainty		The method of evaluating uncertainty in emission factor	The method of evaluating uncertainty in activity data	The method of evaluating uncertainty in emissions/removals
		(-)	(+)	(-)	(+)	(-)	(+)			
Plastics	CO <sub>2</sub>	-1%	+1%	-10%	+10%	-10%	+10%	Quoted from MOE (2020b), a reference of emission factors.	The uncertainty in municipal waste statistics based on expert judgment is applied.	Combined by using the formula for propagation of errors.
PET bottles	CO <sub>2</sub>	-0.4%	+0.4%	-10%	+10%	-10%	+10%	Quoted from MOE (2020b), a reference of emission factors.		
Synthetic textiles	CO <sub>2</sub>	-2%	+2%	-10%	+10%	-10%	+10%	It is evaluated at the 95% confidence interval in actual measurement data of carbon content in synthetic textiles.		
Paper/ cardboard	CO <sub>2</sub>	-13%	+13%	-10%	+10%	-16%	+16%	It is evaluated by combining the 95% confidence interval in actual measurement data of carbon content with that of fossil-derived carbon.		
Nappies	CO <sub>2</sub>	-13%	+13%	-10%	+10%	-16%	+16%	Due to lack of information for the uncertainty of the emission factor, the uncertainty of Paper/ cardboard is substituted based on expert judgment.		

Table 7-44 Uncertainty assessment for municipal solid waste on the category “waste incineration (5.C.1.-)” (CH<sub>4</sub> and N<sub>2</sub>O)

Item	GHGs	Emission /removal factor uncertainty		Activity data uncertainty		Emission /removal uncertainty		The method of evaluating uncertainty in emission factor	The method of evaluating uncertainty in activity data	The method of evaluating uncertainty in emissions/removals	
		(-)	(+)	(-)	(+)	(-)	(+)				
No corresponding category (CH <sub>4</sub> )	Continuous incineration /Stoker furnace	CH <sub>4</sub>	-39%	+39%	-10%	+10%	-40%	+40%	The uncertainty is quoted from MOE (2010), a reference of emission factors.	The uncertainty is based on expert judgment in municipal waste statistics is applied.	Combined by using the formula for propagation of errors.
	Continuous incineration /Fluidized bed furnace	CH <sub>4</sub>	-100%	+719%	-10%	+10%	-100%	+719%			
	Semi-continuous incineration/ Stoker furnace	CH <sub>4</sub>	-82%	+82%	-10%	+10%	-83%	+83%			
	Semi-continuous incineration / Fluidized bed furnace	CH <sub>4</sub>	-100%	+162%	-10%	+10%	-100%	+162%			
	Batch-type incineration/ Stoker furnace	CH <sub>4</sub>	-75%	+75%	-10%	+10%	-76%	+76%			
	Batch-type incineration /Fluidized bed furnace	CH <sub>4</sub>	-100%	+394%	-10%	+10%	-100%	+394%			
	Gasification melting furnace/ Shaft furnace	CH <sub>4</sub>	-100%	+203%	-10%	+10%	-100%	+203%			
	Gasification melting furnace/ Fluidized bed furnace	CH <sub>4</sub>	-100%	+133%	-10%	+10%	-100%	+134%			
	Gasification melting furnace/ Rotary kiln	CH <sub>4</sub>	-54%	+54%	-10%	+10%	-55%	+55%			
No corresponding category (N <sub>2</sub> O)	Continuous incineration /Stoker furnace	N <sub>2</sub> O	-34%	+34%	-10%	+10%	-35%	+35%	The uncertainty is quoted from MOE (2010), a reference of emission factors.	The uncertainty is based on expert judgment in municipal waste statistics is applied.	Combined by using the formula for propagation of errors.
	Continuous incineration /Fluidized bed furnace	N <sub>2</sub> O	-98%	+98%	-10%	+10%	-99%	+99%			
	Semi-continuous incineration/ Stoker furnace	N <sub>2</sub> O	-82%	+82%	-10%	+10%	-82%	+82%			
	Semi-continuous incineration / Fluidized bed furnace	N <sub>2</sub> O	-64%	+64%	-10%	+10%	-64%	+64%			
	Batch-type incineration/ Stoker furnace	N <sub>2</sub> O	-100%	+111%	-10%	+10%	-100%	+111%			
	Batch-type incineration /Fluidized bed furnace	N <sub>2</sub> O	-100%	+133%	-10%	+10%	-100%	+134%			
	Gasification melting furnace/ Shaft furnace	N <sub>2</sub> O	-45%	+45%	-10%	+10%	-46%	+46%			
	Gasification melting furnace/ Fluidized bed furnace	N <sub>2</sub> O	-100%	+252%	-10%	+10%	-100%	+252%			
	Gasification melting furnace/ Rotary kiln	N <sub>2</sub> O	-87%	+87%	-10%	+10%	-88%	+88%			

#### ● Time-series Consistency

Because data on the amount of waste incinerated by type of waste are not available for years prior to FY1997, the data are estimated by using the total incinerated amount of MSW for each year and the ratio of amount of waste incinerated by waste type for FY1998. The emissions are calculated in a consistent manner.

#### d) Category-specific QA/QC and Verification

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.



### e) Category-specific Recalculations

By revising the fraction of synthetic textiles in total textiles, CO<sub>2</sub> emissions for whole time series were recalculated. By revising biomass-based plastic products data, CO<sub>2</sub> emissions from FY2005 onward were recalculated. By updating the statistical data, emissions in FY2019 were recalculated. For detail, see the section “7.1.5. General Recalculations for Emissions from Waste Sector”.

See Chapter 10 for impact on trend.

### f) Category-specific Planned Improvements

No improvements are planned.

## 7.4.1.2. Industrial Waste (5.C.1.-)

### a) Category Description

This category covers CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emissions from incineration of industrial waste without energy recovery by each waste type and the emissions are reported in the corresponding category either “biogenic, industrial solid waste (ISW)”, “biogenic, non-fossil liquid waste”, “biogenic, sludge” “non-biogenic, industrial solid waste” or “non-biogenic, fossil liquid waste” (see Table 7-24).

### b) Methodological Issues

#### 1) CO<sub>2</sub>

##### ● Estimation Method

Emissions of fossil-fuel derived CO<sub>2</sub> from this source are calculated by using the volume of fossil-fuel derived waste oil, plastics, and paper/cardboard incinerated, Japan’s country-specific emission factors, and the percentage of incinerated industrial waste with energy recovery at industrial waste incineration facilities in accordance. Note that since it is difficult to estimate percentages of water content in waste oil and plastic in industrial waste, the emission factors for these sources are identified as wet basis. Also, since industrial textiles does not include synthetic textiles under the regulation of the Waste Management and Public Cleansing Act, the industrial textiles is regarded as waste natural fiber: thus the CO<sub>2</sub> emissions from incineration of industrial textiles are not included in national total because these emissions are biogenic-origin.

$$E_i = EF_i \times A_i \times (1 - R_i)$$

$E_i$  : CO<sub>2</sub> Emissions from incineration of waste type  $i$  [kg-CO<sub>2</sub>]

$EF_i$  : Emission factor for incineration of waste type  $i$  [kg-CO<sub>2</sub>/t]  
(wet basis for waste oil and plastic; dry basis for paper/cardboard)

$A_i$  : Amount of incinerated waste type  $i$  [t]  
(wet basis for waste oil and plastic; dry basis for paper/cardboard)

$R_i$  : Percentage of industrial waste incinerated at facilities with energy recovery (for waste type  $i$ )

##### ● Emission Factor

##### ➤ Equation

In accordance with the approach taken by the 2006 IPCC Guidelines, emission factor is calculated by multiplying the carbon content of each type of waste by the oxidation factor for incineration facilities.

$$EF_i = CF_i \times FCF_i \times OF \times 44/12$$

$EF_i$  : Emission factor for industrial waste  $i$  [kg-CO<sub>2</sub>/t]

$CF_i$  : Carbon content in industrial waste  $i$  [%]

$FCF_i$  : Fossil-fuel derived fraction in industrial waste  $i$  [%]

$OF$  : Oxidation factor [%]

➤ **Carbon Content (CF)**

Carbon contents in industrial waste are shown the table below.

Table 7-45 Carbon contents of industrial waste (CF)

Item	Carbon contents	Note	References
Fossil-fuel derived waste oil	80%	wet basis	Environmental Agency (1992)
Plastics	70%	wet basis	Environmental Agency (1992)
Paper/cardboard	40.8%	dry basis	Substituted the carbon content of MSW (MOE, 2020b) for that of IW because its properties are similar to those of MSW

➤ **Fossil-fuel derived fraction in carbon in paper/cardboard in industrial waste (FCF)**

For the fossil-fuel derived fractions in carbon in industrial waste are shown following table.

Table 7-46 Fossil-fuel derived fractions in carbon in fossil-fuel derived industrial waste (FCF)

Item	Fossil-fuel derived fraction	Reference
Fossil-fuel derived waste oil	100%	Expert judgement
Plastics	Variable	See Table 7-32
Paper/cardboard	9.6%	Substituted the fossil-fuel derived fraction of MSW (MOE, 2020b) for that of IW because its properties are similar to those of MSW

➤ **Oxidation factor (OF)**

The default value of 100% given in the *2006 IPCC Guidelines* is used.

➤ **Emission factor (EF)**

Emission factors calculated by methodologies above are shown in Table 7-47.

Table 7-47 Emission factors for fossil-fuel derived fraction of waste oil, plastics and paper/cardboard in industrial waste (EF)

Item	Unit	Emission factor	Note
Fossil-fuel derived waste oil	kg-CO <sub>2</sub> /t (wet)	2,933	–
Plastics	kg-CO <sub>2</sub> /t (wet)	2,567	In case of FCF=1
Paper/cardboard	kg-CO <sub>2</sub> /t (dry)	144	–

● **Activity Data**

For the activity data for CO<sub>2</sub> emissions from the incineration of waste oil, plastics and paper/cardboard in industrial waste, the amount of incineration provided by the *Cyclical Use of Waste Report* (MOE) is used. Note that the statistical data for industrial waste from this report includes but does not distinguish specially-controlled industrial waste. To avoid double counting in the activity data estimation, the amount of specially-controlled industrial waste incinerated is subtracted from the statistical data (see also the section "7.4.1.3. Specially-Controlled Industrial Waste (5.C.1.-)"). Details of methodologies to estimate activity data are shown below.

$$A_{oil} = IW_{oil} \times (1 - F_{bio}) - SIW_{oil}$$

$A_{oil}$  : Activity data for the incineration of waste fossil-fuel derived oil (wet basis) [ t (wet)]

$IW_{oil}$  : Amount of waste oil incinerated in industrial waste (wet basis) [ t (wet)]

$SIW_{oil}$  : Amount of waste oil incinerated in specially-controlled industrial waste<sup>1)</sup> (wet basis) [ t (wet)]

$F_{bio}$  : Fraction of waste oil from animal and vegetable origin<sup>2)</sup> [%]

Note:

- 1) All the waste oil in specially-controlled industrial waste to be estimated for emissions are waste fossil-fuel derived oil.
- 2) From the survey conducted by the MOE

Table 7-48 Fraction of waste oil from animal and vegetable origin

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Fraction of waste animal and vegetable oil	%	2.6	3.5	4.5	5.4	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0

$$A_{plastics} = IW_{plastics} - A_{inf. plastics}$$

$A_{plastics}$  : Activity data for the incineration of plastics (wet basis) [t (wet)]

$IW_{plastics}$  : Amount of plastics incinerated in industrial waste (wet basis) [t (wet)]

$A_{inf. plastics}$  : Amount of infectious plastics incinerated in specially-controlled industrial waste (wet basis) [t (wet)]

Note: Fossil-fuel derived fraction of plastics in industrial waste plastics incinerated is estimated in the same way as indicated in “7.4.1.1. Municipal Solid Waste (5.C.1.-) b) 1) CO<sub>2</sub>”. See also Table 7-32. Note it is assumed that activity data for plastics (IW) incinerated does not include PET bottles unlike MSW plastics.

$$A_{paper} = (IW_{paper} - A_{inf.exc. plastics}) \times (1 - u_{paper})$$

$A_{paper}$  : Activity data for the incineration of paper/cardboard (dry basis) [t (dry)]

$IW_{paper}$  : Amount of paper/cardboard incinerated in industrial waste (wet basis) [t (wet)]

$A_{inf. exc. plastics}$  : Amount of infectious waste incinerated in specially-controlled industrial waste except plastics (wet basis) [t (wet)]

$u_{paper}$  : Percentage of waste content in paper or cardboard in industrial waste [%]

Note: Of the specially-controlled industrial waste, infectious waste (except plastics) is assumed to be paper/cardboard. Percentage of water content in paper/cardboard in industrial waste is given the value 15% (see Table 7-10).

For more detail of activity data estimated, see Table 7-51.

### ● **Percentage of Industrial Waste Incinerated at Industrial Incineration Facilities for Energy Recovery (by type)**

Percentage of industrial waste that is incinerated at industrial incineration facilities with energy recovery stands for the one being incinerated at the facilities actually supply electricity or heat outside of them. The values are obtained from the *Survey of Industrial Waste Treatment Facilities* (MOE).

In Japan, industrial incineration facilities are installed mainly by private sector waste disposal enterprises. In comparison with the municipal waste incinerators installed primarily by municipal governments, energy recovery (for use in power generation and as a heat source) has not yet been so popular. The percentage for the industrial waste category is therefore smaller.

Table 7-49 Percentage of IW incinerated at incineration facilities with energy recovery

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Waste oil <sup>1)</sup>	%	0.6	0.7	0.6	2.5	4.1	4.1	2.3	4.0	4.2	4.8	4.4	3.1	3.2	3.8	3.8
Plastics	%	1.4	1.4	4.1	6.6	13.3	17.8	17.5	13.3	16.7	19.2	18.4	17.6	17.1	20.8	20.8
Wood <sup>2)</sup>	%	0.2	0.8	1.1	1.5	5.9	15.7	13.1	8.5	10.5	10.2	9.7	8.5	7.6	7.9	7.9
Sludge <sup>3)</sup>	%	0.9	0.8	1.0	1.1	2.2	3.0	3.4	8.3	12.5	12.2	12.0	10.6	11.5	11.2	11.2
Other <sup>4)</sup>	%	0.2	0.8	1.1	1.5	1.5	2.2	1.8	1.9	2.6	4.2	5.0	3.3	3.6	3.3	3.3

Note:

- 1) "Waste oil" includes fossil-fuel derived/animal and vegetable oil.
- 2) "Wood" includes paper/cardboard and wood.
- 3) Not applicable for "sewage sludge".
- 4) "Other" includes textiles (natural fiber), and animal and vegetable residues/animal carcasses.

## 2) CH<sub>4</sub>

### ● Estimation Method

Emissions of CH<sub>4</sub> from this source have been calculated by multiplying the volume of industrial waste incinerated by Japan's country specific emission factor and by percentage of industrial waste incinerated at incineration facilities with energy recovery.

$$E = \sum_j \{EF_j \times A_j \times (1 - R_j)\}$$

- $E$  : Emission of methane from the incineration of industrial waste [kg-CH<sub>4</sub>]  
 $EF_j$  : Emission factor for waste type  $j$  (wet basis) [kg-CH<sub>4</sub>/t]  
 $A_j$  : Incinerated amount of waste type  $j$  (wet basis) [t]  
 $R_j$  : Percentage of industrial waste  $j$  incinerated at facilities with energy recovery

### ● Emission Factor

Based on expert judgment which takes into account the countermeasures against dioxin emissions from incinerators, for the emission factors by waste type for the period FY1990-2001 (MOE, 2006b) and from FY2002 onward (MOE, 2010), respectively, different values are used. These emission factors are established based on actual measurement survey. The correction taking into account CH<sub>4</sub> concentrations in the atmosphere is not made to these emission factors. The emission factor for paper/cardboard or wood in MOE (2006b) and MOE (2010) is substituted for the emission factor for textiles (natural fiber), and animal and vegetable residues/animal carcasses.

Table 7-50 CH<sub>4</sub> emission factors for industrial waste by waste type

Item	Unit	FY1990-2001	FY2002-
Waste oil (fossil-fuel derived/animal and vegetable)	g-CH <sub>4</sub> /t	4.8	4.0
Plastics	g-CH <sub>4</sub> /t	30	8.0
Paper/cardboard	g-CH <sub>4</sub> /t	22	225
Wood	g-CH <sub>4</sub> /t	22	225
Textiles (natural fiber)	g-CH <sub>4</sub> /t	22	225
Animal and vegetable residues/animal carcasses	g-CH <sub>4</sub> /t	22	225
Sludge	g-CH <sub>4</sub> /t	14	1.5
Other than sewage sludge	g-CH <sub>4</sub> /t	14	1.5

Reference: Environmental Agency (2000), MOE (2006b), MOE (2010), Ishikawa Pref. et al. (1991-1999), JSAE (1996)

### ● Activity Data

The volume of waste incinerated (wet basis) by waste type is used as the activity data for CH<sub>4</sub> emissions from the incineration of industrial waste.

➤ **Paper/cardboard, Wood, Textiles (natural fiber) and Animal and Plant Residues/Animal Carcasses:**

The volume of waste incinerated for each type is obtained from the *Cyclical Use of Waste Report* (MOE). Animal and vegetable residues/animal carcasses waste is defined as the sum of items “animal and vegetable residues” and “animal carcasses” in the said reference.

➤ **Sludge**

Activity data is taken as the aggregate of the values obtained from the “Volume of Other Incinerated Organic Sludge” section in the *Cyclical Use of Waste Report* (MOE), and the “Volume of Incinerated Sewage Sludge” reported in a survey by the Ministry of Lands, Infrastructure, Transport and Tourism (MLIT).

➤ **Waste Oil (Fossil-fuel derived/Animal and Vegetable) and Plastics**

The activity data for waste oil and plastics are provided by the *Cyclical Use of Waste Report* (MOE). Because the values provided by this report include the amount of specially-controlled industrial waste which is allocated to the category of specially-controlled industrial waste (5.C.1.-), it is subtracted from the total amount to avoid double counting. Unlike the activity data for CO<sub>2</sub> emission estimates, both fossil-fuel derived oil and animal and vegetable oil are included in waste oil for the activity data for CH<sub>4</sub> emission estimates. Note that activity data for plastics includes biomass-based plastics.

Table 7-51 Incinerated industrial waste by waste types (Activity data)

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Waste fossil-fuel derived oil	kt (wet)	1,258	1,498	1,646	1,493	1,467	1,410	1,546	1,297	1,420	1,191	1,375	1,301	1,317	1,205	1,257
Waste animal and vegetable oil	kt (wet)	40	69	103	115	121	110	117	103	115	100	113	103	107	103	108
Plastics	kt (wet)	842	1,794	1,780	1,808	1,703	1,511	1,632	1,778	1,591	1,826	1,777	1,840	1,864	1,848	1,895
Paper/cardboard	kt (wet)	335	712	718	323	292	225	349	152	130	114	109	116	103	5	8
Wood	kt (wet)	2,679	4,744	3,114	1,865	1,101	1,135	1,181	1,388	1,137	1,120	1,062	1,263	1,247	1,161	1,224
Textiles (natural fiber)	kt (wet)	31	49	50	43	24	26	24	35	39	27	36	29	21	23	24
Animal and vegetable residues/animal carcasses	kt (wet)	77	125	272	167	190	184	153	151	153	168	154	133	159	204	210
Sewage sludge	kt (wet)	3,060	3,827	4,300	4,988	4,694	4,734	4,817	4,934	4,753	4,550	4,452	4,684	4,709	4,602	4,445
Sludge other than sewage sludge	kt (wet)	1,972	2,023	2,071	2,288	2,010	2,020	1,713	1,954	2,021	1,880	1,884	2,003	1,938	1,962	2,029

### 3) N<sub>2</sub>O

#### ● Estimation Method

Emissions of N<sub>2</sub>O from this source are calculated separately for the major emission source, sewage sludge, and the waste other than sewage sludge. With respect to sewage sludge, emission factors are set by type of flocculants and furnaces; and the ones for “high-molecular-weight, flocculant fluidized bed incinerator” are further determined by the incineration temperatures. Emissions from the industrial waste other than sewage sludge are estimated by multiplying the volume of waste incinerated by Japan’s country-specific emission factor. Among those emissions, the ones to be reported in the waste sector are calculated by multiplying the percentage of industrial waste incinerated at the industrial waste incineration facilities with energy recovery.

$$E = \sum \{EF_j \times A_j \times (1 - R_j)\}$$

$E$  : Emission of nitrous oxide from the incineration of industrial waste [kg-N<sub>2</sub>O]

$EF_j$  : Emission factor for waste type  $j$  (wet basis) [kg-N<sub>2</sub>O/t]

$A_j$  : Incinerated amount of waste type  $j$  (wet basis) [t]

$R_j$  : Percentage of industrial waste  $j$  incinerated at facilities with energy recovery

### ● Emission Factor

#### ➤ Sewage Sludge

Emission factor for N<sub>2</sub>O emissions from sewage sludge incineration are determined by taking a weighted average of actually measured emission factors for N<sub>2</sub>O at each incineration facility based on the survey on the volume of sewage sludge incinerated at the facilities conducted by MLIT. Since emission factors are different depending on the types of flocculants, incinerators, and furnace temperatures, they are established for each category as given in Table 7-52.

Table 7-52 N<sub>2</sub>O emission factors for sewage sludge incineration (wet basis)

Type of flocculant	Type of incinerator	Combustion Temperature	Emission factor <sup>1)</sup> [g-N <sub>2</sub> O/t]
High-molecular weight flocculant	Fluidized bed incinerator	Normal temperature combustion (around 800°C)	1,508
	Fluidized bed incinerator <sup>2)</sup>	High temperature combustion (around 850°C)	645
	Multiple hearth	—	882
Other	—	—	—
Lime Sludge	—	—	294
—	- Multiple hearth air injection incineration method fluidized bed incinerator - Two-stage incineration method circulating fluidized bed incinerator - Stoker furnace	High temperature combustion (around 850°C)	263
—	Carbonization furnace for solid fuel production	—	31.2

Reference:

Hyogo Pref. (1994), Kanagawa Pref. (1994), National Institute for Land and Infrastructure Management: NILIM (2001), NILIM (2002), Nakamura et al. (1998), Matsubara et al. (1994), Takeishi et al. (1996), MOE (2006b), MOE (2013b), MOE (2015)

Note:

1) The same emission factors are used for all the reporting years.

2) Excludes multiple hearth air injection incineration method fluidized bed incinerator and two-stage incineration method circulating fluidized bed incinerator.

#### ➤ Waste other than Sewage Sludge

Based on expert judgment which takes into account the countermeasures against dioxin emissions from incinerators, for the emission factors by waste type for the period FY1990-2001 (MOE, 2006b) and from FY2002 onward (MOE, 2010), respectively, different values are used. These emission factors are established based on actual measurement survey. The correction taking into account CH<sub>4</sub> concentrations in the atmosphere is not made to these emission factors. The emission factor applied for paper/cardboard or wood is also used for textiles (natural fiber) and animal and vegetable residues/animal carcasses in the MOE (2006b) and MOE (2010).

Table 7-53 N<sub>2</sub>O Emission factors for industrial waste by type (wet basis)

Item	Unit	FY1990-2001	FY2002-
Waste oil (fossil-fuel derived/animal and vegetable)	g-N <sub>2</sub> O /t	12	62
Plastics	g-N <sub>2</sub> O /t	180	15
Paper/cardboard	g-N <sub>2</sub> O /t	21	77
Wood	g-N <sub>2</sub> O /t	21	77
Textiles (natural fiber)	g-N <sub>2</sub> O /t	21	77
Animal and vegetable residues/animal carcasses	g-N <sub>2</sub> O /t	21	77
Sludge (excluding sewage sludge)	g-N <sub>2</sub> O /t	457	99

Reference: MOE (2000), MOE (2010), Ishikawa Pref. et al. (1991-1997), JSAE (1996), Nakamura et al. (1998), Matsubara et al. (1994), Suzuki et al. (2001), Takeishi et al. (1994), Takeishi et al. (1996), Ueno et al. (1995), Yasuda et al. (1994)

### ● Activity Data

#### ➤ Sewage Sludge

Data in the “volume of incinerated sewage sludge, by flocculants and by incinerator types” reported in a survey by MLIT are used as activity data (wet basis).

Table 7-54 Amount of sewage sludge incinerated (Activity data)

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
High-molecular-weight flocculant/fluidized bed incinerator (normal temp.)	kt (wet)	1,112	1,869	2,397	2,839	1,535	1,532	1,552	1,549	1,318	1,695	1,218	1,531	1,551	1,715	1,581
High-molecular-weight flocculant/fluidized bed incinerator (high temp.)	kt (wet)	128	219	723	1,469	2,581	2,587	2,641	2,644	2,644	2,283	2,665	2,503	2,522	2,257	2,275
High-molecular-weight flocculant/multiple hearth	kt (wet)	560	656	572	102	61	52	43	40	NO	NO	NO	NO	NO	NO	NO
Lime sludge	kt (wet)	1,010	663	272	289	109	83	74	22	1	1	1	1	1	1	0
Other	kt (wet)	55	161	175	8	1	3	0	12	70	27	27	27	27	63	35
- Multiple hearth air injection/blowing incineration method fluidized bed incinerator, - Two-stage incineration method circulating fluidized bed incinerator, - Stoker furnace	kt (wet)	195	259	161	280	338	439	444	565	604	411	412	465	431	346	306
Carbonization furnace for solid fuel production	kt (wet)	NO	NO	NO	NO	70	39	63	103	116	133	128	156	177	220	248

#### ➤ Industrial Waste other than Sewage Sludge

Activity data (wet basis) is determined in the same manner as for the CH<sub>4</sub> emissions from industrial waste, with the exception that the “volume of other incinerated organic sludge” is used as activity data for the sludge (excluding sewage sludge).

### c) Uncertainties and Time-series Consistency

#### ● Uncertainties

The uncertainties in CO<sub>2</sub> emission factors are evaluated by using the 95% confidence interval of carbon content data in fossil fuel-based waste. The uncertainties in CH<sub>4</sub> and N<sub>2</sub>O emission factors are evaluated by using the 95% confidence interval in the actual measurement on the surveys for emissions factors. As for the uncertainties in activity data, the uncertainties in industrial waste data indicated in Table 7-2 are applied. Details of the uncertainty assessment on this category are indicated in the Table 7-55.

Table 7-55 Uncertainty assessment for industrial waste on the category “waste incineration (5.C.1.-)”

Item	GHGs	Emission /removal factor uncertainty		Activity data uncertainty		Emission /removal uncertainty		The method of evaluating uncertainty in emission factor	The method of evaluating uncertainty in activity data	The method of evaluating uncertainty in emissions/removals
		(-)	(+)	(-)	(+)	(-)	(+)			
Waste oil	CO <sub>2</sub>	-2%	+2%	-30%	+30%	-30%	+30%	Due to the lack of information for the uncertainty of the emission factor, twice as much as the uncertainty in municipal waste plastics is substituted based on expert judgment. The uncertainty is quoted from MOE (2010), a reference of emission factors.	The uncertainty based on expert judgment in industrial waste statistics is applied.	Combined by using the formula for propagation of errors.
	CH <sub>4</sub>	-100%	+181%	-30%	+30%	-104%	+184%			
	N <sub>2</sub> O	-76%	+76%	-30%	+30%	-81%	+81%			
Plastics	CO <sub>2</sub>	-2%	+2%	-30%	+30%	-30%	+30%	Due to the lack of information for the uncertainty of the emission factor, twice as much as the uncertainty in municipal waste plastics is substituted based on expert judgment. The uncertainties are quoted from MOE (2010), a reference of emission factors.		Combined by using the formula for propagation of errors.
	CH <sub>4</sub>	-100%	+216%	-30%	+30%	-104%	+218%			
	N <sub>2</sub> O	-44%	+44%	-30%	+30%	-53%	+53%			
Paper/ cardboard	CO <sub>2</sub>	-13%	+13%	-30%	+30%	-104%	+401%	It is evaluated by combining the 95% confidence interval in actual measurement data of carbon content with that of fossil-derived fraction in the carbon.		Combined by using the formula for propagation of errors.
Paper/ cardboard or wood	CH <sub>4</sub>	-100%	+412%	-30%	+30%	-104%	+413%	The uncertainty is quoted from MOE (2010), a reference of emission factors.		Combined by using the formula for propagation of errors.
	N <sub>2</sub> O	-64%	+64%	-30%	+30%	-71%	+71%			
Sludge	CH <sub>4</sub>	-100%	+201%	-30%	+30%	-104%	+203%			Combined by using the formula for propagation of errors.
	N <sub>2</sub> O	-84%	+84%	-30%	+30%	-89%	+89%			
Textiles (Natural fiber)	CH <sub>4</sub>	-100%	+412%	-30%	+30%	-104%	+413%	Due to the lack of information for the uncertainty of the emission factor, the uncertainty in paper/cardboard or wood is substituted based on expert judgment.		Combined by using the formula for propagation of errors.
	N <sub>2</sub> O	-64%	+64%	-30%	+30%	-71%	+71%			
Animal and vegetable residues/ animal carcasses	CH <sub>4</sub>	-100%	+412%	-30%	+30%	-104%	+413%			Combined by using the formula for propagation of errors.
	N <sub>2</sub> O	-64%	+64%	-30%	+30%	-71%	+71%			

● **Time-series Consistency**

Emissions are calculated in a consistent manner.

**d) Category-specific QA/QC and Verification**

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

**e) Category-specific Recalculations**

By revising carbon content and fossil-fuel derived fraction of paper/cardboard in industrial waste, CO<sub>2</sub> emissions for whole time series were recalculated. By revising biomass-based plastic products data,



CO<sub>2</sub> emissions from FY2005 onward were recalculated. By updating the statistical data, emissions in FY2019 were recalculated. For detail, see the section “7.1.5. General Recalculations for Emissions from Waste Sector”. See Chapter 10 for impact on trend.

#### *f) Category-specific Planned Improvements*

No improvements are planned.

### 7.4.1.3. Specially-Controlled Industrial Waste (5.C.1.-)

#### *a) Category Description*

The specially-controlled industrial waste includes wastes with properties, such as explosiveness, toxicity and infectivity, that may be harmful to human health or to living environment. Waste types in this category are indicated in the Table 7-56.

Table 7-56 Substance in incineration of specially-controlled industrial waste

Waste type	Substance
Flammable waste oil	Gasoline, Kerosene, Gas oil or diesel oil
Specified hazardous industrial waste oil	Trichlorethylene, tetrachlorethylene, dichloromethane, carbon tetrachloride, 1,2-dichloroethane, 1,1-dichloroethane, cis-1,2-dichloroethylene, 1,1,1-trichloroethane, 1,1,2-trichloroethane, 1,3 dichloropropene, thiuram, simazine, thiobencarb, benzene, selenium, 1,4-dioxane
Infectious waste plastics	Plastics
Infectious waste (except plastic)	Glasses, Textile, Paper

In this category, CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O emissions from incineration of specially-controlled industrial waste are estimated by each waste type and reported in the corresponding category either “Non-biogenic, Hazardous waste”, Non-biogenic, Clinical waste” or “Biogenic, Clinical waste” (see Table 7-24).

Because the actual state of energy recovery from the incineration of specially-controlled industrial waste is not sufficiently understood, the emissions from specially-controlled industrial waste are reported entirely in “Waste Incineration (Category 5.C.)”.

#### *b) Methodological Issues*

##### *1) CO<sub>2</sub>*

###### ● *Estimation Method*

Emissions of CO<sub>2</sub> from the incineration of flammable waste oil, specified hazardous industrial waste oil and infectious waste plastic contained in specially-controlled industrial waste are estimated in accordance with the decision tree given in the *2006 IPCC Guidelines* (Page 5.9, Fig. 5.1) by using Japan’s country-specific emission factors and the volume of waste incinerated.

###### ● *Emission Factor*

###### - *Flammable waste oil*

Emission factors for waste oil in industrial waste is used for flammable waste oil in specially-controlled industrial waste, since the difference of carbon contents and oxidation factor in the two source categories is considered to be small.

- **Specified hazardous industrial waste oil**

In accordance with the approach taken by the *2006 IPCC Guidelines*, emission factor for specified hazardous industrial waste oil is estimated by multiplying the carbon content of the item by the oxidation factor for incineration facilities.

$$EF = CF \times OF \times (1 - u) \times 44/12$$

<i>EF</i>	: Emission factor for the incineration of specified hazardous industrial waste oil [kg-CO <sub>2</sub> /t]
<i>CF</i>	: Carbon content in specified hazardous industrial waste oil (dry basis) [%]
<i>OF</i>	: Oxidation factor [%]
<i>u</i>	: Percentage of water content in specified hazardous industrial waste oil [%]

Average carbon content in specified hazardous industrial waste oil (dry basis) is estimated using weighted average of carbon content in chemical formula of substances shown in Table Table 7-56 for incinerated substances based on MOE (2010-2011). For the oxidation factor, the default value of 100% indicated in the *2006 IPCC Guidelines* is used. The percentage of water content in specified hazardous industrial waste oil is determined to be 5% by expert judgment.

- **Infectious plastic**

For infectious plastic, the emission factors for incineration of plastics in industrial waste are substituted since the difference in terms of carbon contents and oxidation factor in the two source categories is considered to be small.

Table 7-57 CO<sub>2</sub> Emission factors for incineration of specially-controlled waste

Item	Unit	Emission factor
Flammable waste oil	kg-CO <sub>2</sub> /t (wet)	2,933
Specified hazardous industrial waste oil	kg-CO <sub>2</sub> /t (wet)	1,024
Infectious plastics	kg-CO <sub>2</sub> /t (wet)	2,567

● **Activity Data**

Generally, the amount of specially-controlled industrial waste incinerated obtained from the *Cyclical Use of Waste Report* (MOE) is used as the activity data in and after FY2008. As for the past activity data which the survey data is not available, output volume of waste oil indicated in the *Report on Survey of Organizations in Industrial Waste Administration* (Water Supply Division, Health Service Bureau, the Ministry of Health and Welfare) is used on the assumption that the entire volume of waste oil and infectious plastic waste contained in specially-controlled industrial waste is incinerated. Details are shown below.

- **Flammable waste oil**

The amount of specially-controlled industrial waste oil incinerated from the *Cyclical Use of Waste Report* (MOE) is used as the activity data. Since the data includes both of incinerated amounts of flammable waste oil and specified hazardous industrial waste oil, the amounts of flammable waste oil are estimated by following equation. All the waste oil in specially-controlled industrial waste to be estimated for emissions is waste fossil-fuel derived oil.

$$A_{flam.oil} = SIW_{oil} - A_{s-hazard.oil}$$

<i>A<sub>flam.oil</sub></i>	: Amount of flammable waste oil incinerated (wet basis) [t]
<i>SIW<sub>oil</sub></i>	: Total amount of specially-controlled industrial waste oil incinerated (wet basis) [t]
<i>A<sub>s-hazard.oil</sub></i>	: Amount of specified hazardous industrial waste oil incinerated (wet basis) [t]

- **Specified hazardous industrial waste oil**

The activity data is obtained from following equation using the amount of specified hazardous industrial waste oil reduced in incineration from the *Report on the survey for the estimation of GHG emissions from specially-controlled industrial waste* (MOE) and Residual fraction of incinerated waste oil from the *Cyclical Use of Waste Report* (MOE).

$$A_{S-hazard.oil} = R_{S-hazard.oil} \times (1 + r)$$

$A_{S-hazard.oil}$  : Amount of specified hazardous industrial waste oil incinerated (wet basis) [t]

$R_{S-hazard.oil}$  : Amount of specified hazardous industrial waste oil reduced in incineration (wet basis) [t]

$r$  : Residual fraction of incinerated waste oil [%]

- **Infectious plastic**

The activity data is obtained from following equation using the amount of infectious waste incinerated from the *Cyclical Use of Waste Report* (MOE) and the percentage of plastic content in infectious waste from Japan Society of Waste Management Experts: JSWME (1997). All of Infectious plastics are considered to be fossil-fuel derived.

$$A_{inf.plastics} = ISW_{inf} \times C_{inf.plastics}$$

$A_{inf.plastics}$  : Amount of infectious plastics incinerated (wet basis) [ t ]

$ISW_{inf}$  : Total amount of infectious waste incinerated (wet basis) [ t ]

$C_{inf.plastics}$  : Percentage of plastic content in infectious waste [%]

## 2) CH<sub>4</sub>

### ● Estimation Method

Emissions of CH<sub>4</sub> from the incineration of waste oil and infectious waste included in the specially-controlled industrial waste are calculated by multiplying the volume of incinerated waste by type (wet basis) by Japan's country-specific emission factor.

### ● Emission Factor

Because actual measurement data are not available, the emission factors for the incineration of industrial waste are used as substitutes for the emission factor for the specially-controlled industrial waste by type. Specifically, the substitute emission factors used are: the waste fossil-fuel derived oil in industrial waste for the flammable waste oil and specified hazardous waste oil; the plastic in industrial waste for the infectious plastic; and the paper/cardboard and wood in industrial waste for the other infectious waste (biogenic).

### ● Activity Data

- **Flammable waste oil**

Activity data is the same as those used for CO<sub>2</sub> emission.

- **Specified hazardous industrial waste oil**

Activity data is the same as those used for CO<sub>2</sub> emission.

- **Infectious plastics**

Activity data is the same as those used for CO<sub>2</sub> emission.

### - *Infectious waste except plastics*

The activity data is obtained from similar equation to Infectious plastics, as follows.

$$A_{inf.exc. plastics} = ISW_{inf.} \times (1 - C_{inf.plastics})$$

$A_{inf.exc. plastics}$  : Amount of infectious waste except plastics incinerated (wet basis) [ t ]

$ISW_{inf.}$  : Total amount of infectious waste incinerated (wet basis) [ t ]

$C_{inf.plastics}$  : Percentage of plastic content in infectious waste [%]

### 3) $N_2O$

#### ● *Estimation Method*

Emissions of  $N_2O$  from the incineration of waste oil and infectious waste in specially-controlled industrial waste are calculated by multiplying the incinerated volume of each type of waste (wet basis) by Japan's country-specific emission factor.

#### ● *Emission Factor*

Because actual measurement data are not available, the  $N_2O$  emission factors for the incineration of industrial waste are used as substitutes for determining the emission factor for each type of specially-controlled industrial waste. Specifically, the substitute emission factors used are: the waste oil in industrial waste for the flammable waste oil and specified hazardous industrial waste oil; the plastics in industrial waste for the infectious plastics; and the paper/cardboard and wood in industrial waste for the waste other than infectious plastics.

#### ● *Activity Data*

The same activity data used for  $CH_4$  emissions is used.

Table 7-58 Amount of incineration of specially-controlled industrial waste (Activity data)

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Flammable waste oil	kt (wet)	238	353	520	478	390	278	267	271	266	236	278	222	263	317	332
Specified hazardous industrial waste oil	kt (wet)	18	27	40	37	41	43	25	54	122	145	128	93	99	100	104
Infectious waste (plastics)	kt (wet)	78	128	167	169	154	176	131	133	176	166	160	154	187	207	205
Infectious waste (except plastics)	kt (wet)	105	172	225	228	106	121	90	92	121	114	110	106	129	142	142

### c) *Uncertainties and Time-series Consistency*

#### ● *Uncertainties*

The uncertainty assessment is conducted as well as the assessment for the industrial waste incineration. As for the uncertainties in activity data, the uncertainties in specially-controlled industrial waste data indicated in Table 7-2 are applied. Details of the uncertainty assessment on this category are indicated in Table 7-59.

Table 7-59 Uncertainty assessment for specially-controlled industrial waste on the category “waste incineration (5.C.1.-)”

Item	GHGs	Emission /removal factor uncertainty		Activity data uncertainty		Emission/removal uncertainty		The method of evaluating uncertainty in emission factor	The method of evaluating uncertainty in activity data	The method of evaluating uncertainty in emissions/removals
		(-)	(+)	(-)	(+)	(-)	(+)			
Specially-controlled industrial waste	CO <sub>2</sub>	-2%	+2%	-60%	+60%	-60%	+60%	Due to the lack of information for the uncertainty of the emission factor, the uncertainty in municipal waste plastics is substituted based on expert judgment.	The uncertainty in specially-controlled industrial waste based on expert judgment is used.	Combined by using the formula for propagation of errors.
	CH <sub>4</sub>	-100%	+216%	-60%	+60%	-117%	+224%			
	N <sub>2</sub> O	-44%	+44%	-60%	+60%	-74%	+74%			

### ● *Time-series Consistency*

Since some basic data used for calculating activity data are available only for part of time series, consistent data over the time series are developed based on the estimation. The emissions are calculated in a consistent manner.

### *d) Category-specific QA/QC and Verification*

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

### *e) Category-specific Recalculations*

By updating the statistical data, emissions from FY2017 to FY2019 were recalculated. For detail, see the section “7.1.5. General Recalculations for Emissions from Waste Sector”. See Chapter 10 for impact on trend.

### *f) Category-specific Planned Improvements*

No improvements are planned.

## 7.4.2. Open Burning of Waste (5.C.2.)

### 7.4.2.1. Municipal Solid Waste (5.C.2.-)

#### *a) Category Description*

In Japan, since the Waste Management and Public Cleansing Act prohibits open burning of waste, the emissions from open burning of municipal solid waste are reported as “NO”.

### 7.4.2.2. Industrial Waste (5.C.2.-)

#### *a) Category Description*

This category covers CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emissions from illegal open burning of industrial waste (wood, construction and demolition, plastics, and other/unknown), and the emissions are reported in the category “non-biogenic, industrial solid waste (ISW)”.

## b) Methodological Issues

### 1) CO<sub>2</sub>

#### ● Estimation Method

CO<sub>2</sub> emissions from the open burning of industrial waste plastics are estimated in accordance with the decision tree given in the *2006 IPCC Guidelines* by using Japan's country-specific emission factors and the volume of waste burned in the open air.

#### ● Emission Factor

In accordance with the approach taken by the *2006 IPCC Guidelines*, emission factor is calculated by multiplying the carbon content of industrial waste plastics by the oxidation factor for open burning.

$$EF = CF \times OF \times 44/12$$

*EF* : Emission factor for the open burning of industrial waste plastics (wet basis) [kg-CO<sub>2</sub>/t]

*CF* : Carbon content in industrial waste plastics (wet basis) [%]

*OF* : Oxidation factor [%]

Table 7-60 CO<sub>2</sub> emission factors and relevant parameters of open burning of industrial waste plastics

Item	Value	Reference	Note
<i>EF</i>	1,489 [kg-CO <sub>2</sub> /t (wet)]	–	Country-specific
<i>CF</i>	70 %	Environmental Agency (1992)	See also “7.4.1.2. Industrial Waste (5.C.1.-)”.
<i>OF</i>	58 %	<i>2006 IPCC Guidelines</i>	Default value

#### ● Activity Data

The amount of plastics as industrial waste burned in the open air obtained from the *Report on Survey of Organizations in Industrial Waste Administration* (MOE) is used as the activity data in and after FY1996. As for the past activity data from FY1990 to FY1995, for which the survey data is not available, the data of FY1996 is uniformly used as a substitute since there are no other appropriate way to estimate before FY1995. Since it is unclear that plastics burned in the open air include biogenic fraction, whole of those plastics are assumed to be derived from fossil-fuel.

Table 7-61 The amount of fossil-fuel derived industrial waste burned in the open air (Activity data)

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Plastics	kt (wet)	3.4	3.4	0.9	0.2	0.1	0.1	0.1	0.1	0.1	0.02	0.05	0.1	0.1	0.1	0.1

### 2) CH<sub>4</sub>, N<sub>2</sub>O

#### ● Estimation Method

Emissions of CH<sub>4</sub> and N<sub>2</sub>O from the open burning of industrial waste are estimated in accordance with the decision tree given in the *2006 IPCC Guidelines* by using the IPCC default emission factors and the Japan's country-specific volume of waste burned in the open air.

#### ● Emission Factor

As no knowledge is obtained for making it possible to set emission factors specific to Japan, the default values given in the *2006 IPCC Guidelines* are applied.

Table 7-62 CH<sub>4</sub> and N<sub>2</sub>O emission factors for open burning of industrial waste

Gas	Unit	EFs	Reference
CH <sub>4</sub>	kg-CH <sub>4</sub> /t (wet)	6.5	2006 IPCC Guidelines
N <sub>2</sub> O	kg-N <sub>2</sub> O/t (dry)	0.15	2006 IPCC Guidelines

### ● Activity Data

The total amount (wet basis) summed up all industrial waste burned in the open air obtained from the *Report on Survey of Organizations in Industrial Waste Administration* (MOE) is used as the activity data for CH<sub>4</sub> emission estimates. As for the activity data for N<sub>2</sub>O emission estimates, the amounts (wet basis) mentioned above are converted to dry basis by using water contents for each waste type. To be consistent with the IPCC default emission factor applied in estimations, default water contents of the 2006 IPCC Guidelines (wood: 15%, plastics: 0%, construction and demolition: 0%, and other/unknown: 10%) are applied in this conversion. As for the past activity data from FY1990 to 1995, for which the survey data is not available, the data of FY1996 is uniformly used as a substitute since there are no other appropriate way to estimate.

Table 7-63 The amount of industrial waste burned in the open air (Activity data)

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Total wet weight amount	kt (wet)	72.2	72.2	28.9	3.5	1.3	1.2	0.9	1.3	0.6	1.0	0.5	0.7	0.8	0.8	0.8
Total dry weight amount	kt (dry)	62.4	62.4	25.5	3.1	1.1	1.0	0.8	1.2	0.5	0.8	0.5	0.6	0.7	0.7	0.7

### c) Uncertainties and Time-series Consistency

#### ● Uncertainties

Details of the uncertainty assessment on this category are indicated in Table 7-64.

Table 7-64 Uncertainty assessment on the category “open burning of waste (5.C.2.-)”

Item	GHGs	Emission/removal factor uncertainty		Activity data uncertainty		Emission/removal uncertainty		The method of evaluating uncertainty in emission factor	The method of evaluating uncertainty in activity data	The method of evaluating uncertainty in emissions/removals	
		(-)	(+)	(-)	(+)	(-)	(+)				
Industrial waste	Plastics	CO <sub>2</sub>	-2%	+2%	-30%	+30%	-30%	+30%	Due to the lack of information for the uncertainty of the emission factor, the uncertainty in municipal waste plastics is substituted based on expert judgment.	The uncertainty in specially-controlled industrial waste based on expert judgment is used.	Combined by using the formula for propagation of errors.
		CH <sub>4</sub>	-100%	+100%	-30%	+30%	-104%	+104%	The uncertainties are assessed as those of the 2006 IPCC Guidelines' default emission factors.		
		N <sub>2</sub> O	-100%	+100%	-30%	+30%	-104%	+104%			

#### ● Time-series Consistency

Since activity data based on the survey are available only for and after FY1996, consistent data over the time series are developed based on the estimation. The emissions are calculated in a consistent manner.

### d) Category-specific QA/QC and Verification

General inventory QC procedures are conducted in accordance with the 2006 IPCC Guidelines. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

**e) Category-specific Recalculations**

By updating the statistical data, emissions in FY2018 and FY2019 were recalculated. See Chapter 10 for impact on trend.

**f) Category-specific Planned Improvements**

No improvements are planned.

**7.4.3. Waste Incineration and Energy Use (Reported on Energy Sector) (1.A.)****7.4.3.1. Waste Incineration with Energy Recovery (1.A.)****a) Category Description**

In this category, CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O emissions from the incineration of municipal and industrial waste with energy recovery are estimated and reported. The reporting category for the emissions is “Other sectors (Category 1.A.4.)” and the fuel types are classified as “Other fossil fuels” and/or “Biomass” as shown on the Table 7-25.

**b) Methodological Issues**

Methodologies similar to the ones used in “7.4.1.1. Municipal Solid Waste (5.C.1.-)” and “7.4.1.2. Industrial Waste (5.C.1.-)” are used. Emissions are calculated using the following equations:

**1) CO<sub>2</sub>****● Estimation Method****➤ Municipal Solid Waste**

$$E = EF \times A \times R$$

- E* : Emission of CO<sub>2</sub> from waste incineration [kg-CO<sub>2</sub>]  
*EF* : Emission factor for incineration (dry basis) [kg-CO<sub>2</sub>/t]  
*A* : Amount of waste incinerated (dry basis) [t]  
*R* : Percentage of municipal solid waste incinerated at incineration facilities with energy recovery

**➤ Industrial Waste**

$$E = EF \times A \times R$$

- E* : Emission of CO<sub>2</sub> from waste incineration [kg-CO<sub>2</sub>]  
*EF* : Emission factor for waste incineration (wet basis) [kg-CO<sub>2</sub>/t]  
*A* : Amount of waste incinerated (wet basis) [t]  
*R* : Fraction of industrial waste incinerated at industrial waste incineration facilities with energy recovery (by waste type)



## 2) CH<sub>4</sub>, N<sub>2</sub>O

### ● Estimation Method

#### ➤ Municipal Solid Waste

$$E = \sum_i (EF_i \times A_i) \times R$$

- E* : Emissions of CH<sub>4</sub> or N<sub>2</sub>O from incineration of municipal solid waste [kg-CH<sub>4</sub>], [kg-N<sub>2</sub>O]  
*EF<sub>i</sub>* : Emission factor for municipal solid waste incinerator type *i* (wet basis) [kg-CH<sub>4</sub>/t] [kg-N<sub>2</sub>O/t]  
*A<sub>i</sub>* : Amount of municipal solid waste incinerated for incinerator type *i* (wet basis) [t]  
*R* : Percentage of municipal solid waste incinerated at facilities with energy recovery

#### ➤ Industrial Waste

$$E = \sum_j (EF_j \times A_j \times R_j)$$

- E* : Emissions of CH<sub>4</sub> or N<sub>2</sub>O from incineration of industrial waste [kg-CH<sub>4</sub>], [kg-N<sub>2</sub>O]  
*EF<sub>j</sub>* : Emission factor for industrial waste type *j* (wet basis) [kg-CH<sub>4</sub>/t], [kg-N<sub>2</sub>O/t]  
*A<sub>j</sub>* : Amount of industrial waste type *j* incinerated (wet basis) [t]  
*R<sub>j</sub>* : Fraction of industrial waste type *j* incinerated at industrial waste incineration facilities with energy recovery

### ● Activity Data Converted into Energy Units (Reference Value)

Activity data converted into energy units to be reported in CRF is estimated as indicated below.

#### ➤ Municipal Solid Waste

$$A_E = A \times GCV \times R / 10^6$$

- A<sub>E</sub>* : Calorific value of activity data of MSW [TJ]  
*A* : Total amount of MSW incinerated [kg (wet basis)]  
*GCV* : Gross calorific value of MSW [MJ/kg]  
*R* : Fraction of MSW incinerated at MSW incineration facility with energy recovery

Based on the actual measurement results obtained at municipality, the calorific value of MSW is 9.9 (MJ/kg).

#### ➤ Industrial Waste

$$A_E = \sum_j A_j \times GCV_j \times R / 10^6$$

- A<sub>E</sub>* : Calorific value of activity data of industrial waste [TJ]  
*A<sub>j</sub>* : Amount of industrial waste type *j* incinerated [kg (wet basis)]  
*GCV<sub>j</sub>* : Gross calorific value of industrial waste type *j* [MJ/kg]  
*R* : Fraction of industrial waste type *j* incinerated at industrial waste incineration facility with energy recovery

Calorific value of industrial waste is indicated in Table 7-69 (as referred to hereinafter).

### c) Uncertainties and Time-series Consistency

Methodologies similar to the ones used in “7.4.1.1. Municipal Solid Waste (5.C.1.-)” and “7.4.1.2. Industrial Waste (5.C.1.-)” are used.

**d) Category-specific QA/QC and Verification**

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

**e) Category-specific Recalculations**

Same recalculations as the category waste incineration (without energy recovery) were conducted. For details, see the paragraphs for category-specific recalculations on “7.4.1.1. Municipal Solid Waste (5.C.1.-)” and “7.4.1.2. Industrial Waste (5.C.1.-)”.

**f) Category-specific Planned Improvements**

No improvements are planned.

**7.4.3.2. Direct Use of Waste as Alternative Fuel (1.A.)****a) Category Description**

In this category, CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O emissions from waste directly used as alternative fuel are estimated and reported. The reporting category for the emissions for each type of waste is, according to its use as raw material or fuel, either “Energy industries (Category 1.A.1.)”, “Manufacturing industries and Construction (1.A.2.)” or “Other sectors (Category 1.A.4.)”. The fuel types are classified as “Other fossil fuels” and/or “Biomass” as indicated in Table 7-25.

GHG emissions during the direct use of waste as a raw material, such as plastics used as reducing agents in blast furnaces or as a chemical material in coking furnaces, or use of intermediate products manufactured using the waste as a raw material, are estimated in this category. The waste used as raw material and the ones used as alternative fuel are combined and expressed as “Raw Material/Fuel Use” in this section.

**b) Methodological Issues****1) CO<sub>2</sub>**● **Estimation Method**

Emissions are estimated by multiplying the incinerated volume of each type of waste used as raw material or fuel by Japan’s country-specific emission factor. The wastes included in the estimation are the portions used as raw material or fuel of: plastics in MSW, plastics and waste fossil-fuel derived oil in industrial waste, and waste tires.

● **Emission Factor**

Emission factors are established for the plastics from MSW that are used as chemical raw material in coke ovens and waste tires. The remaining emission sources used the emission factors for “7.4.1. Waste Incineration (without Energy Recovery) (5.C.1.)”.

Table 7-65 CO<sub>2</sub> Emission factors specially defined for this category

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
MSW-coke oven	kg-CO <sub>2</sub> /t (dry)	1,467	1,467	1,467	1,467	1,467	1,467	1,467	1,467	1,467	1,467	1,467	1,467	1,467	1,467	1,467
Waste tire	kg-CO <sub>2</sub> /t (dry)	1,867	1,794	1,799	1,746	1,759	1,744	1,743	1,744	1,736	1,698	1,677	1,673	1,661	1,645	1,641

### ● Activity Data

For details of the amount of waste used as raw materials or fuels, see the 7.4.3.2.a-7.4.3.2.c.

Table 7-66 Amount of direct use of waste as alternative fuel (Activity data: wet basis)

Waste type	Application breakdown	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
MSW	Plastics	Liquefaction	kt (wet)	NO	NO	3	7	1	NO	NO	NO	NO	NO	NO	NO	NO	NO	
		Blast furnace reducing agent	kt (wet)	NO	NO	25	37	27	26	26	30	27	31	29	28	29	28	27
		Coke oven chemical feedstock	kt (wet)	NO	NO	11	175	177	169	171	NO	17	29	25	32	17	25	21
		Casification	kt (wet)	NO	NO	1	59	53	51	62	58	51	55	55	57	46	45	42
Industrial waste	Waste oil	(Unclassified)	kt (wet)	1,243	1,461	1,452	1,848	1,701	1,686	1,764	1,707	1,633	1,786	1,664	1,664	1,809	1,900	1,953
		Blast furnace reducing agent	kt (wet)	NO	NO	57	160	134	114	134	107	149	144	156	168	131	148	120
	Plastics	Chemical industry	kt (wet)	5	4	5	2	1	1	1	1	0.4	0.4	0.2	3	3	4	5
		Paper industry	kt (wet)	NO	NO	3	3	18	16	15	14	18	16	17	18	18	18	17
		Cement burning	kt (wet)	NO	9	102	302	445	469	479	518	595	576	623	643	718	746	746
		Automobile manufacture	kt (wet)	16	10	8	4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
		Liquefaction	kt (wet)	NO	NO	1	1	1	1	1	1	1	1	0.1	NO	1	1	1
		Casification	kt (wet)	NO	NO	NO	11	117	78	79	97	90	81	79	91	97	86	99
	Wood	(Unclassified)	kt (wet)	1,635	1,635	2,061	2,683	3,900	4,065	4,151	4,425	4,878	4,628	4,555	4,832	4,690	5,097	5,376
	Waste tire	Cement burning	kt (wet)	111	275	361	181	95	77	66	62	53	59	63	70	64	70	69
Boiler		kt (wet)	119	126	75	12	8	6	6	6	2	2	5	3	3	2	2	
Iron manufacture		kt (wet)	NO	NO	57	51	30	31	30	27	27	20	19	17	14	18	16	
Casification		kt (wet)	NO	NO	NO	27	49	45	45	44	50	49	51	58	61	56	10	
Metal refining		kt (wet)	67	37	30	10	1	1	NO	NO	NO	NO	NO	NO	NO	NO	NO	
Tire manufacture		kt (wet)	NO	32	39	24	23	20	27	27	27	22	23	23	21	20	9	2
Paper manufacture		kt (wet)	NO	26	42	210	388	377	363	372	415	439	407	436	446	402	412	
Power generation		kt (wet)	NO	NO	7	9	9	32	37	40	46	51	58	47	66	66	96	
Refuse-derived fuel	(Unclassified)	kt (wet)	34	39	148	415	380	389	384	386	388	361	360	359	362	318	318	
Refuse paper and plastic fuel (RPF)	Petroleum product manufacturer	kt (wet)	NO	NO	0.4	5	4	3	4	3	4	4	3	4	0.2	0.1	0.4	
	Chemical industry	kt (wet)	NO	NO	7	15	22	26	27	26	20	22	19	18	17	17	9	
	Paper industry	kt (wet)	NO	8	25	465	803	840	877	926	912	940	1,014	1,022	1,036	1,013	992	
	Cement manufacturer	kt (wet)	NO	NO	0.2	8	15	16	14	16	17	14	11	13	15	18	16	

Note:

- The amount of biogenic fraction such as biomass-based plastics, waste animal and vegetable oil, and wood are not included in the activity data for the estimation of CO<sub>2</sub> emissions.
- For the activity data to estimate CO<sub>2</sub> emissions except for waste oils and plastics in industrial waste, the figures in the above table are converted into dry basis amount by subtracting water contents.
- Waste oil includes “used lubricant” and “used solvent”.

## 2) CH<sub>4</sub>, N<sub>2</sub>O

### ● Estimation Method

Emissions are estimated by multiplying the amount of each type of waste used as raw material or fuel by the country-specific emission factor.

### ● Emission Factor

Emission factors for waste used as raw material and fuel are determined by multiplying the emission factor for applicable types of furnaces by the calorific value of each waste type, and converting the result to the weight-based values.

Table 7-67 shows the data used in the estimation.

$$EF_i = EF_{E,i} \times GCV_i / 1000$$

- $EF_i$  : Emission factor for waste type  $i$  [ kg-CH<sub>4</sub> / t(wet)], [kg-N<sub>2</sub>O/ t(wet)]  
 $EF_{E,i}$  : Emission factor for waste type  $i$  on calorie basis [kg-CH<sub>4</sub>/TJ], [kg-N<sub>2</sub>O/TJ]  
 $GCV_i$  : Gross calorific value of waste type  $i$  [MJ/kg]

Table 7-67 Data used for the calculation of CH<sub>4</sub> and N<sub>2</sub>O emission factors  
for direct use of wastes as alternative fuel

Waste type	Application breakdown	Emission factor for furnaces and ovens (Energy sector)		Calorific value	
		CH <sub>4</sub>	N <sub>2</sub> O		
MSW	Plastics	Liquefaction	Boilers (Heavy fuel oil A, diesel oil, kerosene, naphtha, other liquid fuels)		Calorific value of plastics
		Blast furnace reducing agent	NA		NA
		Coke oven chemical feedstock	NA		NA
		Gasification	NA		NA
Industrial waste	Waste oil	(Unclassified)	Boilers (Heavy fuel oil A, diesel oil, kerosene, naphtha, other liquid fuels)		Specific gravity of reclaimed oil/waste oil <sup>1)</sup>
	Plastics	Blast furnace reducing agent	NA		NA
		Chemical industry	Boilers (wood, charcoal, and other solid fuel)	Fluidized-bed boilers (solid fuel)	Calorific value of plastics
		Paper industry			
		Automobile manufacturer			
		Cement burning	Other industrial furnaces (solid fuel)		
	Liquefaction	Boilers (Heavy fuel oil A, diesel oil, kerosene, naphtha, other liquid fuels)			
Gasification	NA		NA		
Wood	(Unclassified)	Boilers (wood, charcoal)	Boilers (other than fluidized-bed) (solid fuel)	Calorific value of wood <sup>2)</sup>	
Waste tire	Iron manufacture	NA		NA	
	Cement burning	Other industrial furnaces (solid fuel)		Calorific value of waste tires	
	Gasification	Other industrial furnaces (gas fuels) and other industrial furnaces (liquid fuels) <sup>3)</sup>			
	Metal refining (pyrolysis)	Boilers (gas fuels)			
	Boiler	Boilers (wood, charcoal, and other solid fuel)	Boilers (other than fluidized-bed) (solid fuel)		
	Tire manufacture				
	Paper manufacture				
Power generation					
Refuse-derived fuel (RDF)	(Unclassified)	Boilers (wood, charcoal, and other solid fuel)	Boilers (other than fluidized-bed) (solid fuel)	Calorific value of RDF	
Refuse-derived fuel (RPF)	Petroleum product manufacturer	Boilers (wood, charcoal, and other solid fuel)	Boilers (other than fluidized-bed) (solid fuel)	Calorific value of RPF <sup>4)</sup>	
	Chemical industry				
	Paper industry				
	Cement manufacturer	Other industrial furnaces (solid fuel)			

Note:

- 1) Calorific value per unit volume is determined by dividing by the specific gravity of waste oil (0.9 kg/l) obtained from JSWME (1997).
- 2) Data from Environmental Agency (1995)
- 3) The percentage of substances recovered during the gasification of waste tires. A weighted average is calculated by using the proportions of gas and oil (22% and 43%) reported in the Hyogo Pref. (2003).
- 4) Weighted average of calorific values calculated based on the manufacturing ratio of Coal substitution RPF and Coke substitution RPF given by the Japan RPF Industry Association (2004)

Table 7-68 CH<sub>4</sub> and N<sub>2</sub>O emission factors for the use of waste as raw material or fuel  
used in the Energy sector

Furnace type/Fuel type	CH <sub>4</sub> Emission factor [kg-CH <sub>4</sub> /TJ]	N <sub>2</sub> O Emission factor [kg-N <sub>2</sub> O/TJ]
Boilers (Heavy fuel oil A, diesel oil, kerosene, naphtha, other liquid fuels)	0.26	0.19
Boilers (gas fuels)	0.23	0.17
Boilers (steam coal, coke, other solid fuels)	0.13	–
Boilers (wood, charcoal)	74.9	–
Boilers (other than fluidized-bed) (solid fuels)	–	0.85
Normal pressure fluidized-bed boilers (solid fuels)	–	54.39
Other industrial furnaces (liquid fuel)	0.83	1.8
Other industrial furnaces (solid fuel)	13.1	1.1
Other industrial furnaces (gaseous fuel)	2.3	1.2

Reference: MOE (2006a)

Table 7-69 Calorific Value of waste incinerated and used as raw material or fuel

Item	Unit	GCV	Reference	
Waste oil (including reclaimed oil)	TJ/l	40.2	<i>General Energy Statistics</i> (ANRE); estimated with 0.9[kg/L] (JSWME, 1997)	
Plastics	MJ/kg	29.3	<i>General Energy Statistics</i> (ANRE)	
Paper/cardboard	MJ/kg	15.1	JSWME (1997), dry basis; value is obtained by subtracting water content	
Wood	MJ/kg	14.4	<i>General Energy Statistics</i> (ANRE)	
Textiles	MJ/kg	17.9	JSWME (1997), dry basis; value is obtained by subtracting water content	
Food waste (Animal and vegetable residues/animal carcasses)	MJ/kg	4.4	JSWME (1997), dry basis; value is obtained by subtracting water content	
Sludge (including sewage sludge)	MJ/kg	4.7	<i>General Energy Statistics</i> (ANRE), dry basis; value is obtained by subtracting water content	
Waste tire	2004 and before	MJ/kg	20.9	<i>General Energy Statistics</i> (ANRE)
	2005 and later	MJ/kg	33.2	<i>General Energy Statistics</i> (ANRE)
RDF	MJ/kg	18.0	<i>General Energy Statistics</i> (ANRE)	
RPF	MJ/kg	29.3	<i>General Energy Statistics</i> (ANRE)	

### ● Activity Data

#### ➤ Amount of Waste Used as Raw Material or Fuel

Activity data are determined for each category using the wet-basis values (Table 7-66). For more details, see each section.

#### ➤ Activity Data Converted into Energy Units (Reference Value)

Activity data converted into energy units to be reported in CRF are calculated as indicated below.

$$A_{E,i} = N_i \times GCV_i / 10^6$$

$A_{E,i}$  : Activity data of waste type  $i$ , converted into energy units [TJ]  
 $N_i$  : Amount of waste type  $i$  used as raw material or fuel [kg (wet)]  
 $GCV_i$  : Gross calorific value of waste type  $i$  [MJ/kg]

#### c) Uncertainties and Time-series Consistency

See the respective section.

#### d) Category-specific QA/QC and Verification

See the respective section.

#### e) Category-specific Recalculations

See the respective section.

#### f) Category-specific Planned Improvements

See the respective section.

### 7.4.3.2.a. Municipal Waste (Plastic) Used as Alternative Fuel (1.A.1 and 1.A.2)

#### a) Category Description

This category covers the emissions from municipal waste (plastic) used as alternative fuels. Plastics in MSW collected under the Containers and Packaging Recycling Law are processed into petrochemical, blast furnace reducing agent, chemical raw material in coke oven, and gasification to be used as alternative fuel or raw material. Note that PET bottles are not included in municipal waste in this source.

## b) Methodological Issues

### 1) CO<sub>2</sub>

#### ● Estimation Method

Emissions are calculated by multiplying the amount of fossil-fuel derived plastic in MSW by each usage (petrochemical, blast furnace reducing agent, chemical raw material in coke oven, and gasification) by Japan's country-specific emission factor.

#### ● Emission Factor

For the emission factors for plastics in MSW in the usage of petrochemical, blast furnace reducing agent, and gasification, the same values applied in "7.4.1.1. Municipal Solid Waste (5.C.1.-) are applied. The emission factor for plastics used as chemical raw material in coke ovens is set as the volume of hydrocarbon that is used as chemical raw material and from which no CO<sub>2</sub> is emitted into the air by subtracting the percentage of carbon in the plastics that migrates to hydrocarbon oil in the coke oven (47.9%) from emission factor for plastics (MSW).

$$EF_{coke} = EF_{plastics} \times (1 - M) \times FCF_{MSW\ plastics}$$

$EF_{coke}$	: Emission factor for plastics used as raw material in coke ovens (dry basis)
$EF_{plastics}$	: Emission factor for the incineration of plastics in municipal solid waste (dry basis)
$M$	: Fraction of carbon in plastics used as chemical raw material for coke ovens that migrates to hydrocarbon
$FCF_{MSW\ plastics}$	: Fossil-fuel derived fraction of plastics in MSW [%]

#### ● Activity Data

The amount of plastics in MSW used as raw material or fuel by usage (wet basis) is estimated by the total amount collected by designated legal bodies and municipalities to be processed as raw material or fuel by usage (wet basis). The methodology to estimate activity data for this category is the same as that in the section "7.4.1.1. Municipal Solid Waste (5.C.1.-) b) 1) CO<sub>2</sub>".

$$A_i = WP_i \times (1 - u_{plastics})$$

$A_i$	: Amount of fossil-fuel derived plastics used as raw material or fuel for usage $i$ [t (dry)]
$WP_i$	: Amount of plastics used as raw material or fuel for usage $i$ [t (wet)]
$u_{plastics}$	: Percentage of water content in plastics [%]

#### ➤ The Amount of Plastics in MSW Used as Raw Material or Fuel by Usage (Wet Basis)

##### - Processing of plastics collected by designated legal bodies

The amount of the plastics in MSW collected by designated legal bodies into raw material or fuel is determined from the amount reported (pyrolytic oil: petrochemical, blast furnace reducing agent, chemical raw material in coke-oven, syngas, and gasification) in the "Plastic Containers and Packaging (Other Plastics, Food Trays)" section of the *Statistics of Commercial Recycling of Plastics (Recycling)* (Japan Containers and Packaging Recycling Association: JCPRA). Usage in products that do not emit CO<sub>2</sub> is deducted.

##### - Processing of plastics collected by municipalities

The amount of plastics in MSW collected by municipalities and processed into raw material or fuel is calculated as indicated below.

$$P_{LG} = \sum (PR - P_{JCPRA}) \times F_i \times R_i$$

- $P_{LG}$  : Amount of plastics in MSW collected by municipalities and processed into raw material or fuel [t (wet)]  
 $PR$  : Amount of all plastics that are commercially recycled under the Plastic Containers and Packaging Recycling Law (wet basis)<sup>1)</sup> [t (wet)]  
 $P_{JCPRA}$  : Amount of plastics (wet basis) that is commercially recycled through designated legal bodies<sup>2)</sup> [t (wet)]  
 $F_i$  : Percentage of commercially recycled plastics by recycling method  $i^3)$  [%]  
 $R_i$  : Percentage of commercially recycled plastic products by recycling method  $i^4)$  [%] (The percentage for designated legal bodies is substituted for the value for municipalities.)

Note:

- 1) The amount is determined from the *Annual Recycling Statistics under the Plastic Containers and Packaging Recycling Law* (MOE).
- 2) The amount is determined from the “Actual Collection of Plastic Containers and Packages” section of the *Statistics of Commercial Recycling of Plastics (Recycling)* (JCPRA).
- 3) The rates are obtained from the percentages for various methods of commercial recycling of the plastics collected through municipal channels in the Results of the *2001 Questionnaire to Municipalities on Waste Plastic Processing* compiled by the Plastic Waste Management Institute.
- 4) The values are calculated by using data from the *Annual Recycling Statistics under the Plastic Containers and Packaging Recycling Law* (MOE) and the *Statistics of Commercial Recycling of Plastic (Recycling)* (JCPRA).

### ➤ **Water Content Ratio**

Water content ratio of 4% is determined based on the data provided by the Japan Containers and Packaging Recycling Association (MOE, 2006b).

### ➤ **Fossil-fuel Derived Fraction of Plastics in MSW**

See Table 7-32 in the section “7.4.1.1. Municipal Solid Waste (5.C.1.-).”

## 2) $CH_4$ , $N_2O$

For estimation method and emission factors, see the section “7.4.3.2. Direct Use of Waste as Alternative Fuel (1.A.)”. The amount of plastics used as raw material or fuel by usage (wet basis) is determined by the total amount collected by designated legal bodies and municipalities to be processed as raw material or fuel by usage (wet basis); this value includes the amount of biomass-based plastics consumed.

## c) **Uncertainties and Time-series Consistency**

### ● **Uncertainties**

The uncertainty assessment is conducted as well as assessment in the category of the municipal waste incineration. Details of the uncertainty assessment on this category are shown in the Table 7-70.

Table 7-70 Uncertainty assessment for municipal waste plastics used as alternative fuels (1.A.1 and 1.A.2)

Item	GHGs	Emission /removal factor uncertainty		Activity data uncertainty		Emission /removal uncertainty		The method of evaluating uncertainty in emission factor	The method of evaluating uncertainty in activity data	The method of evaluating uncertainty in emissions/removals
		(-)	(+)	(-)	(+)	(-)	(+)			
Plastics	CO <sub>2</sub>	-1%	+1%	-10%	+10%	-10%	+10%	The equivalent assessment of the uncertainty in municipal waste plastics in “5.C Incineration” is used.	The uncertainty in municipal waste statistics based on expert judgment is used.	Combined by using the formula for propagation of errors.
	CH <sub>4</sub>	-39%	+39%	-10%	+10%	-40%	+40%			
	N <sub>2</sub> O	-34%	+34%	-10%	+10%	-35%	+35%	The equivalent assessment of the uncertainty in municipal waste in “5.C Incineration” is used.		

### ● **Time-series Consistency**

Time series consistency in emission estimates has been ensured. However, the statistical data for activity data have been available since FY2000 because the use of waste as alternative fuel or raw material was not a common practice prior to FY2000 in Japan.

**d) Category-specific QA/QC and Verification**

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

**e) Category-specific Recalculations**

By revising biomass-based plastic products data, CO<sub>2</sub> emissions from FY2005 onward were recalculated. By updating the statistical data, emissions in FY2019 were recalculated. See Chapter 10 for impact on trend.

**f) Category-specific Planned Improvements**

No improvements are planned.

**7.4.3.2.b. Industrial Waste (Plastics, Waste Oil, and Wood) Used as Alternative Fuels (1.A.2.))****a) Category Description**

This category covers GHG emissions from industrial waste (plastics, waste oil, and wood) used as raw material or fuels.

**b) Methodological Issues****1) CO<sub>2</sub>**● **Estimation Method and Emission Factor**

Emissions are estimated by multiplying the amount of plastics and fossil-fuel derived waste oil used as raw material or fuels by emission factor used for incineration of industrial waste (See “7.4.1.2. Industrial Waste (5.C.1.-)”).

● **Activity Data**➤ **Plastics**

Estimated activity data are the amounts of plastics (wet basis) in industrial waste used as raw material or fuel in steel industry, chemical industry, paper industry, cement Manufacturer, automobile manufacturer, and “other industry”. The amount of plastics in industrial waste used as raw material or fuel in each industry is provided by the following data sources: for steel industry, the *Current State of Plastics Waste Recycling and Future Tasks* published by the Japan Iron and Steel Federation; for cement manufacturing industry, from the *Cement Handbook* published by the Japan Cement Association; for chemical industry, paper industry, and automobile manufacturer, the amount of plastics used for fluid bed boiler provided by the Japan Chemical Industry Association, the Japan Paper Association, the Japan Automobile Manufacturers Association. For “other industry”, the activity data is obtained from the *Review Report on Improvement of Accuracy and Faster Compilation of Waste Statistics* (Environmental Regeneration and Material Cycles Bureau of MOE) distinguished between plastics liquefaction and gasification.

➤ **Waste Oil (Fossil-fuel derived)**

The activity data for waste oil is mainly obtained from the *Cyclical Use of Waste Report* (MOE). The valuables, which are not included in the *Cyclical Use of Waste Report* (MOE), is additionally obtained from the other sources as “Used lubricant” and “Used solvent”.



- **Waste Oil**

The amount of waste oil indicated as “Fuel Usage” of “Direct Recycle Usage” and “Recycle Usage after Treatment” of industrial waste is used as the activity data of the waste oil that includes biogenic fraction. Hence in the estimation method for CO<sub>2</sub> emissions, the amount of biogenic “waste animal and vegetable oil” is subtracted from this item in the same way as indicated in “7.4.1.2. Industrial Waste (5.C.1.-) 7.4.1.2. b)1) CO<sub>2</sub>”. The data for FY1997 and before are estimated by using the trend of the amount of incinerated industrial waste oil.

- **Used lubricants**

The amount of recycled heavy oil products derived from used lubricant, indicated in the *Lubricant Recycle Handbook*, Japan Lubricating Oil Society is also used as activity data of fossil fuel-derived waste oil. All used lubricants are assumed to be fossil-fuel derived. The data for FY2001 and before are estimated by using the trend of the amount of incinerated industrial waste oil.

- **Used solvents**

The data of the amount of used solvents to be used as alternative fuel (valuables-origin), surveyed by the Japan Solvent Recycling Industry Association is also used as activity data for fossil fuel-derived waste oil. All used solvents are assumed to be fossil fuel- derived.

2) **CH<sub>4</sub>, N<sub>2</sub>O**

● **Estimation Method and Emission Factor**

See the section “7.4.3.2. Direct Use of Waste as Alternative Fuel (1.A.)”

● **Activity Data**

➤ **Plastics**

The activity data used for CO<sub>2</sub> emission estimates from this source is also used for CH<sub>4</sub> and N<sub>2</sub>O emission estimates. Note plastics as blast furnace reducing agent and plastics gasified are not included in the activity data (see also Table 7-26).

➤ **Waste Oil (Fossil-fuel derived / Animal and Vegetable)**

The activity data used for CO<sub>2</sub> emission estimates from this source is also used for CH<sub>4</sub> and N<sub>2</sub>O emission estimates. Unlike the activity data for CO<sub>2</sub> emissions, waste animal and vegetable oil are also included for the estimation of activity data from this source.

➤ **Wood**

The amount of usage of wood as raw material or fuel is obtained from the “fuel usage” in the “direct recycle usage” and the “fuel usage” in the “recycle usage after treatment” in the *Cyclical Use of Waste Report* (MOE). The values before FY1997 are estimated by using the average value in the period of FY1998-2002.

c) **Uncertainties and Time-series Consistency**

● **Uncertainties**

The uncertainty assessment is conducted as well as assessment in the category of the industrial waste incineration. Details of the uncertainty assessment on this category are shown in the Table 7-71.

Table 7-71 Uncertainty assessment for industrial waste plastics used as alternative fuels (1.A.2)

Item	GHGs	Emission /removal factor uncertainty		Activity data uncertainty		Emission /removal uncertainty		The method of evaluating uncertainty in emission factor	The method of evaluating uncertainty in activity data	The method of evaluating uncertainty in emissions/ removals
		(-)	(+)	(-)	(+)	(-)	(+)			
Plastics	CO <sub>2</sub>	-2%	+2%	-30%	+30%	-30%	+30%	The equivalent assessment of the uncertainty in industrial waste plastics in “5.C Incineration” is used.	The uncertainty based on expert judgment in industrial waste statistics is applied.	Combined by using the formula for propagation of errors.
	CH <sub>4</sub>	-100%	+216%	-30%	+30%	-104%	+218%			
	N <sub>2</sub> O	-44%	+44%	-30%	+30%	-53%	+53%			
Waste oil	CO <sub>2</sub>	-2%	+2%	-30%	+30%	-30%	+30%	The equivalent assessment of the uncertainty in industrial waste oil in “5.C Incineration” is used.		Combined by using the formula for propagation of errors.
	CH <sub>4</sub>	-100%	+181%	-30%	+30%	-104%	+184%			
	N <sub>2</sub> O	-76%	+76%	-30%	+30%	-81%	+81%			
Wood	CH <sub>4</sub>	-100%	+412%	-30%	+30%	-104%	+413%	The equivalent assessment of the uncertainty in industrial waste paper/cardboard or wood in “5.C Incineration” is used.		Combined by using the formula for propagation of errors.
	N <sub>2</sub> O	-64%	+64%	-30%	+30%	-71%	+71%			

### ● *Time-series Consistency*

Data on the amount of waste oil and wood used as alternative fuels have been available since FY1998. For waste oil, consistent data over the time series are developed by using the total amount of waste oil incinerated without the use of waste oil as alternative fuel. For wood, the average of FY1998-2002 data is used to estimate the amount of wood for the past years. The emissions are calculated in a consistent manner.

### d) *Category-specific QA/QC and Verification*

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

### e) *Category-specific Recalculations*

By revising biomass-based plastic products data, CO<sub>2</sub> emissions from FY2005 onward were recalculated. By updating the statistical data, emissions in FY2019 were recalculated. For detail, see the section “7.1.5. General Recalculations for Emissions from Waste Sector”. See Chapter 10 for impact on trend.

### f) *Category-specific Planned Improvements*

No improvements are planned.

## 7.4.3.2.c. Waste Tires Used as Alternative Fuels (1.A.1 and 1.A.2)

### a) *Category Description*

This category covers the emissions from the use of waste tires as raw materials or fuels.

### b) *Methodological Issues*

#### 1) *CO<sub>2</sub>*

#### ● *Estimation Method*

The emissions are calculated by multiplying the incinerated amount of waste tires used as raw materials or fuels by Japan’s country-specific emission factor.

- **Emission Factor**

The emission factor for waste tires is calculated by multiplying the fossil fuel-derived carbon content of the waste tires by the oxidation factor of the waste tires at the facilities that use waste tires as fuel. The volume of the fossil fuel-derived carbon in the waste tires is calculated by the material contents of new tires. The oxidation factor for waste tires is set to the default value of 100% indicated in the 2006 IPCC Guidelines.

$$EF = C \times OF \times 1000 \times 44/12$$

*EF* : Emission factor for the incineration of waste tires (dry basis) [kg-CO<sub>2</sub>/t]  
*C* : Fossil fuel-derived carbon content in waste tires  
*OF* : Oxidation factor of waste tires

- **Activity Data**

Activity data (dry basis) is calculated by subtracting the water content in the waste tires determined from analyses of three constituents of divided tires (Environmental Sanitation Center, 2001) from the amount of waste tires used as raw material or fuel (wet basis) in the *Tire Industry of Japan* (Japan Automobile Tire Manufacturers Association).

## 2) CH<sub>4</sub>, N<sub>2</sub>O

- **Estimation Method and Emission Factor**

See the section “7.4.3.2. Direct Use of Waste as Alternative Fuel (1.A.)”

- **Activity Data**

The volume of waste tires used as raw material or fuel by usage that is determined during the calculation of the CO<sub>2</sub> emissions from this source is used. For the activity data, the volume of waste tires recorded in the following categories are used: “Cement burning” for use in cement kilns; “Small and medium size boilers”, “Tire manufacture”, “Paper manufacturer”, and “Power generation” for use in boilers; “Metal refining” for use in carbonization; and “Gasification” for use in gasification processes.

### c) Uncertainties and Time-series Consistency

- **Uncertainties**

The uncertainty assessment is conducted as well as assessment in the category of the industrial waste incineration. Details of the uncertainty assessment on this category are shown in the Table 7-72.

Table 7-72 Uncertainty assessment for waste tire used as alternative fuels (1.A.1 and 1.A.2)

Item	GHGs	Emission /removal factor uncertainty		Activity data uncertainty		Emission /removal uncertainty		The method of evaluating uncertainty in emission factor	The method of evaluating uncertainty in activity data	The method of evaluating uncertainty in emissions/removals
		(-)	(+)	(-)	(+)	(-)	(+)			
Waste tire	CO <sub>2</sub>	-2%	+2%	-30%	+30%	-30%	+30%	Due to the lack of information for the uncertainty of the emission factor, the uncertainty in industrial waste plastic is substituted based on expert judgment.	The uncertainty based on expert judgment in industrial waste statistics is applied.	Combined by using the formula for propagation of errors.
	CH <sub>4</sub>	-100%	+216%	-30%	+30%	-104%	+218%			
	N <sub>2</sub> O	-44%	+44%	-30%	+30%	-53%	+53%			

- **Time-series Consistency**

The emissions are calculated in a consistent manner.

**d) Category-specific QA/QC and Verification**

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

**e) Category-specific Recalculations**

No recalculations are conducted.

**f) Category-specific Planned Improvements**

No improvements are planned.

### 7.4.3.3. Incineration of Waste Processed as Fuel (1.A.)

#### 7.4.3.3.a. Incineration of Refuse-based Solid Fuels (RDF and RPF) (1.A.1 and 1.A.2)

**a) Category Description**

In this category, CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O emissions from waste that is processed and used as fuel are estimated and reported. Refuse-derived solid fuels (RDF as Refuse Derived Fuel and RPF as Refuse Paper and Plastic Fuel) are used for the estimation of emissions from fuels produced from waste. The reporting categories for the above emissions are included in “Energy industries (1.A.1.)” and “Manufacturing industries and construction (1.A.2)” as indicated in Table 7-26. The fuel types are classified as “Other fossil fuels” and/or “Biomass” as indicated in Table 7-25.

**b) Methodological Issues**

**1) CO<sub>2</sub>**

- **Estimation Method**

Emissions are estimated by multiplying the amount of RDF and RPF incinerated by Japan’s country-specific emission factor.

$$E_{RDF} = EF_{RDF} \times AD_{RDF}$$

$E_{RDF}$  : CO<sub>2</sub> Emissions from RDF use [kg-CO<sub>2</sub>]  
 $EF_{RDF}$  : Emission factor for RDF use (dry basis) [kg-CO<sub>2</sub>/t]  
 $AD_{RDF}$  : Activity data for RDF use (dry basis) [t]

$$E_{RPF} = EF_{RPF} \times AD_{RPF}$$

$E_{RPF}$  : CO<sub>2</sub> Emissions from RPF use [kg-CO<sub>2</sub>]  
 $EF_{RPF}$  : Emission factor for RPF use (dry basis) [kg-CO<sub>2</sub>/t]  
 $AD_{RPF}$  : Activity data for RPF use (dry basis) [t]

### ● **Emission Factor**

Emission factor associated with the use of the refuse-derived solid fuels (RDF and RPF) is calculated for RDF and RPF respectively by the equation shown below.

#### ➤ **RDF**

By considering fossil-fuel derived fraction in MSW (paper/cardboard, synthetic fibers and plastics) included in RDF, emission factor for RDF use is estimated by the equation shown below.

$$EF_{RDF} = 1000 \times \sum_i (F_{RDF,i} \times CF_i \times FCF_i) \times OF_{RDF} \times 44/12$$

$F_{RDF,i}$  : Fraction of waste type  $i$  derived content contained in RDF (dry basis)  
 $CF_i$  : Fraction of carbon content in waste type  $i$  in RDF (dry basis)  
 $FCF_i$  : Fossil-fuel derived fraction of waste type  $i$  in RDF  
 $OF_{RDF}$  : Oxidation factor of RDF at RDF combustion facilities

#### - **Fraction of Each Waste Type Derived Content Contained in RDF ( $F_{RDF}$ : Dry basis)**

Fractions of each waste type derived content contained in RDF in wet basis are estimated based on the averages of those from result on the waste composition analysis in MOE (2003), supplemented by information from MOE (2020b) and *the Textile Handbook* (Japan Chemical Fibers Association). Water content in each waste type shown in “7.2.1. Managed Disposal Sites (5.A.1.)” and “7.4.1.2. Industrial Waste (5.C.1.-), CO<sub>2</sub>” are applied to convert wet basis waste composition into that of dry basis (paper/cardboard: 20%, synthetic textiles: 20% and plastics: 26.1%). Estimated fractions of these wastes in RDF in dry basis are 38.2% of paper/cardboard, 10.3% of synthetic textiles and 28% of plastics respectively. Note that it is assumed that RDF almost does not include PET bottles.

#### - **Fraction of Carbon Content Contained in Each Waste Type in RDF ( $CF$ : Dry basis)**

Since RDF is usually made from municipal solid waste, the fractions of carbon content in each waste type used in “7.4.1.1. Municipal Solid Waste (5.C.1.-)” are also applied for this category (paper/cardboard: 40.8%, synthetic textiles: 63.0% and plastics: 76.8%).

#### - **Fossil-fuel derived fraction of each waste type in RDF ( $FCF$ )**

Since RDF is usually made from municipal solid waste, fossil-fuel derived fractions of each waste type used in “7.4.1.1. Municipal Solid Waste (5.C.1.-)” are also applied for this category (paper/cardboard: 9.6%, synthetic textiles: 100% and plastics: see Table 7-32).

#### - **Oxidation factor for RDF at RDF Combustion Facilities ( $OF_{RDF}$ )**

The default value provided in the 2006 IPCC Guidelines (100%) is applied for the oxidation factor for this category.

➤ **RPF**

Because the quality of RPF is categorized into “coal-equivalent product” and “coke-equivalent product” (Japan RPF Association, 2004), emission factor for RPF is established for each quality of product. However, in the case that the amount of use of each quality of product for estimating activity data is unavailable, emission factor is established by the weighted average of each emission factor for coal-equivalent product and coke-equivalent product with the average fraction of amount of use of each product (see “*Emission Factor for the Use of RPF (Weighted Average) (Dry basis)*” as described herein below.)

Coal-equivalent product

$$\begin{aligned} EF_{RPF,coal} &= 1000 \times P_{RPF,coal} \times C \times OF_{RPF} \times 44/12 \times FCF_{plastics} \\ &= 1000 \times 0.528 \times 0.737 \times 1.0 \times 44/12 \times FCF_{plastics} \\ &= 1426 \text{ [kg-CO}_2\text{/t]} \times FCF_{plastics} \end{aligned}$$

Coke-equivalent product

$$\begin{aligned} EF_{RPF,coke} &= 1000 \times P_{RPF,coke} \times C \times OF_{RPF} \times 44 / 12 \times FCF_{plastics} \\ &= 1000 \times 0.910 \times 0.737 \times 1.0 \times 44 / 12 \times FCF_{plastics} \\ &= 2457 \text{ [kg-CO}_2\text{/t]} \times FCF_{plastics} \end{aligned}$$

$EF_{RPF,coal}$	: Emission factor for the use of coal-equivalent product RPF (dry basis) [kg-CO <sub>2</sub> /t]
$EF_{RPF,coke}$	: Emission factor for the use of coke-equivalent product RPF (dry basis) [kg-CO <sub>2</sub> /t]
$P_{RPF,coal}$	: Fraction of plastic-derived content contained in coal-equivalent product RPF (dry basis)
$P_{RPF,coke}$	: Fraction of plastic-derived content contained in coke-equivalent product RPF (dry basis)
$C$	: Fraction of carbon content contained in plastic (dry basis)
$OF_{RPF}$	: Oxidation factor of RPF at RPF combustion facilities
$FCF_{plastics}$	: Fossil-fuel derived fraction of plastics in RPF

- **Fraction of Waste Plastic-derived Content Contained in RPF ( $P_{RPF,coal/coke}$ : Dry basis)**

The fraction of waste plastic-derived content contained in RPF in wet basis is established at 50% for coal-equivalent product and at 90% for coke-equivalent product based on the results of fact-finding survey conducted by the Japan RPF Industry Association (MOE, 2006b).

The fraction of waste plastic-derived content contained in RPF in dry basis is calculated with the fraction of water content of RDF, to which the average water content of industrial waste plastics used for RPF production is applied; it is established at 5% based on expert judgment.

- **Fraction of Carbon Content Contained in Plastic (Dry basis) (C)**

Due to the fact that most of plastic contained in RDF is industrial waste-derive (Seki, 2004), the fraction of carbon content contained in plastic in dry basis (73.7%) is calculated by using the fraction of carbon content contained in industrial waste plastic applied in “7.4.1.2. Industrial Waste (5.C.1.-), CO<sub>2</sub>” (70%) and the fraction of water content of industrial waste plastic (5%).

- **Oxidation factor for RPF at RPF Fuel Facilities ( $OF_{RPF}$ )**

As applied in “7.4.1.2. Industrial Waste (5.C.1.-)”, the value provided in the 2006 IPCC Guidelines (100%) is also applied for the oxidation factor for RPF at RPF combustion facilities.

- **Fossil-fuel derived fraction of plastic in RPF ( $FCF_{plastics}$ )**

The same values for industrial waste plastics are applied (See Table 7-32).

- **Emission Factor for RPF Use (Weighted Average) ( $EF_{RPF,av}$ : Dry basis)**

In the case that the amount of use of coal-equivalent product RPF and coke-equivalent product RPF for estimating activity data is unavailable, emission factor is determined by the weighted average of each emission factor for coal-equivalent product and coke-equivalent product with the average fraction of the amount of use of each product.

Production percentage of RPF of coal-equivalent product and coke-equivalent product (wet basis) is obtained from the survey results conducted by Japan RPF Industry Association and is converted into the value in dry basis. The fraction of water content of RPF is established at 3% for coal-equivalent product and at 1% for coke-equivalent product based on the RPF quality standards provided by the Japan RPF Industry Association. The estimated fractions of production percentage in dry basis are applied to all the reporting years because relevant statistics is unavailable.

$$\begin{aligned} EF_{RPF,av} &= EF_{RPF,coal} \times P_{coal} + EF_{RPF,coke} \times P_{coke} \\ &= (1426 \times FCF_{plastics}) \times 0.797 + (2457 \times FCF_{plastics}) \times 0.203 \\ &= 1636 \text{ [kg-CO}_2\text{/t]} \times FPF_{plastics} \end{aligned}$$

$EF_{RPF,av}$	: Emission factor for RPF use (Weighted Average) (dry basis) [kg-CO <sub>2</sub> /t]
$P_{coal}$	: Fraction of the use of coal-equivalent product RPF (dry basis)
$P_{coke}$	: Fraction of the use of coke-equivalent product RPF (dry basis)
$FCF_{plastics}$	: Fossil-fuel derived fraction of plastic in RPF

Table 7-73 CO<sub>2</sub> emission factors for the emissions from the use of refused-derived fuel (RDF) or refuse paper & plastic fuel (RPF)

Item	Emission Factor [kg-CO <sub>2</sub> /t (dry)]
RDF	1,121
RPF (coal-equivalent products)	1,426
RPF (coke-equivalent products)	2,457
RPF (weighted average values)	1,636

Note: Each emission factor indicated in the table are applied 100% of fossil-fuel derived fraction of plastics ( $FCF_{plastics}$ )

● **Activity Data**

➤ **RDF**

The amount of RDF production is used as the substitute for the amount of use of RDF. Activity data (dry basis) is calculated by subtracting the water content of RDF from the amount of RDF production at RDF production facilities (wet basis) provided by the *Report on Survey of State of Treatment of Municipal Solid Waste*. For the fiscal years that the data are unavailable, emission estimates are conducted substituting the values of the refuse processing capacity.

$$A_{RDF} = a_{RDF} \times (1 - u_{RDF})$$

$A_{RDF}$	: Activity data for RDF use (dry basis)
$a_{RDF}$	: Amount for RDF production at RDF production facilities (wet basis) [t]
$u_{RDF}$	: Fraction of water content in RDF

➤ **RPF**

The amounts of RPF used in chemical industry, paper industry, cement manufacturer, and petroleum product manufacturer are estimated (See also Table 7-66). The amount of RPF (dry basis) for paper industry is obtained from the survey results conducted by the Japan Paper Association. The amounts of RPF (dry basis) for the chemical industry, cement manufacturers, and petroleum product manufacturers are obtained by using the averaged water content of RPF and the survey results (wet basis) conducted

by the Japan Chemical Industry Association, the Japan Cement Association and the Petroleum Association of Japan.

## 2) CH<sub>4</sub>, N<sub>2</sub>O

### ● Estimation Method and Emission Factor

For the estimation method and the emission factors used, see “7.4.3.2. Direct Use of Waste as Alternative Fuel (1.A.)”.

### ● Activity Data

#### ➤ RDF

The entire amount of RDF production (wet basis) used for CO<sub>2</sub> emission estimates is also used for the amount of use of RDF for boiler.

#### ➤ RPF

Out of the amount of RPF used for CO<sub>2</sub> emission estimates, the amounts of RPF used in chemical industry, paper industry, and petroleum products manufacturer are applied to the amount of PRF used for boiler (wet basis). The amount of PRF used in cement industry is applied to the amount of RPF used for cement kiln (wet basis). Because the amount of RPF used in paper industry is on a dry basis, the average water content of RPF is added to obtain the value on a wet basis.

#### ➤ Activity Data Converted into Energy Units (Reference Value)

Activity data converted into energy units to be reported in CRF is calculated as indicated below.

$$A_{E,i} = A_i \times GCV_i / 10^6$$

$A_{E,i}$  : Activity data of fuel type  $i$  converted into energy units [TJ]

$A_i$  : Amount of consumed fuel type  $i$  [kg (wet)]

$GCV_i$  : Gross calorific value of fuel type  $i$  [MJ/kg]

## c) Uncertainties and Time-series Consistency

### ● Uncertainties

The uncertainty assessment is conducted as well as the assessment for the municipal waste or industrial waste incineration. Details of the uncertainty assessment on this category are indicated in the Table 7-74.

Table 7-74 Uncertainty assessment for incineration of waste refuse-based solid fuels (1.A.1 and 1.A.2)

Item	GHGs	Emission /removal factor uncertainty		Activity data uncertainty		Emission /removal uncertainty		The method of evaluating uncertainty in emission factor	The method of evaluating uncertainty in activity data	The method of evaluating uncertainty in emissions/removals
		(-)	(+)	(-)	(+)	(-)	(+)			
RDF	CO <sub>2</sub>	-1%	+1%	-10%	+10%	-10%	+10%	Due to the lack of information for the uncertainty of the emission factor, the uncertainty in municipal waste plastics is substituted based on expert judgment.	The uncertainty in municipal waste statistics based on expert judgment is used.	Combined by using the formula for propagation of errors.
	CH <sub>4</sub>	-39%	+39%	-10%	+10%	-40%	+40%			
	N <sub>2</sub> O	-34%	+34%	-10%	+10%	-35%	+35%			
RPF	CO <sub>2</sub>	-2%	+2%	-30%	+30%	-30%	+30%	Due to the lack of information for the uncertainty of the emission factor, the uncertainty in municipal waste plastics is substituted based on expert judgment.	The uncertainty based on expert judgment in industrial waste statistics is applied.	Combined by using the formula for propagation of errors.
	CH <sub>4</sub>	-100%	+216%	-30%	+30%	-104%	+218%			
	N <sub>2</sub> O	-44%	+44%	-30%	+30%	-53%	+53%			



- ***Time-series Consistency***

Since data on the amount of RDF produced are not available for the years prior to FY1997, these data are estimated by using the trend on capacity of refuse-based fuel-producing facilities. The emissions are calculated in a consistent manner.

- d) Category-specific QA/QC and Verification***

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

- e) Category-specific Recalculations***

By revising biomass-based plastic products data, CO<sub>2</sub> emissions from FY2005 onward were recalculated. By updating the statistical data, emissions in FY2019 were recalculated. See Chapter 10 for impact on trend.

- f) Category-specific Planned Improvements***

No improvements are planned.

### 7.5. Wastewater Treatment and Discharge (5.D.)

The CH<sub>4</sub> and N<sub>2</sub>O emissions from wastewater handling are reported under the category “Wastewater Treatment and Discharge (5.D.)”. The target categories are shown in Table 7-75. Since an emission factor that takes into account emissions from wastewater and sludge treatment processes is used in Japan, emissions from these processes are reported altogether. Note since this category includes various type of sources, it is difficult to analyze the trend in the IEFs.

Table 7-75 Categories overview for wastewater treatment and discharge (5.D.)

Category	Wastewater type			Treatment type		CH <sub>4</sub>	N <sub>2</sub> O		
5.D.1. (7.5.1)	Domestic wastewater	Public sewer system	Sewage	Sewage treatment plants (7.5.1.1)	Standard activated sludge process		○	○	
					Anaerobic-aerobic activated sludge process			○	
					Anaerobic-anoxic-oxic process and recycled nitrification; denitrification process			○	
					Recycled nitrification-denitrification membrane bioreactor			○	
		Other sewer system	Miscellaneous wastewater	Domestic sewage treatment plants (mainly <i>Johkasou</i> ) (7.5.1.2)	Community plant		○	○	
					Current type <i>Johkasou</i>	Advanced type	TN removal type	○	○
							TN and TP removal type		
							BOD removal type		
							Other advanced type		
					Standard type		○	○	
			Old type <i>Johkasou</i>		○	○			
			Vault toilet		○	○			
			Collected human waste	Human waste and <i>Johkasou</i> sludge (from domestic sewage treatment plants)	Human-waste treatment plants (7.5.1.3)	High-load denitrification treatment		○	○
						Membrane separation		○	○
		Anaerobic treatment				○	○		
		Aerobic treatment				○			
		Standard denitrification treatment		○					
Other		○							
Into public waters	Wastewater	Untreated wastewater	Natural decomposition of domestic wastewater (7.5.1.4)	Discharge of untreated wastewater	From old type <i>Johkasou</i>	○	○		
		Treated wastewater			From vault toilet	○	○		
					From on-site treatment	○	○		
	Sludge	Human waste and <i>Johkasou</i> sludge	Sewage sludge	Discharge of treated wastewater	(From each treatment plant)	NA	○		
					Ocean dumping of sludge <sup>1)</sup>	(From domestic sewage treatment plants)	○	○	
						(From sewage treatment plants)	○	○	
	5.D.2. (7.5.2)	Industrial wastewater	In treatment systems	Manufacture of food	Industrial wastewater treatment (7.5.2.1)	(Industrial wastewater treatment plants)		○	○
Manufacture of pulp, paper and paper products				○				○	
Manufacture of chemical and allied product				○				○	
Manufacture of iron and steel				○				○	
Manufacture of beverages, tobacco and feed				○				○	
Manufacture of textile products				○				○	
Manufacture of petroleum and coal products									
Manufacture of plastic products									
Manufacture of rubber products									
Manufacture of leather tanning, leather products and fur skins									
Into public waters	Wastewater	Untreated wastewater	Natural decomposition of Industrial wastewater (7.5.2.2)	Discharge of untreated wastewater	(from industrial plants/facilities)	○	○		
		Treated wastewater			(from industrial wastewater treatment plants)	NA	○		
Landfill leachate			Landfill leachate treatment (7.5.2.3)		○	○			

Note:

- 1) Due to legal regulations on sludge disposal at sea, there has been no activity since FY2009.

Estimated GHG emissions from wastewater handling are shown in Table 7-76. In FY2020, emissions from this source category are 3,668 kt-CO<sub>2</sub> eq. and accounted for 0.3% of the national total emissions (excluding LULUCF). The emissions from this source category decreased by 31.2% compared to those in FY1990. This emission decrease is the result of decrease in the amount of CH<sub>4</sub> emissions from “Natural decomposition of domestic wastewater” because the practice of wastewater treatment at wastewater treatment plants increased in Japan. Due to the same reason, the N<sub>2</sub>O emissions from the subcategory of “Sewage Treatment Plants (5.D.1.-)” for FY1995 through FY1998 increased.

Table 7-76 GHG emissions from wastewater treatment and discharge (5.D.)

Gas	Category	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020		
CH <sub>4</sub>	5.D.1. Domestic wastewater	Sewage treatment plant	kt-CH <sub>4</sub>	8.6	9.9	11.1	12.1	12.7	12.7	12.5	12.6	12.4	12.6	12.1	12.5	13.4	13.4		
		Domestic sewage treatment plant	kt-CH <sub>4</sub>	30.4	35.0	38.8	38.3	36.8	36.2	35.8	35.3	34.7	34.3	33.8	32.9	32.4	31.3	30.8	
		Human-waste treatment plant	kt-CH <sub>4</sub>	5.2	3.2	1.8	1.0	0.6	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.3	0.3	0.3	0.3
	5.D.2. Industrial wastewater	Natural decomposition of domestic wastewater	kt-CH <sub>4</sub>	61.7	50.8	39.5	28.7	21.1	20.0	19.3	18.1	17.2	16.4	15.8	15.0	14.3	13.7	13.1	
		Industrial wastewater treatment	kt-CH <sub>4</sub>	2.2	2.2	2.1	1.9	1.8	1.7	1.7	1.6	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
		Natural decomposition of industrial wastewater	kt-CH <sub>4</sub>	8.2	7.8	7.9	8.3	4.9	4.8	4.5	4.1	4.3	4.6	4.1	3.7	3.7	3.7	3.7	
		Landfill leachate treatment	kt-CH <sub>4</sub>	1.2	1.2	1.1	0.8	0.4	0.3	0.4	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	Total	kt-CH <sub>4</sub>	117.7	110.0	102.2	91.2	78.1	76.3	74.2	72.5	71.2	70.0	68.6	65.9	65.1	64.3	63.1		
		kt-CO <sub>2</sub> eq.	2,942	2,750	2,556	2,280	1,954	1,908	1,855	1,811	1,779	1,749	1,714	1,648	1,629	1,607	1,578		
	N <sub>2</sub> O	5.D.1. Domestic wastewater	Sewage treatment plant	kt-N <sub>2</sub> O	1.39	1.55	1.58	1.67	1.67	1.55	1.59	1.59	1.55	1.55	1.45	1.49	1.74	1.74	
Domestic sewage treatment plant			kt-N <sub>2</sub> O	1.52	1.65	1.70	1.57	1.53	1.54	1.56	1.56	1.56	1.55	1.56	1.56	1.55	1.57	1.56	
Human-waste treatment plant			kt-N <sub>2</sub> O	0.22	0.26	0.12	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
5.D.2. Industrial wastewater		Natural decomposition of domestic wastewater	kt-N <sub>2</sub> O	2.79	2.72	2.49	2.29	2.11	2.13	2.04	2.08	2.01	2.02	2.00	1.98	1.94	2.03	2.01	
		Industrial wastewater treatment	kt-N <sub>2</sub> O	1.00	0.96	0.81	1.10	1.09	1.12	1.16	1.15	1.13	1.13	1.13	1.13	1.13	1.13	1.13	
		Natural decomposition of industrial wastewater	kt-N <sub>2</sub> O	1.06	1.02	1.02	0.97	0.66	0.65	0.62	0.59	0.56	0.54	0.55	0.55	0.55	0.55	0.55	
		Landfill leachate treatment	kt-N <sub>2</sub> O	0.03	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.005	0.005	0.005	0.004	0.004	
Total		kt-N <sub>2</sub> O	8.01	8.18	7.72	7.65	7.10	7.14	6.94	6.99	6.86	6.80	6.69	6.68	6.68	7.03	7.02		
		kt-CO <sub>2</sub> eq.	2,387	2,439	2,301	2,280	2,115	2,129	2,069	2,082	2,045	2,027	2,028	1,992	1,990	2,096	2,091		
Total		kt-CO <sub>2</sub> eq.	5,329	5,189	4,857	4,560	4,069	4,037	3,925	3,893	3,825	3,777	3,742	3,640	3,618	3,703	3,668		

### 7.5.1. Domestic Wastewater (5.D.1.)

Domestic and commercial wastewater generated in Japan is treated at various wastewater treatment facilities (e.g., sewage treatment plants, Domestic sewage treatment plants, human-waste treatment plants) and GHG emissions from these sources are reported under “Domestic and Commercial Wastewater (5.D.1.)”. Because the CH<sub>4</sub> and N<sub>2</sub>O emission characteristics differ from one wastewater treatment facility to another, a different emission estimation method is established for each facility.

The characteristics, effectiveness, and economic efficiency of wastewater treatment systems are thoroughly reviewed, and the most suitable systems are selected for each area in Japan with care also being taken to avoid excessive expenditure. As indicated in the *Waste Treatment in Japan* (MOE), public sewerage system is spreading from large cities to smaller municipalities and used by 76.7% of the population at the end of FY2020.

Domestic sewage treatment plants (e.g. current type *Johkasou*) are being promoted as an effective means of supplementing sewerage systems in smaller municipalities with low population densities and little flat land. In FY2020, *Johkasou* is used by 18.7% of the population, with the remainder being treated after collection or on-site.

“NA” is reported on the CRF table for activity data instead of reporting the amount of organic carbon based on BOD values because the activity data for this source are estimated using a country-specific method by each gas and each wastewater treatment facility.

### 7.5.1.1. Sewage Treatment Plant (5.D.1.-)

#### a) Category Description

This category covers CH<sub>4</sub> and N<sub>2</sub>O emissions from treatment of wastewater at sewage treatment plants.

#### b) Methodological Issues

##### ● Estimation Method

Emissions of CH<sub>4</sub> and N<sub>2</sub>O from this source are calculated using Japan's country-specific method in accordance with the decision tree of the 2006 IPCC Guidelines (Page 6.10, Fig. 6.2). Emissions are calculated by multiplying the volume of sewage treated at sewage treatment plants by the emission factor.

$$E = EF \times A$$

- $E$  : Amount of CH<sub>4</sub> or N<sub>2</sub>O emitted from sewage treatment plants in conjunction with domestic/commercial wastewater treatment [kg-CH<sub>4</sub>], [kg-N<sub>2</sub>O]  
 $EF$  : Emission factor [kg-CH<sub>4</sub>/m<sup>3</sup>], [kg-N<sub>2</sub>O/m<sup>3</sup>]  
 $A$  : Yearly amount of sewage treated at a sewage treatment plant [m<sup>3</sup>]

##### ● Emission Factors

#### 1) CH<sub>4</sub>

Emission factors are established by adding the simple averages for each treatment process, having taken the actual volume of CH<sub>4</sub> released from sludge treatment and water treatment processes measured at sewage treatment plants from research studies (sampling surveys) conducted in several different seasons for 8 plants in Japan (MOE, 2006b).

$$\begin{aligned} EF_{CH_4} &= EF_{WWTT} + EF_{SSTT} \\ &= 8.8 \times 10^{-4} \text{ [kg-CH}_4\text{/m}^3\text{]} \end{aligned}$$

- $EF_{CH_4}$  : CH<sub>4</sub> Emission factor  
 $EF_{WWTT}$  : Average of emission factor for wastewater treatment processes (528.7 [mg-CH<sub>4</sub>/m<sup>3</sup>])  
 $EF_{SSTT}$  : Average of emission factor for sludge treatment processes (348.0 [mg-CH<sub>4</sub>/m<sup>3</sup>])

#### 2) N<sub>2</sub>O

Emission factors are established on the basis of measured values of N<sub>2</sub>O volume emitted from wastewater and sludge treatment processes at sewage treatment plants which is obtained from research studies (sampling surveys) conducted in several different seasons for 42 plants in Japan; these studies consist of measurements in several plants for each type of wastewater treatment process.

Since the research studies revealed that the amount of N<sub>2</sub>O emission varies according to the type of wastewater treatment process at sewage treatment plants, the N<sub>2</sub>O emission factor for each wastewater treatment type is developed based on the latest findings in the country (MOE, 2013b).

$$EF_{N_2O} = EF_{WWTTi} + EF_{SSTT}$$

- $EF_{N_2O}$  : N<sub>2</sub>O Emission factor  
 $EF_{WWTTi}$  : Emission factor for wastewater treatment process  $i$  (See Table 7-77.)  
 $EF_{SSTT}$  : Average of emission factor for sludge treatment process (0.6 [mg-N<sub>2</sub>O/m<sup>3</sup>])

Table 7-77 N<sub>2</sub>O Emission factor by wastewater treatment process at sewage treatment plant

Wastewater treatment process	N <sub>2</sub> O EF for wastewater treatment process <sup>3)</sup> [mg-N <sub>2</sub> O/m <sup>3</sup> ]	N <sub>2</sub> O EF for sludge treatment process [mg-N <sub>2</sub> O/m <sup>3</sup> ]
Standard activated sludge process <sup>1)</sup>	142	0.6
Anaerobic-aerobic activated sludge process	29.2	0.6
Anaerobic-anoxic-oxic process and recycled nitrification; denitrification process <sup>2)</sup>	11.7	0.6
Recycled nitrification-denitrification membrane bioreactor	0.5	0.6

Note:

- 1) Includes all the wastewater treatment processes other than indicated above.
- 2) Includes all the wastewater treatment processes which remove nitrogen the same level or greater than Anaerobic-anoxic-oxic process and recycled nitrification; denitrification process, but excludes recycled nitrification-denitrification membrane bioreactor.
- 3) Since the main purpose of the “Standard activated sludge process” is to remove BOD from wastewater, the nitrification reaction cannot be completed during the process, resulting in more N<sub>2</sub>O generated. In the meanwhile, advanced treatment procedures such as “Anaerobic-aerobic activated sludge process”, “Anaerobic-anoxic-oxic process and recycled nitrification; denitrification process”, and “Recycled nitrification-denitrification membrane bioreactor” allow sufficient nitrification reaction to occur for nitrogen removal etc, and accordingly generate less N<sub>2</sub>O.

### ● Activity Data

Activity data for N<sub>2</sub>O emissions by wastewater treatment process at sewage treatment plants are provided by MLIT. Total amount of wastewater treated used for N<sub>2</sub>O emission estimates are also used for the activity data for CH<sub>4</sub> emission estimates.

Table 7-78 Activity data for wastewater treated at sewage treatment plant

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Standard activated sludge process	10 <sup>6</sup> m <sup>3</sup>	9,761	10,780	10,686	11,405	11,358	11,288	10,485	10,736	10,699	10,401	10,394	9,648	9,908	11,843	11,843
Anaerobic-aerobic activated sludge process	10 <sup>6</sup> m <sup>3</sup>	73	446	1,523	1,039	909	909	953	931	938	933	962	1,107	1,248	728	728
Anaerobic-anoxic-oxic process and recycled nitrification; denitrification process	10 <sup>6</sup> m <sup>3</sup>	23	89	487	1,374	2,181	2,308	2,355	2,629	2,684	2,819	3,033	2,998	3,132	2,683	2,683
Recycled nitrification-denitrification membrane bioreactor	10 <sup>6</sup> m <sup>3</sup>	NO	NO	NO	0.1	2.0	20.2	20.2	14.9	0.1	0.2	4.8	0.4	6.3	19.4	19.4
Total	10 <sup>6</sup> m <sup>3</sup>	9,857	11,316	12,696	13,818	14,450	14,525	13,813	14,311	14,320	14,153	14,393	13,754	14,293	15,272	15,272

### c) Uncertainties and Time-series Consistency

#### ● Uncertainties

The uncertainties in emission factors for CH<sub>4</sub> and N<sub>2</sub>O in sewage treatment plant are evaluated by using the 95% confidence intervals of actual measurement data which are used for calculation of emission factors. As for the uncertainties in activity data, the uncertainties in sewage data indicated in Table 7-2 are applied. Details of the uncertainty assessment on this category are indicated in Table 7-79.

Table 7-79 Uncertainty assessment for sewage treatment plant on the category “Domestic wastewater (5.D.1.-)”

Item	GHGs	Emission /removal factor uncertainty		Activity data uncertainty		Emission /removal uncertainty		The method of evaluating uncertainty in emission factor	The method of evaluating uncertainty in activity data	The method of evaluating uncertainty in emissions/removals
		(-)	(+)	(-)	(+)	(-)	(+)			
Sewage treatment plant	CH <sub>4</sub>	-31%	+31%	-5%	+5%	-31%	+31%	The uncertainty is assessed by using the 95% interval confidence of actual measurement data in MOE (2006b).	The uncertainty in sewage statistics based on expert judgment is used.	Combined by using the formula for propagation of errors.
	N <sub>2</sub> O	-100%	+146%	-5%	+5%	-100%	+146%			

- **Time-series Consistency**

The emissions are calculated in a consistent manner.

**d) Category-specific QA/QC and Verification**

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

**e) Category-specific Recalculations**

By updating the statistical data, emissions in FY2019 were recalculated. See Chapter 10 for impact on trend.

**f) Category-specific Planned Improvements**

No improvements are planned.

### 7.5.1.2. Domestic Sewage Treatment Plant (Mainly *Johkasou*) (5.D.1.-)

**a) Category Description**

A part of domestic and commercial wastewater not processed in the public sewerage in Japan is processed in community plants, current type *Johkasou*, the old type *Johkasou*, and vaults. The *Johkasou* means decentralized wastewater treatment facilities installed at an individual home.

Table 7-80 Type of sewage and sewage treatment

Plant type			Sewage type	Description	
Community plants				Small-scale wastewater treatment facility regionally installed	
<i>Johkasou</i>	Current type	Advanced type	Human waste and miscellaneous wastewater	Wastewater treatment unit installed at an individual household	TN removal type
					TN and TP removal type
	BOD removal type				
	Other advanced type				
	Standard type				Advanced type certified in performance under the amended Building Standards Act in effect FY2001
	Old type		Human waste only		Standard type under former the Building Standards Act
					Old type which is not allowed to be newly installed under the amended Purification Tank Act since FY2001
Vaults toilet					Installed at an individual household

This category covers CH<sub>4</sub> and N<sub>2</sub>O emissions from domestic sewage treatment plants. Emissions from human waste within its residence time in vault toilets are reported under this category, whereas the emissions that occur after the waste is collected from vault toilets are accounted for under “Human waste treatment plant (5.D.1.-)”.

**b) Methodological Issues**

- **Estimation Method**

Emissions of CH<sub>4</sub> and N<sub>2</sub>O from this source are calculated using Japan’s country-specific method, in accordance with decision tree the *2006 IPCC Guidelines* (Page 6.10, Fig. 6.2). Emissions are calculated by multiplying the annual population of treatment for each type of domestic sewage treatment plant by the emission factor.

$$E = \sum_i (EF_i \times A_i)$$

$E$  : Emissions of methane and nitrous oxide from the processing of domestic and commercial wastewater at domestic sewage treatment plants (i.e. household *Johkasou*) [kg-CH<sub>4</sub>], [kg-N<sub>2</sub>O]

$EF_i$  : Emission factor for domestic sewage treatment plant  $i$  [kg-CH<sub>4</sub>/person], [kg-N<sub>2</sub>O/person]

$A_i$  : Population (persons) requiring waste processing at domestic sewage treatment plant  $i$  per year

### ● Emission Factors

CH<sub>4</sub> and N<sub>2</sub>O emission factors for this source are determined from domestic research studies as shown on the Table 7-81.

Table 7-81 Emission factors for CH<sub>4</sub> and N<sub>2</sub>O from domestic wastewater treatment systems

CH <sub>4</sub> emission factors (Unit: kg-CH <sub>4</sub> /person-year)						
Plant type		FY1990-1995	FY1996-2000	FY2001-2004	FY2005-	Reference
Community plant <sup>1)</sup>		0.195	Interpolation		0.062	1990-1995: Tanaka (1998) 2005-: Ike and Soda (2010)
Current type <i>Johkasou</i>	Advanced type	TN removal type	NA <sup>2)</sup>	1.044	MOE (2012) and MOE (2013c)	
		TN and TP removal type				
		BOD removal type		1.984		
		Other advanced type				
Standard type <sup>3)</sup>		2.477				
Old type <i>Johkasou</i> <sup>3)</sup>		0.46				
Vault toilet <sup>3)</sup>		0.062				
N <sub>2</sub> O emission factors (Unit: kg-N <sub>2</sub> O/person-year)						
Plant type		FY1990-1995	FY1996-2000	FY2001-2004	FY2005-	Reference
Community plant <sup>1)</sup>		0.0394	Interpolation		0.0048	1990-1995: Tanaka et al. (1995) <sup>4)</sup> 2005-: Ike and Soda (2010)
Current type <i>Johkasou</i>	Advanced type	TN removal type	NA <sup>2)</sup>	0.123	MOE (2012) and MOE (2013c)	
		TN and TP removal type				
		BOD removal type		0.055		
		Other advanced type				
Standard type <sup>3)</sup>		0.0717				
Old type <i>Johkasou</i> <sup>3)</sup>		0.039				
Vault toilet <sup>3)</sup>		0.000022				

Note:

- 1) For the values from FY2005 onward, the emission factors are applied taking into account the performance improvement of the plants.
- 2) The installation of current advanced type *Johkasou* was started under the technical guidelines for *Johkasou* of the Building Standards Act revised in FY2001.
- 3) The same emission factor is applied for through the reporting years because there is no significant technological advancement
- 4) The simple mean values of the upper limit and the lower limit of actual measured values indicated in the reference is applied.

### ● Activity Data

Annual treatment population by type of domestic sewage treatment plant for community plants, current type *Johkasou*, old type *Johkasou*, and vault toilets given in the *Waste Treatment in Japan* (MOE) is used as the activity data for CH<sub>4</sub> and N<sub>2</sub>O emitted in association with domestic sewage treatment plants. Activity data for current type *Johkasou* are classified as advanced type and standard type by using installation share derived from installation number of each type, which can be assumed as a share of annual treatment population, shown in the *Survey of guidance promotion of Johkasou* (MOE).

Table 7-82 Annual treatment population by type of domestic sewage treatment plant (Activity data)

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Community plant	1000 person	493	398	414	552	293	286	289	304	302	294	286	320	336	306	259
Current type <i>Johkasou</i> (Sub total)	1000 person	6,274	8,515	10,806	12,792	14,082	14,276	14,341	14,492	14,564	14,600	14,630	14,557	14,506	14,381	14,421
Advanced type																
TN removal type	1000 person	NO	NO	NO	263	1,433	1,900	2,261	2,612	2,948	3,105	3,447	3,862	3,954	4,507	4,772
TN and TP removal type	1000 person	NO	NO	NO	3	14	16	28	35	37	39	40	42	43	56	51
BOD removal type	1000 person	NO	NO	NO	34	33	46	22	25	22	19	18	20	29	54	58
Other advanced type	1000 person	NO	NO	NO	4,501	6,132	6,129	6,095	6,123	6,098	6,153	6,022	5,666	5,691	5,345	5,110
Standard type	1000 person	6,274	8,515	10,806	7,991	6,471	6,184	5,935	5,697	5,459	5,284	5,103	4,968	4,788	4,419	4,429
Old type <i>Johkasou</i>	1000 person	26,828	26,105	23,289	18,303	13,948	13,315	13,052	12,383	11,822	11,415	11,018	10,543	10,151	9,875	9,319
Vault toilet	1000 person	38,920	29,409	20,358	13,920	9,984	9,348	8,849	8,242	7,727	7,197	6,871	6,528	6,086	5,745	5,481
Total	1000 person	72,515	64,427	54,867	45,567	38,307	37,225	36,531	35,421	34,415	33,506	32,805	31,948	31,079	30,307	29,480

### c) Uncertainties and Time-series Consistency

#### ● Uncertainties

The uncertainties in emission factors for CH<sub>4</sub> and N<sub>2</sub>O in current type *Johkasou*, old type *Johkasou*, and vault toilet are evaluated by using the 95% confidence intervals of actual measurement data which are used for calculation of emission factors. As for the uncertainties in emission factors for CH<sub>4</sub> and N<sub>2</sub>O in community plant, the uncertainties in similar emission sources are substituted. As for the uncertainties in activity data, the uncertainties in domestic wastewater data indicated in Table 7-2 are applied. Details of the uncertainty assessment on this category are indicated in the Table 7-83.

Table 7-83 Uncertainty assessment for domestic sewage treatment plant on the category  
“Domestic wastewater (5.D.1.-)”

Item	GHGs	Emission /removal factor uncertainty		Activity data uncertainty		Emission /removal uncertainty		The method of evaluating uncertainty in emission factor	The method of evaluating uncertainty in activity data	The method of evaluating uncertainty in emissions/removals
		(-)	(+)	(-)	(+)	(-)	(+)			
Community Plant	CH <sub>4</sub>	-32%	+32%	-10%	+10%	-33%	+33%	The uncertainty is assessed based on expert judgment. (The uncertainty in current type <i>Johkasou</i> is substituted). Quoted from MOE (2013c)	The uncertainty in municipal waste statistics based on expert judgment is used.	Combined by using the formula for propagation of errors.
	N <sub>2</sub> O	-45%	+45%	-10%	+10%	-46%	+46%			
Current type <i>Johkasou</i>	CH <sub>4</sub>	-32%	+32%	-10%	+10%	-33%	+33%			
	N <sub>2</sub> O	-45%	+45%	-10%	+10%	-46%	+46%			
Old type <i>Johkasou</i>	CH <sub>4</sub>	-84%	+84%	-10%	+10%	-84%	+84%			
	N <sub>2</sub> O	-87%	+87%	-10%	+10%	-88%	+88%			
Vault toilet	CH <sub>4</sub>	-49%	+49%	-10%	+10%	-50%	+50%			
	N <sub>2</sub> O	-72%	+72%	-10%	+10%	-73%	+73%			

#### ● Time-series Consistency

The emissions are calculated in a consistent manner.

### d) Category-specific QA/QC and Verification

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.



**e) Category-specific Recalculations**

By updating the statistical data, emissions in FY2019 were recalculated. See Chapter 10 for impact on trend.

**f) Category-specific Planned Improvements**

No improvements are planned.

**7.5.1.3. Human-Waste Treatment Plant (5.D.1.-)****a) Category Description**

This category covers emissions of CH<sub>4</sub> and N<sub>2</sub>O emissions from treatment of vault toilet human waste and *Johkasou* sludge collected at human waste treatment plants.

**b) Methodological Issues****1) CH<sub>4</sub>****● Estimation Method**

Emissions of CH<sub>4</sub> from this source are calculated using Japan's country-specific methodology in accordance with decision tree of the *2006 IPCC Guidelines* (Page 6.10, Fig. 6.2). Emissions are calculated by multiplying the volume of domestic wastewater treated at human waste treatment plants by the emission factor.

$$E = \sum_i (EF_i \times A_i)$$

*E* : Emission of methane from the processing of domestic and commercial wastewater at human waste treatment plants [kg-CH<sub>4</sub>]

*EF<sub>i</sub>* : Emission factor for human waste treatment plants (for treatment process *i*) [kg-CH<sub>4</sub>/m<sup>3</sup>]

*A<sub>i</sub>* : Input volume of human waste and *Johkasou* sludge at human waste treatment plants (for treatment process *i*) [m<sup>3</sup>]

**● Emission Factors**

Emission factors for CH<sub>4</sub> are determined by treatment processes type, including anaerobic, aerobic, standard denitrification and high-load denitrification treatments as well as membrane separation systems, for each of the human waste treatment plants (MOE, 2006b).

Table 7-84 CH<sub>4</sub> emission factors by each treatment process

Treatment method	CH <sub>4</sub> Emission factor [kg-CH <sub>4</sub> /m <sup>3</sup> ]	Reference
Anaerobic treatment	0.543	Estimated by multiplying the actual methane emissions given in Japan Environmental Sanitation Center (1990) by the value of 1 – CH <sub>4</sub> recovery rate (90%).
Aerobic treatment	0.00545	Simple average value of standard de-nitrification and high-load de-nitrification since actual data on emissions is not available.
Standard de-nitrification treatment	0.0059	Tanaka et al. (1995)
High load de-nitrification treatment	0.005	Tanaka et al. (1995)
Membrane separation	0.00545	Because the current status of its emissions is not identified, substituted the emission factor for aerobic treatment.
Other	0.00545	Because the current status of its emissions is not identified, substituted the emission factor for aerobic treatment.

### ● Activity Data

Activity data for CH<sub>4</sub> emissions associated with the processing of wastewater at human waste treatment plants is determined from the calculated throughput volume for each of the treatment processes (Table 7-87), by multiplying the total volume of human waste and *Johkasou* sludge processed at human waste treatment plants that are indicated in *Waste Treatment in Japan* (MOE) (Table 7-85) by the capacity of each treatment process (Table 7-86).

$$A_i = W_H \times C_i / C_T$$

- $A_i$  : Activity data for human waste treatment method  $i$  [kl]  
 $W_H$  : Total amount of human waste and septic tank sludge [kl]  
 $C_i$  : Capacity of waste treatment method  $i$  [kl]  
 $C_T$  : Total capacity of all waste treatment methods [kl]

Table 7-85 Volume of human waste and *Johkasou* sludge treated at their treatment plants

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Human waste from vault toilet	1000 kl	20,406	18,049	14,673	10,400	7,917	7,365	7,018	6,771	6,375	6,153	5,890	5,627	5,415	5,191	4,974
<i>Johkasou</i> sludge	1000 kl	9,224	11,545	13,234	13,790	13,760	13,547	13,519	13,726	13,562	13,537	13,648	13,536	13,534	13,415	13,372
Total	1000 kl	29,630	29,594	27,907	24,190	21,677	20,912	20,537	20,497	19,937	19,690	19,538	19,163	18,949	18,606	18,346

Table 7-86 Trends in treatment capacity by treatment process

Unit	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Anaerobic treatment	kl/day	34,580	19,869	10,996	6,476	3,891	3,265	3,159	3,059	2,779	2,245	2,155	1,799	1,574	1,527	1,330
Aerobic treatment	kl/day	26,654	19,716	12,166	8,465	6,753	6,200	6,469	6,001	5,899	5,979	5,600	4,743	4,468	3,760	3,666
Standard denitrification	kl/day	25,196	30,157	31,908	29,655	26,173	25,694	25,608	25,153	24,663	24,023	22,812	21,544	21,113	21,599	21,322
High-intensity denitrification	kl/day	8,158	13,817	16,498	17,493	16,104	15,778	15,030	14,529	14,336	13,831	13,651	13,838	13,289	13,093	12,601
Membrane separation	kl/day	NO	1,616	2,375	3,055	3,684	3,684	4,062	4,074	2,204	3,373	3,184	2,853	2,404	2,458	2,410
Other	kl/day	13,777	20,028	25,917	30,277	34,577	34,622	33,556	33,975	34,983	33,940	36,074	37,430	40,223	39,731	40,882

Table 7-87 Activity Data for human waste by treatment types

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Anaerobic treatment	1000 kl	9,455	5,589	3,073	1,642	925	765	738	722	653	530	504	419	359	346	297
Aerobic treatment	1000 kl	7,288	5,546	3,400	2,146	1,605	1,453	1,512	1,417	1,386	1,412	1,311	1,106	1,019	851	818
Standard denitrification	1000 kl	6,889	8,483	8,917	7,518	6,222	6,021	5,984	5,940	5,794	5,672	5,339	5,022	4,816	4,891	4,758
High-intensity denitrification	1000 kl	2,231	3,887	4,611	4,435	3,828	3,697	3,512	3,431	3,368	3,266	3,195	3,226	3,031	2,965	2,812
Membrane separation	1000 kl	NO	455	664	774	876	863	949	962	518	796	745	665	548	557	538
Other	1000 kl	3,767	5,634	7,243	7,676	8,220	8,113	7,841	8,024	8,219	8,014	8,443	8,725	9,175	8,997	9,123
Total	1000 kl	29,630	29,594	27,907	24,190	21,677	20,912	20,537	20,497	19,937	19,690	19,538	19,163	18,949	18,606	18,346

## 2) N<sub>2</sub>O

### ● Estimation Method

Emissions of N<sub>2</sub>O from this source are calculated using Japan's country-specific methodology, in accordance with decision tree of the *2006 IPCC Guidelines* (Page 6.10, Fig. 6.2). Emissions are calculated by multiplying the volume of nitrogen treated at human waste treatment plants, by the emission factor.

$$E = \sum_i (EF_i \times A_i)$$

- $E$  : Emission of nitrous oxide from the processing of domestic and commercial wastewater at human waste treatment plants [kg-N<sub>2</sub>O]  
 $EF_i$  : Emission factor for human waste treatment plants (by treatment process  $i$ ) [kg-N<sub>2</sub>O/kg-N]  
 $A_i$  : Amount of nitrous oxide in human waste and Johkasou sludge input at human waste treatment plants (by treatment process  $i$ ) [kg-N]

### ● Emission Factors

The emission factors for N<sub>2</sub>O are determined for each treatment process including high-load denitrification treatment and membrane separation systems using the results of actual case studies in Japan (MOE, 2006b).

According to the survey study on the emission factors for human waste treatment facilities conducted in FY1994 (Tanaka et al., 1997) and FY2003 (Ohmura et al., 2004) in Japan, because of the advancement of the structure of human waste treatment facilities and the technology of operation and maintenance, actual measurement results show the improvement in the emission factors for high load de-nitrification treatment and membrane separation; therefore, different emission factors are used for FY1994 or before and from FY2003 onwards.

Table 7-88 N<sub>2</sub>O emission factors by each treatment process

Treatment method	N <sub>2</sub> O emission factors [kg-N <sub>2</sub> O-N/kg-N]		
	FY1990-1994	FY1995-2002	From FY2003
High load de-nitrification treatment	0.033 <sup>1)</sup>	Interpolation	0.0029 <sup>2)</sup>
Membrane separation	0.033 <sup>1)</sup>	Interpolation	0.0024 <sup>2)</sup>
Other (including anaerobic treatment, aerobic treatment, standard de-nitrification treatment)	0.0000045 <sup>3)</sup>		

Note:

- 1) Use median value of actual measurements at 13 plants given in Tanaka et al. (1998)
- 2) Use median value of actual measurements at 13 plants given in Omura et al. (2004)
- 3) Referred to Tanaka et al. (1995) (Calculated by dividing upper limit value for standard de-nitrification treatment ( $1.0 \times 10^{-5}$  kg-N<sub>2</sub>O/m<sup>3</sup>) by treated nitrogen concentration in FY1994 (2,211 mg/l)).

### ● Activity Data

The volume of nitrogen treated at human waste treatment plants is calculated by multiplying treated nitrogen concentration by the volume of human waste treated at these facilities (the sum of collected human waste and sewage in sewerage tank), given in the *Waste Treatment in Japan* (MOE). The treated nitrogen concentration is based on weighted average of the volume of nitrogen contained in collected human waste and sewage in sewerage tank derived using the volume of collected human waste and sewage in sewerage tank treated at human waste treatment plants.

$$A_i = (W_H \times N_H + W_J \times N_J) \times F_i / 1000$$

$A_i$	: Activity data for human waste treatment method $i$ [kg-N]
$W_H$	: Input volume of human waste at human waste treatment plants [m <sup>3</sup> ]
$W_J$	: Input volume of <i>Johkasou</i> sludge at human waste treatment plants [m <sup>3</sup> ]
$N_H$	: Nitrogen concentration in human waste [mg-N/l]
$N_J$	: Nitrogen concentration in <i>Johkasou</i> sludge [mg-N/l]
$F_i$	: Percentage throughput of treatment process $i$ [%]

➤ **Input Volume of Human Waste and *Johkasou* sludge at Human Waste Treatment Plants:**

See the data used for the calculation of CH<sub>4</sub> emissions from human waste treatment plants (Table 7-85).

➤ **Percentage Throughput of the Human Waste Treatment Processes:**

See the data used for the calculation of CH<sub>4</sub> emission from human waste treatment plants (Table 7-86).

➤ **Nitrogen Concentration in Human Waste and *Johkasou* Sludge Input at Treatment Plants:**

For the nitrogen concentration in human waste and *Johkasou* sludge input at treatment plants, the values analyzed for the period FY1989-1991, FY1992-1994, FY1995-1997, and FY1998-2000, respectively, are used based on the research conducted by Okazaki (2001). The value of FY2000 is substituted for the values from FY2001 onward. (See Table 7-89).

Table 7-89 Concentration of nitrogen contained in collected human waste and *Johkasou* sludge

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Human waste from vault toilet	mg-N/l	3,940	3,100	2,700	2,700	2,700	2,700	2,700	2,700	2,700	2,700	2,700	2,700	2,700	2,700	2,700
<i>Johkasou</i> sludge	mg-N/l	1,060	300	580	580	580	580	580	580	580	580	580	580	580	580	580
Weighted average	mg-N/l	3,043	2,008	1,695	1,491	1,354	1,327	1,304	1,280	1,258	1,242	1,219	1,203	1,186	1,171	1,155

Table 7-90 Amount of nitrogen in human waste and *Johkasou* sludge processed at human waste treatment plants (Activity data)

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Anaerobic treatment	kt-N	28.8	11.2	5.2	2.4	1.3	1.0	1.0	0.9	0.8	0.7	0.6	0.5	0.4	0.4	0.3
Aerobic treatment	kt-N	22.2	11.1	5.8	3.2	2.2	1.9	2.0	1.8	1.7	1.8	1.6	1.3	1.2	1.0	0.9
Standard denitrification	kt-N	21.0	17.0	15.1	11.2	8.4	8.0	7.8	7.6	7.3	7.0	6.5	6.0	5.7	5.7	5.5
High-intensity denitrification	kt-N	6.8	7.8	7.8	6.6	5.2	4.9	4.6	4.4	4.2	4.1	3.9	3.9	3.6	3.5	3.2
Membrane separation	kt-N	NO	0.9	1.1	1.2	1.2	1.1	1.2	1.2	0.7	1.0	0.9	0.8	0.7	0.7	0.6
Other	kt-N	11.5	11.3	12.3	11.4	11.1	10.8	10.2	10.3	10.3	10.0	10.3	10.5	10.9	10.5	10.5
Total	kt-N	90.2	59.4	47.3	36.1	29.4	27.7	26.8	26.2	25.1	24.5	23.8	23.0	22.5	21.8	21.2

c) **Uncertainties and Time-series Consistency**

● **Uncertainties**

As for the uncertainties in emission factors for CH<sub>4</sub> and N<sub>2</sub>O in human waste treatment plant, the uncertainties in similar emission sources are substituted. As for the uncertainties in activity data, the uncertainties in domestic wastewater data indicated in Table 7-2 are applied. Details of the uncertainty assessment on this category are indicated in the Table 7-91.

Table 7-91 Uncertainty assessment for human waste treatment plant on the category “Domestic wastewater (5.D.1.-)”

Item	GHGs	Emission /removal factor uncertainty		Activity data uncertainty		Emission /removal uncertainty		The method of evaluating uncertainty in emission factor	The method of evaluating uncertainty in activity data	The method of evaluating uncertainty in emissions/removals
		(-)	(+)	(-)	(+)	(-)	(+)			
Human waste treatment plant	CH <sub>4</sub>	-84%	+84%	-10%	+10%	-84%	+84%	The uncertainty is assessed based on expert judgment. (The uncertainty in Old type <i>Johkasou</i> is substituted).	The uncertainty in municipal waste statistics based on expert judgment is used.	Combined by using the formula for propagation of errors.
	N <sub>2</sub> O	-87%	+87%	-10%	+10%	-88%	+88%			

- **Time-series Consistency**

For N<sub>2</sub>O emission factor, consistent data over the time series are constructed based on the actual measurement data by using the methods described in Table 7-88. For other parameters, data are constructed consistently for the entire time series. The emissions are calculated in a consistent manner.

**d) Category-specific QA/QC and Verification**

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

**e) Category-specific Recalculations**

By updating the statistical data, emissions in FY2018 and FY2019 were recalculated. See Chapter 10 for impact on trend.

**f) Category-specific Planned Improvements**

No improvements are planned.

#### 7.5.1.4. Natural Decomposition of Domestic Wastewater (5.D.1.-)

**a) Category Description**

Although most of the domestic wastewater generated by Japanese households is processed at wastewater treatment plants, treated wastewater which is discharged into public waters contains residual nitrogen. Also, some miscellaneous wastewater is discharged into public waters without any treatment. The CH<sub>4</sub> and N<sub>2</sub>O emissions from untreated wastewater and sludge decomposing in public waters and the N<sub>2</sub>O from treated wastewater are reported under this category. The emission sources for this category are shown on Table 7-92.

Table 7-92 Emission sources of category “Natural Decomposition of Domestic Wastewater (5.D.1.-)”

Emission source	Detail
Untreated wastewater (CH <sub>4</sub> , N <sub>2</sub> O)	Untreated miscellaneous wastewater from households using old type <i>Johkasou</i>
	Untreated miscellaneous wastewater from households using vault toilet
	Untreated miscellaneous wastewater from households using on-site disposal systems
Treated wastewater (N <sub>2</sub> O)	Treated wastewater from sewage treatment plants
	Treated wastewater from community plants and current advanced/standard type <i>Johkasou</i>
	Treated wastewater derived from human waste in old type <i>Johkasou</i>
	Treated wastewater from treatment of human waste/ <i>Johkasou</i> sludge in human waste treatment plants
Sludge (CH <sub>4</sub> , N <sub>2</sub> O)	Human waste and <i>Johkasou</i> sludge dumped into the ocean
	Sewage sludge dumped into the ocean

**b) Methodological Issues**

- **Estimation Method**

Estimation method is established in accordance with the method described in the *2006 IPCC Guidelines*. In the natural decomposition of wastewater, both the volume of organic matter extracted as sludge and recovered CH<sub>4</sub> are zero. Accordingly, CH<sub>4</sub> emissions are calculated by multiplying the volume of organic matter contained in the untreated domestic wastewater that is discharged into public waters by the emission factor. The N<sub>2</sub>O emission is calculated by multiplying the volume of nitrogen contained in the wastewater by the emission factor.

$$E = EF \times A$$

- $E$  : Emission of methane or nitrous oxide from the natural decomposition of domestic wastewater  
 [kg-CH<sub>4</sub>], [kg-N<sub>2</sub>O]  
 $EF$  : Emission factor [kg-CH<sub>4</sub>/kg-BOD], [kg-N<sub>2</sub>O/kg-N]  
 $A$  : Volume of organic matter [kg-BOD] or nitrogen [kg-N] in domestic wastewater

### ● Emission Factors

Emission factors are determined in accordance with the *2006 IPCC Guidelines*. The emission factor for CH<sub>4</sub> is established by multiplying the maximum CH<sub>4</sub> generation potential ( $B_0$ ) by a CH<sub>4</sub> conversion factor (MCF). The maximum CH<sub>4</sub> generation potential is set to 0.6 kg-CH<sub>4</sub>/kg-BOD, given in the *2006 IPCC Guidelines*, and the MCF is set to 0.1, a default value for “Sea, river and lake discharge” of “Untreated systems”.

$$\begin{aligned}
 EF_{CH_4} &= B_0 \times MCF \\
 &= 0.6 \text{ [kg-CH}_4\text{/kg-BOD]} \times 0.1 \\
 &= 0.06 \text{ [kg-CH}_4\text{/kg-BOD]}
 \end{aligned}$$

The emission factor for N<sub>2</sub>O is calculated from the value of 0.005 kg N<sub>2</sub>O-N/kg N after conversion of the units.

$$\begin{aligned}
 EF_{N_2O} &= 0.005 \text{ [kg-N}_2\text{O-N/kg-N]} \times 44/28 \\
 &= 0.0079 \text{ [kg-N}_2\text{O/kg-N]}
 \end{aligned}$$

### ● Activity Data

#### ➤ Untreated wastewater

Activity data for CH<sub>4</sub> and N<sub>2</sub>O emissions from untreated wastewater are obtained from the following equation:

$$A = \sum_i P_i \times U$$

- $A$  : Activity data of untreated miscellaneous wastewater from households [g-BOD], [g-N]  
 $P_i$  : User population of treatment system type  $i$  (old type *Johkasou*, vault toilet, on-site disposal system)<sup>1)</sup> [person]  
 $U$  : Unit BOD effluent (40 [g-BOD/person-day]<sup>2)</sup>), or unit nitrogen effluent (2 [g-N/person-day]<sup>2)</sup>) from untreated miscellaneous wastewater

Reference:

- 1) *Waste Treatment in Japan* (MOE)  
 2) JSWA (1999)

Note that a portion of the human waste in on-site disposal systems is utilized as fertilizer on farmlands in Japan. The N<sub>2</sub>O emission from this is already included in the “Direct soil emission (3.D.1.)” category in the Agriculture sector, and therefore, not included in the calculation for this source.

#### ➤ Treated wastewater

Activity data for N<sub>2</sub>O emissions from treated wastewater are obtained from the following equations:

$$A = A_{sp} + A_{dp} + A_{hp}$$

- $A$  : Total nitrogen in treated domestic wastewater (activity data) [t-N]  
 $A_{sp}$  : Total nitrogen in treated wastewater from sewage treatment plants [t-N]  
 $A_{dp}$  : Total nitrogen in treated wastewater from domestic sewage treatment plants [t-N]  
 $A_{hp}$  : Total nitrogen in treated wastewater from human waste treatment plants [t-N]

#### - Sewage treatment plants

Total nitrogen in treated wastewater from sewage treatment plants are obtained from the equation below:

$$A_{sp} = \sum_i (W_i \times D_i) \times 10^{-6}$$

- $W_i$  : Amount of treated wastewater in sewage treatment plant  $i$  [m<sup>3</sup>]  
 $D_i$  : Nitrogen concentration in treated wastewater from sewage treatment plant  $i$  [mg-N/l]

References:

- 1) *Sewage Statistics (JSWA)* for both parameters

#### - Domestic sewage treatment plant

Total nitrogen in treated wastewater from domestic sewage treatment plants (community plant, current advanced/standard type *Johkasou*, and old type *Johkasou*) are obtained from the equation below:

$$A_{dp} = \sum_i \{TN_i \times d \times P_i \times (1 - R_i)\} \times 10^{-6}$$

- $TN_i$  : Unit total nitrogen effluent from domestic sewage plant type  $i$  [g-N/person-day] (see Table 7-93)  
 $P_i$  : User population of domestic sewage treatment plant type  $i$  [person] (see Table 7-82)  
 $R_i$  : Fraction of nitrogen removal in domestic sewage plant type  $i$  [%] (see Table 7-94)  
 $d$  : Annual days [days/year]

Unit nitrogen effluent from each domestic sewage plant type and fraction of nitrogen removal in these plants are shown in the following tables:

Table 7-93 Unit nitrogen effluent from domestic sewage plants

Treatment system	Sewage type	Unit nitrogen effluent [g-N/person-day]	Reference
Community plant	Human waste and miscellaneous wastewater	10	MOE (2009)
Current type <i>Johkasou</i> (both advanced and standard type)			
Old type <i>Johkasou</i>	Human waste	8	

Table 7-94 Fraction of nitrogen removal in domestic sewage plants

Treatment system		Fraction of nitrogen removal [%]	Reference	
Community plant		20	Expert judgement	
Current type <i>Johkasou</i>	Advanced type	TN removal type		60
		TN and TP removal type		
		BOD removal type		
	Other advanced type	20		
Standard type				
Old type <i>Johkasou</i>				

### - **Human waste treatment plant**

Total nitrogen in treated wastewater from human waste treatment plant are obtained from the equation below:

$$A_{hp} = W \times D \times 10^{-6}$$

$W$  : Amount of human waste and *Johkasou* sludge treated in human waste treatment plant<sup>1)</sup> [m<sup>3</sup>]

$D$  : Nitrogen concentration in treated wastewater from human waste treatment plant [mg-N/l]

References:

1) *Waste Treatment in Japan* (MOE)

Nitrogen concentration in treated wastewater of this subcategory is obtained as weighted averages of those in discharged wastewater from each human waste treatment type (Table 7-95) weighted by treatment capacities by treatment process (Table 7-86).

Table 7-95 Nitrogen concentrations in discharged wastewater from each human waste treatment method

Treatment method	Nitrogen concentration [mg-N/l]	Reference
Anaerobic treatment	98.0	Okazaki et al. (2001)
Aerobic treatment	32.5	
Standard de-nitrification treatment	5.5	
High load de-nitrification treatment	19.0	
Membrane separation	10.0	

### ➤ **Sludge**

Activity data for CH<sub>4</sub> and N<sub>2</sub>O emissions from sludge dumped into ocean are obtained from the equations below:

### - **Human waste/Johkasou sludge**

$$A = V_H \times D_H + V_J \times D_J$$

$A$  : Activity data of human waste/*Jokasou* sludge dumped into ocean [g-BOD], [g-N]

$V_H$  : Human waste dumped in ocean <sup>1)</sup> [kl]

$D_H$  : BOD/Nitrogen concentration in human waste<sup>2)</sup> [mg-BOD/l], [mg-N/l]

$V_J$  : *Jokasou* sludge dumped in ocean <sup>1)</sup> [kl]

$D_J$  : BOD/Nitrogen concentration in *Jokasou* sludge<sup>2)</sup> [mg-BOD/l], [mg-N/l]

Reference:

1) *Waste Treatment in Japan* (MOE)

2) Okazaki et al. (2001)

### - **Sewage sludge**

$$A = V \times D$$

$A$  : Activity data of sewage sludge dumped into ocean [g-BOD], [g-N]

$V$  : Sewage sludge dumped into ocean <sup>1)</sup> [kl]

$D$  : BOD/Nitrogen concentration into sewage sludge <sup>2)</sup> [mg-BOD/l], [mg-N/l]

Reference:

1) *Sewage Statistics* (JSWA)

2) The value for *Johkasou* sludge is substituted by Expert judgement based on Okazaki et al. (2001).

Estimated activity data are shown in Table 7-96.



Table 7-96 Amount of organic material and nitrogen in untreated domestic wastewater and discharged into public water zone (Activity data)

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Organic mater in:																
Untreated wastewater (from old type <i>Johkasou</i> )	kt-BOD	392	381	341	267	204	194	191	181	173	167	161	154	148	144	136
Untreated wastewater (from Vault toilet)	kt-BOD	568	429	298	203	146	136	130	120	113	105	101	95	89	84	80
Untreated wastewater (from On-site disposal)	kt-BOD	46	21	9	4	2	2	2	1	1	1	1	1	1	1	1
Human waste, <i>Johkasou</i> sludge	kt-BOD	22	14	9	4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Sewage sludge (Ocean dumping)	kt-BOD	1	1	0.05	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Total	kt-BOD	1,029	846	658	478	351	333	322	302	287	273	263	250	238	229	218
Nitrogen in:																
Untreated wastewater (from old type <i>Johkasou</i> )	kt-N	19.6	19.1	17.0	13.4	10.2	9.7	9.6	9.0	8.6	8.3	8.1	7.7	7.4	7.2	6.8
Untreated wastewater (from Vault toilet)	kt-N	28.4	21.5	14.9	10.2	7.3	6.8	6.5	6.0	5.6	5.3	5.0	4.8	4.4	4.2	4.0
Untreated wastewater (from on-site disposal)	kt-N	2.3	1.1	0.5	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.05	0.05	0.1	0.1	0.0
Treated wastewater	kt-N	297.0	301.2	281.8	267.0	251.6	255.0	243.2	250.0	241.3	243.0	241.9	239.2	235.2	246.8	245.2
Human waste, <i>Johkasou</i> sludge	kt-N	7.2	3.2	2.2	0.8	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Sewage sludge (Ocean dumping)	kt-N	0.1	0.1	0.01	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Total	kt-N	354.6	346.0	316.4	291.5	269.1	271.6	259.3	265.1	255.6	256.7	255.0	251.7	247.2	258.2	256.1

### c) Uncertainties and Time-series Consistency

#### ● Uncertainties

As for the uncertainties in emission factors for CH<sub>4</sub> and N<sub>2</sub>O in this category, the uncertainties in similar emission sources are substituted. As for the uncertainties in activity data, the uncertainties in domestic wastewater data indicated in Table 7-2 are applied. Details of the uncertainty assessment on this category are indicated in the Table 7-97.

Table 7-97 Uncertainty assessment for natural decomposition of domestic wastewater on the category “Domestic wastewater (5.D.1.-)”

Item	GHGs	Emission/removal factor uncertainty		Activity data uncertainty		Emission/removal uncertainty		The method of evaluating uncertainty in emission factor	The method of evaluating uncertainty in activity data	The method of evaluating uncertainty in emissions/removals
		(-)	(+)	(-)	(+)	(-)	(+)			
Natural decomposition	CH <sub>4</sub>	-58%	+58%	-10%	+10%	-59%	+59%	Since the 2006 IPCC Guidelines provide the emission factors as default value for this category, the uncertainty is assessed in accordance with the default method in the guidelines. Due to the lack of information for the uncertainty of the emission factor, the uncertainty in CH <sub>4</sub> is substituted based on expert judgment.	The uncertainty in municipal waste statistics based on expert judgment is used.	Combined by using the formula for propagation of errors.
	N <sub>2</sub> O	-58%	+58%	-10%	+10%	-59%	+59%			

#### ● Time-series Consistency

The emissions are calculated in a consistent manner.

### d) Category-specific QA/QC and Verification

General inventory QC procedures are conducted in accordance with the 2006 IPCC Guidelines. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

**e) Category-specific Recalculations**

By updating the statistical data, emissions in FY2018 and FY2019 were recalculated. See Chapter 10 for impact on trend.

**f) Category-specific Planned Improvements**

No improvements are planned.

**7.5.2. Industrial Wastewater (5.D.2.)**

CH<sub>4</sub> and N<sub>2</sub>O emissions from industrial effluent, which is treated by plants/facilities in accordance with the regulations based on the Water Pollution Prevention Law and the Sewerage Law, are allocated to “Industrial wastewater treatment (5.D.2.-)”, CH<sub>4</sub> and N<sub>2</sub>O emissions from untreated/treated industrial effluent discharged from plants/facilities and decomposed in public waters, are allocated to “Natural decomposition of Industrial wastewater (5.D.2.-)”, and CH<sub>4</sub> and N<sub>2</sub>O emissions from landfill leachate treatment are allocated to “Landfill leachate treatment (5.D.2.-)” under the sub-category of “Industrial Wastewater (5.D.2.)”.

**7.5.2.1. Industrial Wastewater Treatment (5.D.2.-)****a) Category Description**

CH<sub>4</sub> and N<sub>2</sub>O emissions from industrial effluent, which is treated by factories and other facilities in accordance with the regulations based on the Water Pollution Prevention Law and the Sewerage Law, are allocated to “Industrial wastewater treatment (5.D.2.-)”.

**b) Methodological Issues**● **Estimation Method**

In accordance with the decision tree of the *2006 IPCC Guidelines* (Page 6.19, Fig. 6.3), CH<sub>4</sub> and N<sub>2</sub>O emissions are estimated for the industries that release organic-rich wastewater. Since default values given in the *2006 IPCC Guidelines* are considered to be unsuited to Japan’s circumstances, CH<sub>4</sub> emissions are estimated based on Japan’s country-specific methodology, namely, by multiplying the annual amount of organic matter in industrial wastewater subject to report (BOD basis) by the CH<sub>4</sub> emission factor per unit BOD that is based on Japan’s country-specific wastewater handling. Because CH<sub>4</sub> is emitted in wastewater biological treatment processes, BOD-based activity data (amount of organic matter in wastewater degraded through biological treatment) is thought to be preferable to COD-based data. For this reason, CH<sub>4</sub> emissions are calculated using BOD in Japan. With regard to N<sub>2</sub>O emissions, no estimation methodologies are given in the *2006 IPCC Guidelines*. Therefore, in the same manner for estimating CH<sub>4</sub> emissions, N<sub>2</sub>O emissions are estimated by multiplying the amount of nitrogen in industrial wastewater by Japan’s country-specific N<sub>2</sub>O emission factor.

$$E = EF \times A$$

*E* : Amount of CH<sub>4</sub> or N<sub>2</sub>O emissions generated when treating industrial wastewater [kg-CH<sub>4</sub>], [kg-N<sub>2</sub>O]  
*EF* : Emission factor [kg-CH<sub>4</sub>/kg-BOD], [kg-N<sub>2</sub>O/kg-N]  
*A* : Amount of BOD or nitrogen in industrial wastewater [kg-BOD], [kg-N]

● **Emission Factor**

Country-specific emission factors obtained from a set of actual measurement at 8 plants in summer and winter (MOE, 2018 a) are adopted (MOE, 2018 b).

Table 7-98 Emission Factors for industrial wastewater treatment facilities

Category of Manufacturing	CH <sub>4</sub> Emission factor [g-CH <sub>4</sub> /kg-BOD]	N <sub>2</sub> O Emission factor [g-N <sub>2</sub> O/kg-N]
Manufacture of food	1.2	0.47
Manufacture of pulp, paper and paper products	2.5	0.014
Manufacture of chemical and allied product	0.92	17
Manufacture of iron and steel	7.3	4.0
Other manufactures (average emission factors for above categories)	3.0	5.3

In Japan, CH<sub>4</sub> emissions generated by anaerobic wastewater treatment are entirely recovered. For a small amount of CH<sub>4</sub> emissions generated under partially anaerobic conditions created during aerobic treatment, a country-specific emission factor is applied for emission estimates because the condition for this particular CH<sub>4</sub> emission differs from that for the use of default value for the CH<sub>4</sub> emissions generated from anaerobic treatment defined in *the 2006 IPCC Guidelines*.

### ● Activity Data

The activity data for CH<sub>4</sub> emission are estimated based on the amount of organic matter contained in wastewater using BOD concentrations. The emission estimates are conducted for the industries which generate large amount of CH<sub>4</sub> emissions with high BOD concentrations from the treatment of wastewater referring to the industry types provided in the *Revised 1996 IPCC Guidelines* (Table 7-99). The amount of organic matter is obtained by sorting and aggregating by industry type according to the middle industrial classification provided by JSWA (2009).

The use of COD concentrations is required to report activity data on CRF; however, activity data are reported as “NE” because country-specific methodology is used for this source.

$$A_{CH_4,i} = W_i \times BOD_i / 1000$$

Where:

$$W_i = I_i \times F_{CH_4,i} \times F_{onsite,i}$$

- $A_{CH_4,i}$  : Amount of BOD in industrial wastewater from industry type  $i$  (Activity data) [kg-BOD]
- $W_i$  : Amount of industrial wastewater from industry type  $i$  flowing into wastewater treatment facilities [m<sup>3</sup>]
- $BOD_i$  : BOD concentration of runoff water from industry type  $i$  [mg-BOD/l]
- $I_i$  : Amount of industrial wastewater from industry type  $i$  used for product processing and/or washing [m<sup>3</sup>]
- $F_{CH_4,i}$  : Percentage of industrial wastewater from industry type  $i$  treated at treatment facilities emitting CH<sub>4</sub> [%]
- $F_{onsite,i}$  : Percentage of industrial wastewater from industry type  $i$  treated on-site [%]

The activity data for N<sub>2</sub>O emissions are obtained based on the amount of nitrogen contained in industrial wastewater and aggregated by the same industrial sub-category as that applied to the estimation of CH<sub>4</sub> emissions.

$$A_{N_2O,i} = W_i \times TN_i / 1000$$

Where:

$$W_i = I_i \times F_{N_2O,i} \times F_{onsite,i}$$

$A_{N_2O,i}$  : Amount of nitrogen in industrial wastewater from industry type  $i$  (Activity data) [kg-N]

$W_i$  : Amount of industrial wastewater from industry type  $i$  flowing into wastewater treatment facilities [m<sup>3</sup>]

$TN_i$  : Total nitrogen concentration of runoff water from industry type  $i$  [mg-N/l]

$I_i$  : Amount of industrial wastewater from industry type  $i$  used for product processing and/or washing [m<sup>3</sup>]

$F_{N_2O,i}$  : Percentage of industrial wastewater from industry type  $i$  treated at treatment facilities emitting N<sub>2</sub>O [%]

$F_{onsite,i}$  : Percentage of industrial wastewater from industry type  $i$  treated on-site [%]

➤ **Amount of Industrial Wastewater Inflowed into Wastewater Treatment Facilities**

The amount of water used for the treatment of products by industrial sub-category and the volume of water used for washing given in the *Table of Industrial Statistics - Land and Water* (METI) are used for the amount of industrial wastewater treated at wastewater treatment facilities.

➤ **Percentage of Industrial Wastewater Treated at Facilities Generating CH<sub>4</sub>**

Emissions of CH<sub>4</sub> from industrial wastewater treatment are believed to be generated from the treatment of wastewater with the activated sludge method and from the anaerobic treatment. Industrial wastewater treatment percentages for each industry code are set from the percentages of reported wastewater amounts in total wastewater, as given under “active sludge”, “other biological treatment”, “membrane treatment”, “nitrification and denitrification” and “other advanced treatment” in the *Study on the Control of Wastewater loading* (Water and Air Environment Bureau of MOE).

➤ **Percentage of Industrial Wastewater Treated at Facilities Generating N<sub>2</sub>O**

Emissions of N<sub>2</sub>O from industrial wastewater treatment are believed to be generated mainly from biological treatment processes such as denitrification. Data on the fraction of industrial wastewater treated at facilities generating CH<sub>4</sub> is also used for N<sub>2</sub>O emission estimates.

➤ **Percentage of Industrial Wastewater Treated On-site**

Percentage of industrial wastewater treated on-site is set at 1.0 in all industrial sub-categories because there is no statistical information available making it possible to ascertain this percentage.

➤ **BOD and Nitrogen Concentrations in Runoff Wastewater**

For the BOD concentrations for industrial sub-categories, the BOD raw water quality for industrial sub-categories given in JSWA (1999) is used. For the nitrogen concentrations for industrial sub-categories, emission intensities (TN: Total Nitrogen) provided by the same survey for industrial sub-categories are used.

Table 7-99 BOD and nitrogen concentrations by industry type used for emission estimates

Industry code	Category of Manufacturing	mg-BOD/L	mg-N/L
9	Manufacture of food	1,470	62
10	Manufacture of beverages, tobacco and feed	1,138	77
11	Manufacture of textile products	386	36
14	Manufacture of pulp, paper and paper products	556	37
16	Manufacture of chemical and allied product	1,093	191
17	Manufacture of petroleum and coal products	975	289
18	Manufacture of plastic products	268	11
19	Manufacture of rubber products	112	32
20	Manufacture of leather tanning, leather products and fur skins	1,810	60
22	Manufacture of iron and steel	246	310

Table 7-100 BOD load and TN load of industrial wastewater (Activity data)

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
<b>BOD load</b>																
Manufacture of food	kt-BOD	297.8	326.2	306.8	289.4	311.7	299.8	288.0	307.2	348.4	348.4	348.4	348.4	348.4	348.4	348.4
Manufacture of beverages, tobacco and feed	kt-BOD	88.7	100.5	92.0	71.5	58.0	56.9	55.7	52.8	62.0	62.0	62.0	62.0	62.0	62.0	62.0
Manufacture of textile products	kt-BOD	98.1	94.2	65.5	47.7	40.1	42.8	45.4	38.2	36.4	36.4	36.4	36.4	36.4	36.4	36.4
Manufacture of pulp, paper and paper products	kt-BOD	471.8	422.7	457.3	423.4	365.4	353.1	340.9	321.4	324.0	324.0	324.0	324.0	324.0	324.0	324.0
Manufacture of chemical and allied product	kt-BOD	110.2	95.3	103.0	160.1	162.9	157.1	151.3	154.2	146.1	146.1	146.1	146.1	146.1	146.1	146.1
Manufacture of petroleum and coal products	kt-BOD	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Manufacture of plastic products	kt-BOD	6.2	5.9	6.2	6.9	6.9	7.1	7.4	7.1	6.2	6.2	6.2	6.2	6.2	6.2	6.2
Manufacture of rubber products	kt-BOD	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Manufacture of leather tanning, leather products and fur skins	kt-BOD	1.3	1.1	0.8	0.5	0.4	0.4	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Manufacture of iron and steel	kt-BOD	1.2	1.3	1.3	1.5	1.8	1.7	1.7	1.6	1.4	1.4	1.4	1.4	1.4	1.4	1.4
<b>TN load</b>																
Manufacture of food	kt-N	15.5	16.9	16.3	15.0	16.0	15.3	14.6	15.8	17.4	17.4	17.4	17.4	17.4	17.4	17.4
Manufacture of beverages, tobacco and feed	kt-N	3.8	4.2	4.3	3.9	2.6	2.5	2.4	2.8	3.3	3.3	3.3	3.3	3.3	3.3	3.3
Manufacture of textile products	kt-N	10.8	10.5	7.4	5.2	4.4	4.8	5.3	4.3	4.1	4.1	4.1	4.1	4.1	4.1	4.1
Manufacture of pulp, paper and paper products	kt-N	18.4	16.5	17.7	16.2	14.4	13.8	13.2	11.8	12.0	12.0	12.0	12.0	12.0	12.0	12.0
Manufacture of chemical and allied product	kt-N	40.0	38.8	30.1	48.5	50.8	50.7	50.6	50.8	49.8	49.8	49.8	49.8	49.8	49.8	49.8
Manufacture of petroleum and coal products	kt-N	0.1	0.1	0.1	0.1	0.03	0.03	0.03	0.02	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Manufacture of plastic products	kt-N	0.2	0.2	0.3	0.4	0.4	0.4	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Manufacture of rubber products	kt-N	0.04	0.04	0.02	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Manufacture of leather tanning, leather products and fur skins	kt-N	0.1	0.1	0.05	0.03	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Manufacture of iron and steel	kt-N	57.7	53.9	55.5	54.7	45.6	53.4	61.2	58.9	57.5	57.5	57.5	57.5	57.5	57.5	57.5

### c) Uncertainties and Time-series Consistency

#### ● Uncertainties

The uncertainty in emission factors are evaluated according to the survey for EFs (MOE, 2018a). As for the uncertainties in activity data, the uncertainties in industrial wastewater data indicated in Table 7-2 are applied. Details of the uncertainty assessment on this category are indicated in the Table 7-101.

Table 7-101 Uncertainty assessment for industrial wastewater treatment on the category “Industrial wastewater (5.D.2.-)”

Item	GHGs	Emission/removal factor uncertainty [%]		Activity data uncertainty [%]		Emission/removal uncertainty [%]		The method of evaluating uncertainty in emission factor	The method of evaluating uncertainty in activity data	The method of evaluating uncertainty in emissions/removals
		(-)	(+)	(-)	(+)	(-)	(+)			
Industrial wastewater treatment	CH <sub>4</sub>	-60%	+60%	-30%	+30%	-67%	+67%	The uncertainty is evaluated according to the survey for EFs (MOE, 2018a)	The uncertainty in industrial waste statistics based on expert judgment is used.	Combined by using the formula for propagation of errors.
	N <sub>2</sub> O	-95%	+95%	-30%	+30%	100%	+100%			

#### ● Time-series Consistency

Data on the percentage of industrial wastewater treated at CH<sub>4</sub>- and N<sub>2</sub>O-generating facilities since FY2001 are available only for FY2004. Therefore, data are interpolated and extrapolated for the remaining years. The emissions are calculated in a consistent manner.

**d) Category-specific QA/QC and Verification**

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

**e) Category-specific Recalculations**

No recalculations are conducted.

**f) Category-specific Planned Improvements**

No improvements are planned.

**7.5.2.2. Natural Decomposition of Industrial Wastewater (5.D.2.-)****a) Category Description**

Although most of the industrial wastewater in Japan generated in industrial plants and facilities is processed at industrial wastewater treatment plants, treated wastewater which is discharged into public waters contains residual nitrogen. Also, some industrial wastewater is discharged into public waters without any treatment. The CH<sub>4</sub> and N<sub>2</sub>O emissions from untreated wastewater decomposing in public waters and the N<sub>2</sub>O from treated wastewater are reported under this category.

**b) Methodological Issues**● **Estimation Method**

CH<sub>4</sub> and N<sub>2</sub>O emissions from untreated/treated industrial wastewater discharged into public waters are estimated in accordance with the method in the *2006 IPCC Guidelines*, as shown below.

$$E = EF \times A$$

*E* : Emission of methane or nitrous oxide from the natural decomposition of industrial wastewater [kg-CH<sub>4</sub>], [kg-N<sub>2</sub>O]

*EF* : Emission factor [kg-CH<sub>4</sub>/kg-BOD], [kg-N<sub>2</sub>O/kg-N]

*A* : Volume of organic matter [kg-BOD] or nitrogen [kg-N] in industrial wastewater

● **Emission Factor**

As for CH<sub>4</sub> and N<sub>2</sub>O emission factors for both of untreated and treated wastewater discharged into public waters, the default values of the *2006 IPCC Guidelines* are applied in a similar way of the category “7.5.1.4. Natural Decomposition of Domestic Wastewater (5.D.1.-)”.

Table 7-102 CH<sub>4</sub> and N<sub>2</sub>O emission factors for the category natural decomposition of industrial wastewater

Gas	Unit	Emission factor	Reference
CH <sub>4</sub>	kg-CH <sub>4</sub> / kg-BOD	0.06	<i>2006 IPCC Guidelines</i>
N <sub>2</sub> O	kg-N <sub>2</sub> O/ kg-N	0.0079	<i>2006 IPCC Guidelines</i>

● **Activity Data**

Activity data for this category cover 10 middle industrial classification shown on the Table 7-99 of “7.5.2.1. Industrial Wastewater Treatment (5.D.2.-).”

### ➤ *Untreated wastewater*

Activity data for this category are defined as a sum up of BOD or TN loadings from industrial plants/facilities which directly discharge untreated wastewater into public waters. The BOD or TN loadings in wastewater from each plant/facility are calculated by multiplying amount of wastewater and BOD or TN concentration in wastewater from each plant/facility, which data are obtained from the *Comprehensive Survey on Water Pollutant Discharge* (MOE).

$$A = \sum_i (V_i \times Q_i)$$

$A$  : Activity data of untreated wastewater (BOD or TN loadings) [kg-BOD/L], [kg-N/L]

$V_i$  : Amount of untreated industrial wastewater discharged into public waters from industrial plant/facility  $i$  [m<sup>3</sup>]

$Q_i$  : BOD or TN concentration of untreated industrial wastewater discharged from industrial plant/facility  $i$  [g-BOD/L], [g-N/L]

Table 7-103 BOD and TN loadings in untreated wastewater discharged into public waters (Activity data)

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
<b>BOD load</b>																
Manufacture of food	kt-BOD	8.0	8.5	9.0	16.3	6.2	6.3	5.3	4.3	4.6	5.0	5.3	5.5	5.5	5.5	5.5
Manufacture of beverages, tobacco and feed	kt-BOD	0.6	0.6	0.6	0.6	0.3	0.3	0.3	0.3	0.2	0.2	0.3	0.4	0.4	0.4	0.4
Manufacture of textile products	kt-BOD	3.4	2.9	2.2	2.2	4.4	4.5	4.8	5.1	3.8	2.5	2.9	3.3	3.3	3.3	3.3
Manufacture of pulp, paper and paper products	kt-BOD	9.4	8.9	8.9	8.4	3.6	3.6	5.3	6.9	5.2	3.4	3.7	4.1	4.1	4.1	4.1
Manufacture of chemical and allied product	kt-BOD	49.5	50.6	44.9	46.7	28.3	28.4	25.9	23.4	25.3	27.2	24.0	20.8	20.8	20.8	20.8
Manufacture of petroleum and coal products	kt-BOD	25.4	20.8	24.6	26.9	11.3	10.2	9.3	8.5	9.8	11.2	10.2	9.1	9.1	9.1	9.1
Manufacture of plastic products	kt-BOD	0.6	0.6	0.6	0.8	0.7	0.7	0.6	0.5	0.6	0.6	0.4	0.1	0.1	0.1	0.1
Manufacture of rubber products	kt-BOD	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.04	0.1	0.1	0.1	0.04	0.04	0.04	0.04
Manufacture of leather tanning, leather products and fur skins	kt-BOD	0.3	0.3	0.2	0.1	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.000	0.000	0.000	0.000
Manufacture of iron and steel	kt-BOD	39.7	37.3	40.3	36.5	26.1	26.4	22.8	19.1	22.5	26.0	22.2	18.5	18.5	18.5	18.5
<b>TN load</b>																
Manufacture of food	kt-N	5.0	5.3	5.6	5.3	3.2	3.3	3.3	3.3	2.9	2.6	2.5	2.4	2.4	2.4	2.4
Manufacture of beverages, tobacco and feed	kt-N	0.6	0.6	0.6	0.4	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.3	0.3	0.3	0.3
Manufacture of textile products	kt-N	0.8	0.7	0.5	0.4	1.7	1.7	1.8	1.8	1.7	1.6	1.6	1.6	1.6	1.6	1.6
Manufacture of pulp, paper and paper products	kt-N	0.7	0.7	0.7	0.5	0.6	0.6	0.5	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Manufacture of chemical and allied product	kt-N	31.4	32.2	28.5	28.2	21.3	20.6	18.3	16.1	15.8	15.5	15.9	16.2	16.2	16.2	16.2
Manufacture of petroleum and coal products	kt-N	19.6	16.0	18.9	8.8	7.6	7.6	7.4	7.2	7.0	6.7	6.5	6.3	6.3	6.3	6.3
Manufacture of plastic products	kt-N	0.3	0.3	0.3	0.4	0.3	0.3	0.3	0.3	0.3	0.4	0.2	0.1	0.1	0.1	0.1
Manufacture of rubber products	kt-N	0.3	0.3	0.2	0.3	0.1	0.1	0.1	0.1	0.1	0.04	0.03	0.03	0.03	0.03	0.03
Manufacture of leather tanning, leather products and fur skins	kt-N	0.01	0.01	0.01	0.01	0.003	0.003	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Manufacture of iron and steel	kt-N	33.3	31.2	33.7	41.8	17.6	17.6	16.3	14.9	14.6	14.2	14.7	15.2	15.2	15.2	15.2

### ➤ *Treated wastewater*

Activity data are defined as a sum up of TN loadings from industrial plants/facilities which discharge treated wastewater into public waters. The TN loadings in wastewater from each plant/facility are calculated by multiplying amount of wastewater and TN concentration for each plant/facility, which data are obtained from the *Comprehensive Survey on Water Pollutant Discharge* (MOE).

$$A = \sum_i (V_i \times TN_i)$$

$A$  : Activity data of treated wastewater (TN loadings) [kg-N/L]

$V_i$  : Amount of treated industrial wastewater discharged into public water from industrial plant/facility  $i$  [m<sup>3</sup>]

$TN_i$  : TN concentration in treated industrial wastewater discharged from industrial plant/facility  $i$   
[g-BOD/L], [g-N/L]

Table 7-104 TN loadings in treated industrial wastewater discharged into public waters (Activity data)

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Manufacture of food	kt-N	5.8	6.2	6.5	7.0	4.0	4.2	6.0	7.9	6.6	5.3	5.3	5.4	5.4	5.4	5.4
Manufacture of beverages, tobacco and feed	kt-N	1.1	1.1	1.1	0.7	0.6	0.6	0.5	0.5	0.4	0.4	0.7	1.1	1.1	1.1	1.1
Manufacture of textile products	kt-N	2.5	2.1	1.6	2.1	1.7	1.7	1.6	1.5	1.3	1.1	1.2	1.4	1.4	1.4	1.4
Manufacture of pulp, paper and paper products	kt-N	8.4	8.0	8.0	8.0	5.4	5.4	4.6	3.8	4.1	4.4	5.6	6.8	6.8	6.8	6.8
Manufacture of chemical and allied product	kt-N	17.0	17.4	15.5	14.2	15.9	15.4	14.6	13.7	13.2	12.7	11.2	9.7	9.7	9.7	9.7
Manufacture of petroleum and coal products	kt-N	2.2	1.8	2.1	1.1	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Manufacture of plastic products	kt-N	0.2	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Manufacture of rubber products	kt-N	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Manufacture of leather tanning, leather products and fur skins	kt-N	0.28	0.23	0.18	0.09	0.04	0.04	0.03	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02
Manufacture of iron and steel	kt-N	5.3	5.0	5.4	4.1	3.1	3.1	2.6	2.1	2.4	2.7	2.8	2.9	2.9	2.9	2.9

### c) Uncertainties and Time-series Consistency

#### ● Uncertainties

As for the uncertainties in emission factors for CH<sub>4</sub> and N<sub>2</sub>O in this category, the uncertainties in similar emission sources are substituted. As for the uncertainties in activity data, the uncertainties in industrial wastewater data indicated in Table 7-2 are applied. Details of the uncertainty assessment on this category are indicated in the Table 7-105.

Table 7-105 Uncertainty assessment for natural decomposition of industrial wastewater on the category “Industrial wastewater (5.D.2.-)”

Item	GHGs	Emission/removal factor uncertainty		Activity data uncertainty		Emission/removal uncertainty		The method of evaluating uncertainty in emission factor	The method of evaluating uncertainty in activity data	The method of evaluating uncertainty in emissions/removals
		(-)	(+)	(-)	(+)	(-)	(+)			
Natural decomposition	CH <sub>4</sub>	-58%	+58%	-30%	+30%	-66%	+66%	Since the 2006 IPCC Guidelines provide the emission factors as default value for this category, the uncertainty is assessed in accordance with the default method in the guidelines.	The uncertainty in industrial waste statistics based on expert judgment is used.	Combined by using the formula for propagation of errors.
	N <sub>2</sub> O	-58%	+58%	-30%	+30%	-66%	+66%	Due to the lack of information for the uncertainty of the emission factor, the uncertainty in CH <sub>4</sub> is substituted based on expert judgment.		

#### ● Time-series Consistency

The emissions are calculated in a consistent manner.

### d) Category-specific QA/QC and Verification

General inventory QC procedures are conducted in accordance with the 2006 IPCC Guidelines. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.



**e) Category-specific Recalculations**

No recalculations are conducted.

**f) Category-specific Planned Improvements**

No improvements are planned.

**7.5.2.3. Landfill Leachate Treatment (5.D.2.-)****a) Category Description**

CH<sub>4</sub> and N<sub>2</sub>O emissions from landfill leachate treatment in MSW and IW landfill sites are estimated and allocated to “Landfill leachate treatment (5.D.2.-).”

**b) Methodological Issues**● **Estimation Method**

Potential BOD load [kg-BOD/year] and TN load [kg-N/year] to be remained in leachate percolated thorough organic waste disposed of in MSW and IW landfill sites are applied for its activity data, and the methodology for the natural decomposition of domestic wastewater given in *the 2006 IPCC Guidelines* is applied to estimate CH<sub>4</sub> and N<sub>2</sub>O emissions from this source as described below:

$$E = EF \times L_i$$

$E$  : CH<sub>4</sub> and N<sub>2</sub>O emissions

$EF$  : CH<sub>4</sub> and N<sub>2</sub>O emission factor

$L_i$  : Potential BOD load [kg-BOD/year] and TN load [kg-N/year] to be remained in leachate percolated thorough organic waste disposed of in MSW and IW landfill sites

● **Emission Factors**

Emission factors for CH<sub>4</sub> and N<sub>2</sub>O are determined in accordance with the methodology for the natural decomposition of domestic wastewater given in the *2006 IPCC Guidelines* as described below.

CH<sub>4</sub> Emission factor

According to the *2006 IPCC Guidelines*, the emission factor for CH<sub>4</sub> is established by multiplying the maximum CH<sub>4</sub> generation potential ( $B_0$ ) by a CH<sub>4</sub> conversion factor (MCF). The maximum CH<sub>4</sub> generation potential ( $B_0$ ) is determined to be 0.6 kg-CH<sub>4</sub>/kg-BOD which is a default value for “Domestic waste water” given in the *2006 IPCC Guidelines*, and MCF is determined to be 0.8 which is also a default value for “Anaerobic reactor” of “Treated systems” given in the *2006 IPCC Guidelines*.

$$\begin{aligned} EF_{CH_4} &= B_0 \times MCF \\ &= 0.6 \text{ [kg-CH}_4\text{/kg-BOD]} \times 0.8 \\ &= 0.48 \text{ [kg-CH}_4\text{/kg-BOD]} \end{aligned}$$

$B_0$  : Maximum CH<sub>4</sub> generation potential [kg-CH<sub>4</sub>/kg-BOD], (IPCC default value:0.6)

$MCF$  : CH<sub>4</sub> conversion factor (IPCC default value: 0.8)

N<sub>2</sub>O Emission Factor

The emission factor for N<sub>2</sub>O is determined from a default value of 0.005 (kg N<sub>2</sub>O-N/kg N) given in the *2006 IPCC Guidelines* after unit conversion.

$$\begin{aligned}
 EF_{N_2O} &= 0.005 \text{ [kg-N}_2\text{O-N/kg-N]} \times 44/28 \\
 &= 0.0079 \text{ [kg-N}_2\text{O /kg-N]}
 \end{aligned}$$

### ● Activity Data

Based on MOE (2010), the activity data for CH<sub>4</sub> and N<sub>2</sub>O emission estimates are determined by establishing the ratio of organic and nitrogen contents to be remained in leachate for the amount of organic waste disposed of in MSW and IW landfill sites to obtain potential BOD load [kg-BOD/year] and TN load [kg-N/year].

#### CH<sub>4</sub> activity data

$$L_{BODi} = F_{BOD} \times W \times T_i$$

$L_{BODi}$  : Potential BOD load to be remained in leachate percolated thorough organic waste disposed of in MSW and IW landfill sites [kg-BOD/year]

$F_{BOD}$  : Ratio of organic contents for the amount of organic waste landfilled [kg-BOD/t] determined to be 0.188 [kg-BOD/t] based on MOE (2010)

$W$  : Amount of organic waste landfilled with or without intermediate treatments including incineration ash [t/year] obtained by the *Cyclical Use of Waste Report* (MOE)

$T_i$  : Ratio of leachate to be biologically treated in landfill site [%] determined to be 87.6% based on MOE (2010)

#### N<sub>2</sub>O activity data

$$L_{TNi} = F_{TN} \times W \times T_i$$

$L_{TNi}$  : Potential TN load to be remained in leachate percolated thorough organic waste disposed of in MSW and IW landfill sites [kg-N/year]

$F_{TN}$  : Ratio of nitrogen contents for the amount of organic waste landfilled [kg-N/t] determined to be 0.254 [kg-N/t] based on MOE (2010)

$W$  : Amount of organic waste landfilled with or without intermediate treatments including incineration ash [t/year] obtained by the *Cyclical Use of Waste Report* (MOE)

$T_i$  : Ratio of leachate to be biologically treated in landfill site [%] determined to be 87.6% based on MOE (2010)

Table 7-106 BOD load and TN load of landfill leachate (Activity data)

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
BOD load	kt-BOD	2.6	2.5	2.2	1.6	0.8	0.7	0.8	0.6	0.5	0.5	0.5	0.5	0.4	0.4	0.4
TN load	kt-N	3.5	3.3	3.0	2.2	1.1	0.9	1.0	0.8	0.7	0.7	0.6	0.6	0.6	0.5	0.5

### c) Uncertainties and Time-series Consistency

#### ● Uncertainties

As for the uncertainties in emission factors for CH<sub>4</sub> and N<sub>2</sub>O in landfill leachate treatment (5.D.2.-), the uncertainties in similar emission sources are substituted. As for the uncertainties in activity data, the uncertainties in industrial wastewater data indicated in Table 7-2 are applied. Details of the uncertainty assessment on this category are indicated in the Table 7-107.

Table 7-107 Uncertainty assessment for landfill leachate treatment on the category  
“Industrial wastewater (5.D.2.-)”

Item	GHGs	Emission /removal factor uncertainty		Activity data uncertainty		Emission /removal uncertainty		The method of evaluating uncertainty in emission factor	The method of evaluating uncertainty in activity data	The method of evaluating uncertainty in emissions/removals
		(-)	(+)	(-)	(+)	(-)	(+)			
Landfill leachate treatment	CH <sub>4</sub>	-39%	+39%	-100%	+100%	-107%	+107%	The uncertainty is quoted from MOE (2010), a reference of emission factors.	Due to the lack of information for the uncertainty of the activity data, the uncertainty is assessed by expert judgment.	Combined by using the formula for propagation of errors.
	N <sub>2</sub> O	-39%	+39%	-100%	+100%	-107%	+107%	Due to the lack of information for the uncertainty of the emission factor, the uncertainty in the EF of CH <sub>4</sub> in this category is substituted based on expert judgment.		

● **Time-series Consistency**

As described in detail in the preceding sections, emissions are calculated in a consistent manner.

**d) Category-specific QA/QC and Verification**

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

**e) Category-specific Recalculations**

By updating the statistical data, emissions in FY2019 were recalculated. See Chapter 10 for impact on trend.

**f) Category-specific Planned Improvements**

No improvements are planned.

## 7.6. Other (5.E.)

In this category, CO<sub>2</sub> emissions as a result of the decomposition of petroleum-derived surfactants are calculated. Estimated GHG emissions from category “Other” are shown in Table 7-109.

Table 7-108 Categories whose emissions are estimated for Other (5.E.)

Category	Waste type	Treatment type	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O
5.E.1. (7.6.1)	Petroleum-Derived Surfactants	Decomposition at wastewater treatment facilities and/or the environment	○	NA	NA

In FY2020, emissions from this source category are 601 kt-CO<sub>2</sub> eq. and accounted for 0.05% of the national total emissions (excluding LULUCF). The emissions from this source category had decreased by 14.5% compared to those in FY1990. This emission decrease is primarily due to the decrease in CO<sub>2</sub> emissions from the use of alkylbenzenes by introduction of the Pollutant Release and Transfer Register (PRTR).

Table 7-109 GHG emissions from category Other (5.E.)

Gas	Category	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
CO <sub>2</sub>	5.E. Other (Decomposition of petroleum-derived surfactants)	kt-CO <sub>2</sub>	703	668	656	507	527	524	528	605	617	625	619	637	673	582	601

### 7.6.1. Decomposition of Petroleum-Derived Surfactants (5.E.-)

#### a) Category Description

Surfactants are used for various cleaning activities at home and factories in Japan. Petroleum-derived surfactants discharged into wastewater treatment facilities and into the environment, and emit CO<sub>2</sub>. As this emission source did not correspond to any of the existing waste categories (5.A. to 5.D.), it is included in the “Other (5.E.)” section. Because “CH<sub>4</sub> and N<sub>2</sub>O emissions from wastewater treatment” and “CO<sub>2</sub> emissions from the decomposition of petroleum-derived surfactants” concern different types of gas, they are unrelated to each other and pose no duplicate inventory issues.

#### b) Methodological Issues

##### ● Estimation Method

As neither the 2006 IPCC Guidelines specified a method for determining CO<sub>2</sub> emissions, a method specifically established in Japan is applied to the calculation. Because carbon contained in surfactants that emitted into wastewater treatment facilities and into the environment is eventually oxidized to CO<sub>2</sub> and emitted into the atmosphere as a result of surfactants decomposition, CO<sub>2</sub> emissions are estimated based on the amount of carbon contained in surfactants that emitted into wastewater treatment facilities and into the environment.

Based on the facts stated above, the CO<sub>2</sub> emissions are calculated by multiplying the volume of the petroleum-derived surfactant for each type of raw material by the carbon content of each of the materials. The calculation covered synthetic alcohols, alkylbenzenes, alkylphenols, and ethylene oxide. Some of the carbon contained in surfactants discharged into wastewater treatment facilities are adsorbed and assimilated by sludge. However, this portion of carbon is not decomposed biologically. It is released into the atmosphere as CO<sub>2</sub> through incineration and landfilling of sludge. Therefore, the emission is included in CO<sub>2</sub> emission estimates.

### ● Emission Factor

Emission factor is determined for each type of material by calculating the amount of CO<sub>2</sub>, expressed in kg that is emitted from the decomposition of 1 t of a surfactant using the average carbon content in the molecules.

$$EF_i = C_i \times 1,000 \times 44/12$$

$EF_i$  : Emission factor for petroleum-derived raw material  $i$  used in a surfactant

$C_i$  : Average carbon content of petroleum-derived raw material  $i$  used in a surfactant

Table 7-110 Average carbon content of surfactants, by petroleum-derived raw material

Raw material	Carbon number	Molecular weight	Carbon content	Basis for determination
Synthetic alcohol	12	186	77.4%	C12-alcohol as the main constituent.
Alkylbenzene	18	250	86.4%	C12-alkylbenzene as the main constituent.
Alkylphenol	15	210	85.7%	C9-alkylphenol as the main constituent.
Ethylene oxide	2	44	54.5%	Based on ethylene oxide molecules (C <sub>2</sub> H <sub>4</sub> O)

### ● Activity Data

Activity data is the amount of raw materials consumed for petroleum-derived surfactants. As some of the surfactants produced in Japan are exported, the activity data are determined by multiplying the volume of raw materials used in the surfactants obtained from the statistical data for surfactant use by an import/export adjustment factor.

#### ➤ Volume of Surfactants Used

The volumes of the use of surfactant by material are obtained from the consumption of raw materials for surfactants indicated in the *Current Production Statistics - Chemical Industry*. As there is no compilation of usage since FY2002, the volume of use is estimated using the simple averages (k value) of ratio of consumption and production in the period from FY1990 to FY2001.

#### ➤ Export/import Correction Factor

Correction factor is calculated from the export/import statistics in *International Trade Statistics* by the Ministry of Finance (MOF) for categories of anionic surfactants, cationic surfactants, non-ionic surfactants, and other organic surfactants and the volume of surfactants used. As some of the materials for surfactants are used in several types of surfactants, an average of the export/import correction factor is weighted by surfactant production volume as necessary to calculate the correction factor for each classification of surfactant.

$$F_{corr.} = (P + I - E)/P$$

$F_{corr.}$  : Export/Import correction factor

$P$  : Surfactant production [t]

$I$  : Surfactant imported [t]

$E$  : Surfactant exported [t]

Table 7-111 Activity data associated with decomposition of petroleum-based surfactants

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Synthetic alcohol	t	29,239	16,253	28,285	31,609	33,750	34,870	36,193	43,324	42,947	44,299	45,551	45,601	47,840	43,762	48,251
Alkyl benzene	t	105,432	102,794	80,832	47,349	50,519	46,369	44,502	44,980	47,494	44,044	39,485	42,769	44,565	31,291	25,352
Alkyl phenol	t	10,141	8,798	7,454	3,448	2,054	2,263	2,910	4,318	4,885	4,873	4,638	5,661	6,211	4,711	3,755
Ethylene oxide	t	124,984	132,175	146,509	127,150	131,148	134,532	136,679	161,969	163,777	171,380	174,243	176,247	187,729	171,687	185,360

### c) *Uncertainties and Time-series Consistency*

#### ● *Uncertainty*

The uncertainty in emission factor for CO<sub>2</sub> is evaluated by using molecular weight which is used for calculation of emission factors, based on expert judgment. As for activity data, the same assessment as municipal waste statistics is applied based on expert judgment since information on the uncertainty is not available.

Table 7-112 Uncertainty assessment for decomposition of petroleum-derived surfactants on the category “Other (5.E.-)”

Item	GHGs	Emission /removal factor uncertainty		Activity data uncertainty		Emission /removal uncertainty		The method of evaluating uncertainty in emission factor	The method of evaluating uncertainty in activity data	The method of evaluating uncertainty in emissions/removals
		(-)	(+)	(-)	(+)	(-)	(+)			
Decomposition of petroleum-derived surfactants	CO <sub>2</sub>	-1%	+1%	-10%	+10%	-10%	+10%	The uncertainty is assessed by using molecular weight data based on expert judgment.	Due to the lack of information for the uncertainty of the activity data, the uncertainty in municipal waste statistics is substituted by expert judgment.	Combined by using the formula for propagation of errors.

#### ● *Time-series Consistency*

Consistent methodology is used in the estimation. However, data on the amount of raw materials consumed for surfactants have become not available since FY2002 and activity data are estimated from the production amount of the surfactants.

### d) *Category-specific QA/QC and Verification*

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

### e) *Category-specific Recalculations*

By revising the statistical data, emissions in FY2019 were recalculated. See Chapter 10 for impact on trend.

### f) *Category-specific Planned Improvements*

No improvements are planned.

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## Chapter 8. Other

### 8.1. Overview of Sector

*UNFCCC Reporting Guidelines (Decision 24/CP.19)* paragraph 38 indicates that Annex I Parties should report and explicitly describe the details of each country-specific source or sink which are not part of the *IPCC Guidelines*. According to this requirement, emissions from the Other sector (CRF sector 6) are indicated below.

### 8.2. CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O, HFCs, PFCs, SF<sub>6</sub>, and NF<sub>3</sub>

Among CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O, HFCs, PFCs, SF<sub>6</sub> and NF<sub>3</sub>, no emissions or removals are reported in the Other sector.

### 8.3. NO<sub>x</sub>, CO, NMVOC, and SO<sub>x</sub>

Among precursors (NO<sub>x</sub>, CO, NMVOC) and SO<sub>x</sub>, CO emissions from smoking are reported in the Other sector (see Annex 3).



## Chapter 9. Indirect CO<sub>2</sub> and N<sub>2</sub>O Emissions

### 9.1. Overview of Sector

#### a) Category Description

Since Parties may now choose to report indirect CO<sub>2</sub>, in accordance with paragraph 29 of the UNFCCC Inventory Reporting Guidelines, and since the estimation method reflecting Japanese actual status has been established, Japan elects to report indirect CO<sub>2</sub> emissions from the atmospheric oxidation of CH<sub>4</sub>, CO, and NMVOCs, and not to report indirect N<sub>2</sub>O emissions arising from sources other than those in the agriculture and LULUCF sectors.

Indirect CO<sub>2</sub> emissions originating from the use and/or evaporation of NMVOCs and CH<sub>4</sub> from the sectors/categories indicated in Table 9-1 are estimated. Other than evaporation of CH<sub>4</sub> and NMVOCs, CH<sub>4</sub>, CO, and NMVOCs originating from fuel combustion, evaporative fuel emissions from vehicles<sup>1</sup>, and CH<sub>4</sub>, CO, and NMVOCs from the incineration of fossil-fuel derived waste are oxidized to CO<sub>2</sub> in the atmosphere; these indirect CO<sub>2</sub> emissions are not reported, because these emissions are included in CO<sub>2</sub> emissions from fuel combustion (1.A.), and CO<sub>2</sub> emissions from waste incineration and open burning (5.C.)<sup>2</sup>, respectively. Indirect CO<sub>2</sub> emissions originating from biogenic CH<sub>4</sub>, CO, and NMVOC emissions from the agriculture sector, LULUCF sector, waste sector, and the Other sector were not reported from the viewpoint of carbon-neutrality, in accordance with the 2006 IPCC Guidelines.

Table 9-1 Sector/Category of indirect CO<sub>2</sub>

Sector/Category	Originated from CH <sub>4</sub>	Originated from CO	Originated from NMVOCs
1.B Fugitive emissions from Fuels	○	NE, NO	○
2. Industrial processes and product use	○	NE	○

#### b) Methodological Issues

##### ● Estimation Method

CO<sub>2</sub> emissions occurring from the oxidation of evaporative NMVOCs and CH<sub>4</sub> in the atmosphere are estimated with the following conversion formulae which are mentioned in the 2006 IPCC Guidelines;

$$E_{CO_2} = E_{CH_4} \times \frac{44}{16}$$

$$E_{CO_2} = E_{NMVOC} \times C \times \frac{44}{12}$$

$E_{CO_2}$  : Indirect CO<sub>2</sub> emissions [kt]

$E_{CH_4}$  : CH<sub>4</sub> emissions [kt]

$E_{NMVOC}$  : NMVOC emissions [kt]

$C$  : Average carbon content of NMVOCs

<sup>1</sup> Emissions are reported in 1.A.3. Transport.

<sup>2</sup> Japan assumes 100% oxidation during the combustion of fuel in 1.A. Fuel combustion and in 5.C. Waste incineration and open burning.

- **Parameters**

The average carbon content is calculated by weighting it by the composition rate of each NMVOC substance emitted from each source. The carbon contents of each substance are obtained from molecular formulae, and the type of substance and composition rate of NMVOCs were estimated based on the national emission inventory for volatile organic compounds (VOC) by the Ministry of Environment and other information. The average carbon content is calculated for each emission source until FY2014. The average carbon content across all emission sources in FY2014 of 0.73 is applied from FY2015 onward for all emission sources, because the yearly fluctuation of the carbon content is small. But for emission sources such as removers, that started to be reported from the 2018 submission, 0.73 is applied for years FY1990 and onward.

- **Activity Data**

Refer to Chapter 3 for information on CH<sub>4</sub> emissions from fugitive emissions from fuels (1.B.). Refer to Chapter 4 for information on CH<sub>4</sub> emissions from the chemical industry (2.B.) and metal industry (2.C.). Refer to Annex 3 for information on carbon monoxide (CO) and non-methane volatile organic compounds (NMVOCs).

**c) Uncertainties and Time-series Consistency**

- **Uncertainty**

Refer to Annex 2.

- **Time-series Consistency**

For average carbon content of NMVOCs, the composition for each substance is calculated using statistics which are consistent throughout the time-series. Refer to the relevant chapter for activity data.

**d) Category-specific QA/QC and Verification**

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

**e) Category-specific Recalculations**

See Chapter 10 for impact on trend.

**f) Category-specific Planned Improvements**

No improvements are planned.

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## Chapter 10. Recalculation and Improvements

### 10.1. Explanations and Justifications for Recalculations

This section explains improvements on estimation of emissions and removals in the inventory submitted in 2022.

In accordance with the *UNFCCC Reporting Guidelines* and the *2006 IPCC Guidelines*, Annex I Parties should recalculate their inventories for the base year and all subsequent years of the times series in the cases of 1) application of new estimation methods, 2) addition of new categories for emissions and removals, and 3) data refinement. Major changes from the previous inventory are indicated below.

#### 10.1.1. General Issues

As Japan's own specific circumstance, it can generally be said that activity data for the latest year available at the time when the inventory is compiled are often revised in the year following the submission year because of such as the publication of data in the fiscal year basis. In the national inventory submitted this year, activity data in many sources for FY2019 have been changed and as a result, the emissions from those sources for the inventory year have been recalculated.

#### 10.1.2. Recalculations in Each Sector

The information of recalculation for sectors (energy; industrial processes and product use; agriculture; land use, land-use change and forestry; and waste), occurring due to Japan's own specific circumstance and needs, is described separately under sections named as "Category-specific Recalculations" in Chapters 3 to 7.

### 10.2. Implications for Emission Levels

The following shows the changes made to the overall emission estimates due to the recalculations indicated in "Section 10.1. Explanations and Justifications for Recalculations".

#### 10.2.1. GHG Inventory

Compared to the values reported in the previous year's inventory, total emissions (excluding the LULUCF sector, and including indirect CO<sub>2</sub>) in the base year (FY 1990) under the UNFCCC increased by 0.07%, and the total emissions in year FY 2019 increased by 0.06% (Table 10-1).

Comparisons with the previous year's inventory for each sector, by category and by gas are as shown in Table 10-2 to Table 10-6. See each category for details on the reasons of recalculations.







Table 10-3 Comparison of emissions and removals in the inventories submitted in 2021 and 2022 (Industrial processes and product use sector)  
(1/2)

Category	Gas	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	difference																					
																																				[Mt-CO <sub>2</sub> eq.]																				
A. Mineral Products	CO <sub>2</sub>	49.2	50.5	51.0	50.3	51.3	51.1	51.5	48.8	43.9	43.6	43.9	43.0	40.5	40.1	39.8	41.2	41.2	41.2	40.2	37.4	32.8	32.8	33.1	33.6	35.0	34.7	33.7	33.5	34.0	33.6	32.6	32.5	32.5	32.5	32.5	32.5	32.5	32.5																	
	difference	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%														
	difference	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%												
B. Chemical Industry	CO <sub>2</sub>	7.0	7.0	6.8	6.4	6.8	7.0	7.1	7.1	6.4	6.9	6.8	6.3	6.2	6.1	6.1	5.8	5.9	6.0	5.1	4.9	5.4	5.1	4.7	4.8	4.7	4.8	4.7	4.6	4.3	4.5	4.2	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3												
	difference	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%										
	difference	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%									
C. Metal Production	CO <sub>2</sub>	7.2	7.1	6.8	6.7	6.7	6.8	6.9	6.8	6.5	6.5	6.7	6.8	6.6	6.6	6.4	6.5	6.5	6.6	6.7	6.2	5.5	6.1	6.0	6.1	6.2	6.1	6.2	6.1	5.9	5.8	5.7	5.7	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5												
	difference	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%								
	difference	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%						
D. Non-energy Products from Fuels and Solvent Use	CO <sub>2</sub>	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1													
	difference	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%			
	difference	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

\*Excluding Indirect CO<sub>2</sub>

Table 10-3 Comparison of emissions and removals in the inventories submitted in 2021 and 2022 (Industrial processes and product use sector) (2/2)

2. Industrial Processes and Product Use [Mt-CO <sub>2</sub> eq.]		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022			
E. Electronic Industry	Gas	0.00	NO	0.02	0.1	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.3	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1		
	HFCs	0.00	NO	0.02	0.1	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.3	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	
	difference	0.00%	NA	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
	PFCs	1.5	1.7	1.7	2.5	3.1	4.0	4.7	6.0	6.1	6.5	7.0	5.3	5.4	5.3	5.6	4.7	5.1	4.5	3.4	2.1	2.3	1.9	1.7	1.6	1.7	1.7	1.8	1.9	1.9	1.9	1.9	1.9	1.8	1.8	1.8	
	difference	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
	SF <sub>6</sub>	0.4	0.5	0.5	0.5	0.5	0.5	0.8	1.1	1.2	1.4	1.5	1.3	1.4	1.4	1.4	1.4	1.3	1.0	0.8	0.6	0.4	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3
	difference	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	NF <sub>3</sub>	0.03	0.03	0.03	0.04	0.07	0.2	0.2	0.2	0.2	0.2	0.3	0.2	0.2	0.2	0.3	0.3	0.2	0.3	0.4	0.3	0.2	0.2	0.2	0.2	0.2	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	difference	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	F. Product Uses as ODS Substitutes	0.0	NO	0.1	0.9	1.9	2.9	4.1	5.1	5.7	6.1	6.6	7.0	7.9	7.9	9.1	10.3	11.5	13.2	15.8	18.2	20.5	23.0	25.8	29.1	31.9	35.6	39.1	42.3	44.7	46.8	49.5	49.5	49.5	49.5	49.5	
	difference	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	PFCs	4.5	5.3	5.4	7.8	9.6	12.6	12.3	8.8	5.0	3.2	3.2	2.6	2.3	2.5	2.8	2.8	2.8	2.4	1.6	1.4	1.7	1.6	1.6	1.6	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.6	1.6
	difference	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	G. Other Product Manufacture and Use	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	difference	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	PFCs	NA	NO	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	difference	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	SF <sub>6</sub>	8.8	9.7	10.7	10.8	10.3	11.3	12.1	10.8	9.6	5.7	3.7	2.9	2.4	2.2	2.0	1.7	1.8	1.7	1.7	1.7	1.7	1.5	1.4	1.5	1.5	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	
	difference	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	H. Other	0.06	0.07	0.07	0.06	0.07	0.07	0.08	0.09	0.09	0.09	0.09	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.09	0.09	0.07	0.07	0.08	0.09	0.10	0.09	0.10	0.11	0.11	0.11	0.11	0.11	0.11	0.10	0.10	0.10
	difference	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	GHG	110.9	118.4	117.3	119.4	127.0	137.2	130.3	136.4	123.6	111.0	109.0	98.0	91.1	89.7	86.3	87.4	90.3	89.3	84.9	77.5	80.8	82.7	85.2	89.5	92.1	93.3	96.3	99.1	100.1	101.5	101.5	101.5	101.5	101.5	101.5	
	difference	0.02%	0.03%	0.03%	0.04%	0.04%	0.05%	0.05%	0.05%	0.06%	0.08%	0.09%	0.12%	0.15%	0.17%	0.19%	0.20%	0.22%	0.24%	0.25%	0.27%	0.30%	0.32%	0.35%	0.38%	0.42%	0.46%	0.50%	0.54%	0.58%	0.62%	0.66%	0.70%	0.74%	0.78%	0.82%	

\*Excluding indirect CO<sub>2</sub>

Table 10-4 Comparison of emissions and removals in the inventories submitted in 2021 and 2022 (Agriculture sector)

Category	Gas	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	
3. Agriculture																																
[Mt-CO <sub>2</sub> eq.]																																
A. Enteric Fermentation	CH <sub>4</sub>	9.4	9.6	9.7	9.6	9.4	9.3	9.2	9.2	9.1	9.1	9.0	9.0	8.9	8.9	8.7	8.7	8.6	8.7	8.6	8.5	8.2	8.2	8.0	7.7	7.5	7.5	7.5	7.5	7.5	7.6	
	JNGI 2022	9.4	9.6	9.7	9.6	9.4	9.3	9.2	9.1	9.1	9.0	9.0	8.9	8.9	8.7	8.7	8.6	8.7	8.6	8.5	8.2	8.2	8.0	7.7	7.5	7.5	7.5	7.5	7.5	7.5	7.6	
	difference	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
B. Manure Management	CH <sub>4</sub>	3.1	3.1	3.1	3.1	3.0	3.0	3.0	2.9	2.9	2.8	2.8	2.8	2.8	2.8	2.7	2.7	2.6	2.6	2.5	2.5	2.5	2.5	2.4	2.4	2.4	2.3	2.3	2.3	2.3	2.3	
	JNGI 2022	3.3	3.3	3.3	3.3	3.2	3.2	3.1	3.1	3.1	3.1	3.0	3.0	2.9	2.9	2.8	2.8	2.7	2.7	2.6	2.6	2.5	2.5	2.5	2.4	2.4	2.4	2.3	2.3	2.4	2.4	
	difference	6.81%	6.37%	6.43%	6.50%	6.46%	6.26%	6.19%	6.31%	6.19%	6.31%	6.37%	5.96%	5.40%	4.97%	4.53%	4.72%	3.74%	3.35%	2.95%	2.51%	2.12%	2.28%	2.43%	2.55%	2.57%	2.58%	2.71%	2.85%	2.86%	2.03%	
C. Rice Cultivation	N <sub>2</sub> O	4.2	4.2	4.2	4.1	4.0	3.9	3.9	3.9	3.9	3.8	3.8	3.8	3.8	3.8	3.9	4.0	4.1	4.1	4.2	4.2	4.3	4.3	4.2	4.1	4.0	3.9	3.7	3.7	3.7	3.7	
	JNGI 2022	4.2	4.2	4.2	4.1	4.0	3.9	3.9	3.9	3.9	3.8	3.8	3.8	3.8	3.9	4.1	4.2	4.3	4.3	4.4	4.4	4.3	4.3	4.2	4.1	4.0	3.9	3.8	3.8	3.9	3.8	
	difference	1.51%	1.31%	1.23%	1.19%	1.12%	1.10%	1.28%	1.09%	0.92%	1.09%	1.28%	1.09%	0.92%	1.09%	1.17%	1.78%	1.80%	2.24%	2.17%	3.49%	4.34%	5.12%	4.98%	4.01%	3.68%	3.62%	3.70%	3.87%	3.40%	3.53%	
D. Agricultural Soils	CH <sub>4</sub>	12.1	11.8	12.6	12.7	13.5	13.1	12.6	12.9	12.0	12.1	12.2	11.7	11.9	11.6	11.9	11.8	11.9	12.2	12.1	11.9	11.8	11.9	12.2	11.6	11.5	12.1	12.0	12.1	12.1	12.0	11.9
	JNGI 2022	12.1	11.8	12.6	12.7	13.5	13.1	12.6	12.9	12.0	12.1	12.2	11.7	11.9	11.6	11.9	11.8	11.9	12.2	12.1	11.9	11.8	11.9	12.2	11.6	11.5	12.1	12.0	12.1	12.1	12.0	
	difference	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.20%	
E. Field Burning of Agricultural Residues	N <sub>2</sub> O	7.1	7.0	6.9	7.0	6.9	6.6	6.5	6.4	6.3	6.3	6.3	6.1	6.1	6.1	5.9	5.9	5.9	6.2	5.4	5.2	5.5	5.4	5.4	5.5	5.4	5.4	5.4	5.5	5.6	5.6	
	JNGI 2022	7.6	7.4	7.4	7.5	7.3	7.0	6.9	6.8	6.7	6.8	6.6	6.5	6.5	6.4	6.4	6.3	6.7	5.9	5.9	5.6	6.0	5.9	5.9	6.0	6.0	5.9	5.9	5.9	5.9	5.8	
	difference	6.63%	6.45%	6.43%	6.62%	6.62%	6.62%	6.47%	6.53%	6.47%	6.65%	6.76%	6.94%	7.08%	7.12%	7.30%	7.43%	7.73%	8.13%	8.19%	8.60%	9.02%	9.35%	9.18%	9.06%	8.97%	9.11%	9.03%	7.69%	6.47%	4.40%	
F. Field Burning of Agricultural Residues	CH <sub>4</sub>	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.09	0.09	0.08	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.06	0.06	
	JNGI 2022	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.09	0.09	0.08	0.08	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.06	0.06	
	difference	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
G. Liming	N <sub>2</sub> O	0.04	0.04	0.04	0.03	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	
	JNGI 2022	0.04	0.04	0.04	0.03	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	
	difference	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
H. Urea Application	CO <sub>2</sub>	0.6	0.5	0.5	0.5	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.2	0.4	0.4	0.4	0.3	0.3	0.2	0.2	
	JNGI 2022	0.6	0.5	0.5	0.5	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.2	0.4	0.4	0.4	0.3	0.3	0.2	0.2	
	difference	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		
3. Total	GHG	36.7	36.4	37.2	37.1	37.3	36.4	35.7	35.7	34.6	34.6	34.0	34.0	34.2	33.7	33.6	34.0	33.8	34.1	33.1	32.8	33.0	32.2	31.9	32.1	31.8	31.5	31.5	31.7	31.6	31.7	
	JNGI 2022	37.5	37.1	37.9	37.8	38.0	37.1	36.3	36.4	35.2	35.3	35.3	34.6	34.6	34.4	34.4	34.6	34.4	34.8	33.7	33.5	33.7	33.0	32.6	32.2	32.2	32.2	32.2	32.2	32.2	32.1	
	difference	2.04%	1.93%	1.88%	1.92%	1.87%	1.80%	1.74%	1.74%	1.73%	1.82%	1.88%	1.89%	1.85%	1.78%	1.81%	1.78%	1.85%	1.82%	1.98%	1.80%	1.97%	2.22%	2.40%	2.37%	2.21%	2.15%	2.19%	2.18%	2.00%	1.64%	



Table 10-6 Comparison of emissions and removals in the inventories submitted in 2021 and 2022 (Waste sector)

Category	Gas	[Mt-CO <sub>2</sub> eq.]																																
		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
A. Solid Waste Disposal	CH <sub>4</sub>	9.6	9.5	9.4	9.4	9.3	9.0	8.8	8.8	8.5	8.2	7.9	7.6	7.3	7.0	6.8	6.4	6.1	5.8	5.5	5.2	4.9	4.6	4.3	4.1	3.9	3.7	3.5	3.3	3.1	2.9	2.8		
	JNGI 2021	9.5	9.4	9.4	9.3	9.2	8.9	8.7	8.4	8.1	7.8	7.5	7.3	7.0	6.7	6.4	6.1	5.8	5.5	5.1	4.8	4.5	4.3	4.1	3.9	3.6	3.4	3.2	3.1	2.9	2.8			
	JNGI 2022	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	
	difference	-0.99%	-0.98%	-1.00%	-0.99%	-0.98%	-0.96%	-0.96%	-0.93%	-0.89%	-0.88%	-0.86%	-0.84%	-0.84%	-0.84%	-0.84%	-0.83%	-0.83%	-0.83%	-0.84%	-0.84%	-0.83%	-0.82%	-0.82%	-0.80%	-0.78%	-0.76%	-0.74%	-0.72%	-0.69%	-0.52%	-0.66%	-0.66%	
B. Biological Treatment of Solid Waste	CH <sub>4</sub>	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	
	JNGI 2021	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	
	JNGI 2022	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
	difference	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
C. Incineration and Open Burning of Waste	N <sub>2</sub> O	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	
	JNGI 2021	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	
	JNGI 2022	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	
	difference	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
D. Waste Water Treatment and Discharge	CH <sub>4</sub>	12.2	12.3	13.3	13.1	15.6	15.9	16.3	16.9	16.9	17.0	17.0	16.8	16.9	15.7	15.1	15.2	14.7	14.2	13.4	13.6	14.6	14.2	12.5	11.7	12.3	12.2	11.7	11.7	11.1	10.8	11.6	11.5	
	JNGI 2021	12.3	12.3	13.4	13.2	15.7	16.0	16.4	17.0	17.0	17.0	16.8	16.9	15.7	15.1	15.2	14.7	14.2	13.4	13.6	14.7	14.2	12.5	11.7	12.3	12.2	11.7	11.7	11.1	10.8	11.6	11.4		
	JNGI 2022	0.57%	0.34%	0.28%	0.42%	0.57%	0.65%	0.71%	0.65%	0.79%	0.64%	0.56%	0.58%	0.58%	0.58%	0.58%	0.59%	0.30%	0.44%	0.10%	0.37%	0.04%	0.17%	0.17%	0.07%	0.07%	0.05%	0.00%	0.07%	0.00%	0.69%	0.21%	-1.1%	
	difference	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
E. Other	CH <sub>4</sub>	1.4	1.5	1.6	1.6	1.8	1.9	2.0	2.1	2.1	2.2	2.2	2.2	2.1	1.9	1.9	2.0	1.8	1.7	1.6	1.6	1.6	1.5	1.5	1.5	1.5	1.5	1.4	1.5	1.3	1.4	1.5	1.5	
	JNGI 2021	1.4	1.5	1.6	1.6	1.8	1.9	2.0	2.1	2.1	2.2	2.2	2.2	2.1	1.9	1.9	2.0	1.8	1.7	1.6	1.6	1.6	1.5	1.5	1.5	1.5	1.5	1.4	1.5	1.3	1.4	1.5	1.5	
	JNGI 2022	1.4	1.5	1.6	1.6	1.8	1.9	2.0	2.1	2.1	2.2	2.2	2.2	2.1	1.9	1.9	2.0	1.8	1.7	1.6	1.6	1.6	1.5	1.5	1.5	1.5	1.4	1.5	1.3	1.4	1.5	1.5	1.5	
	difference	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
5. Total	CH <sub>4</sub>	2.9	2.9	2.9	2.8	2.8	2.8	2.7	2.7	2.7	2.6	2.6	2.6	2.5	2.4	2.4	2.3	2.3	2.2	2.1	2.1	2.0	2.0	1.9	1.9	1.8	1.8	1.7	1.7	1.6	1.6	1.6		
	JNGI 2021	2.9	2.9	2.9	2.8	2.8	2.8	2.7	2.7	2.7	2.6	2.6	2.6	2.5	2.4	2.4	2.3	2.3	2.2	2.1	2.1	2.0	2.0	1.9	1.9	1.8	1.8	1.7	1.7	1.6	1.6	1.6		
	JNGI 2022	2.9	2.9	2.9	2.8	2.8	2.8	2.7	2.7	2.7	2.6	2.6	2.6	2.5	2.4	2.4	2.3	2.3	2.2	2.1	2.1	2.0	2.0	1.9	1.9	1.8	1.8	1.7	1.7	1.6	1.6	1.6		
	difference	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
5. Total	GHG	29.6	29.6	30.7	30.3	32.8	33.0	33.2	33.6	33.1	32.6	32.3	30.7	29.6	29.3	28.5	27.8	26.5	26.2	26.7	23.7	23.6	22.8	22.8	22.8	22.6	21.7	21.5	20.5	20.0	20.7	20.4		
	JNGI 2021	29.6	29.6	30.7	30.3	32.8	33.0	33.2	33.6	33.2	32.6	32.4	30.7	29.6	29.3	28.5	27.7	26.5	26.1	26.7	23.7	23.5	22.5	22.5	22.5	22.5	21.7	21.5	20.5	20.0	20.7	20.3		
	JNGI 2022	29.6	29.6	30.7	30.3	32.8	33.0	33.2	33.6	33.2	32.6	32.4	30.7	29.6	29.3	28.5	27.7	26.5	26.1	26.7	23.7	23.5	22.5	22.5	22.5	22.5	21.7	21.5	20.5	20.0	20.7	20.3		
	difference	-0.09%	-0.18%	-0.19%	-0.13%	0.00%	0.03%	-0.04%	0.10%	0.19%	0.12%	0.09%	0.10%	0.10%	0.10%	0.10%	-0.04%	-0.03%	-0.01%	-0.12%	0.04%	-0.15%	-0.07%	-0.10%	-0.11%	-0.11%	-0.13%	-0.08%	-0.11%	0.27%	0.01%	-0.45%		

## 10.2.2. KP-LULUCF Inventory

Compared to the values reported in the previous year's inventory, total emissions/removals arising from KP-LULUCF activities in FY2019 resulted to be an increase of removals by 1.88% (Table 10-7).

Table 10-7 Comparison of emissions and removals in the inventories submitted in 2021 and 2022 for KP-LULUCF activities

KP-LULUCF activities		[Mt-CO <sub>2</sub> eq.]								
Activity	Gas	1990	2013	2014	2015	2016	2017	2018	2019	
Afforestation and Reforestation	CO <sub>2</sub>	JNGI 2021	-	-1.5	-1.6	-1.6	-1.6	-1.5	-1.4	-1.4
		JNGI 2022	-	-1.5	-1.5	-1.5	-1.5	-1.5	-1.4	-1.3
		<i>difference</i>	-	-4.62%	-4.58%	-4.58%	-4.58%	-4.55%	-4.57%	-4.50%
	CH <sub>4</sub>	JNGI 2021	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		JNGI 2022	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		<i>difference</i>	-	-4.58%	-4.54%	-4.54%	-4.53%	-4.54%	-4.56%	-4.51%
	N <sub>2</sub> O	JNGI 2021	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		JNGI 2022	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		<i>difference</i>	-	-4.58%	-4.54%	-4.54%	-4.53%	-4.54%	-4.56%	-4.51%
Deforestation	CO <sub>2</sub>	JNGI 2021	-	2.0	2.0	2.3	2.3	1.8	1.8	2.0
		JNGI 2022	-	2.0	2.0	2.3	2.3	1.8	1.8	1.7
		<i>difference</i>	-	-1.23%	-1.65%	-0.69%	-0.70%	2.25%	2.26%	-16.48%
	CH <sub>4</sub>	JNGI 2021	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		JNGI 2022	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		<i>difference</i>	-	-1.77%	-1.77%	-1.75%	-1.72%	-1.62%	-1.53%	-1.80%
	N <sub>2</sub> O	JNGI 2021	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		JNGI 2022	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		<i>difference</i>	-	36.83%	56.71%	36.69%	45.92%	21.58%	27.21%	18.88%
Forest Management	CO <sub>2</sub>	JNGI 2021	-	-51.2	-51.6	-49.3	-46.7	-46.4	-45.3	-41.7
		JNGI 2022	-	-51.3	-51.6	-49.4	-46.7	-46.5	-45.3	-41.4
		<i>difference</i>	-	0.06%	0.04%	0.08%	0.08%	0.13%	0.00%	-0.81%
	CH <sub>4</sub>	JNGI 2021	-	0.00	0.02	0.00	0.00	0.02	0.00	0.00
		JNGI 2022	-	0.00	0.02	0.00	0.00	0.02	0.00	0.00
		<i>difference</i>	-	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%
	N <sub>2</sub> O	JNGI 2021	-	0.09	0.10	0.10	0.10	0.10	0.10	0.10
		JNGI 2022	-	0.10	0.10	0.10	0.10	0.10	0.11	0.11
		<i>difference</i>	-	3.45%	3.39%	3.41%	3.40%	3.34%	3.37%	3.38%
Cropland Management	CO <sub>2</sub>	JNGI 2021	7.5	5.4	6.2	5.7	5.5	4.7	4.1	5.2
		JNGI 2022	7.5	5.4	6.2	5.7	5.5	4.7	4.1	4.7
		<i>difference</i>	0.00%	-0.04%	0.02%	0.04%	-0.03%	-0.05%	-0.24%	-8.94%
	CH <sub>4</sub>	JNGI 2021	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04
		JNGI 2022	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04
		<i>difference</i>	0.00%	0.01%	0.01%	0.01%	0.00%	-0.01%	-0.02%	-0.09%
	N <sub>2</sub> O	JNGI 2021	0.04	0.01	0.01	0.01	0.01	0.01	0.01	0.01
		JNGI 2022	0.04	0.01	0.01	0.01	0.01	0.01	0.01	0.01
		<i>difference</i>	7.95%	5.60%	7.63%	10.47%	17.43%	6.58%	6.26%	7.16%
Grazing Land Management	CO <sub>2</sub>	JNGI 2021	0.4	1.0	1.6	1.3	1.0	0.8	0.6	1.0
		JNGI 2022	0.4	1.0	1.6	1.3	1.0	0.8	0.6	0.7
		<i>difference</i>	0.02%	0.00%	0.04%	0.06%	0.07%	0.07%	0.05%	-27.76%
	CH <sub>4</sub>	JNGI 2021	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		JNGI 2022	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		<i>difference</i>	0.00%	-0.05%	-0.09%	-0.13%	-0.23%	-0.19%	-0.04%	-0.11%
	N <sub>2</sub> O	JNGI 2021	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		JNGI 2022	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		<i>difference</i>	-7.27%	-10.05%	-8.41%	-7.74%	-7.05%	-7.05%	-7.05%	-7.05%
Revegetation	CO <sub>2</sub>	JNGI 2021	-0.1	-1.2	-1.2	-1.3	-1.3	-1.3	-1.3	-1.3
		JNGI 2022	-0.1	-1.2	-1.2	-1.3	-1.3	-1.3	-1.3	-1.4
		<i>difference</i>	-0.08%	0.11%	0.12%	0.12%	0.12%	0.11%	0.09%	0.18%
Total	JNGI 2021	7.9	-45.4	-44.4	-42.7	-40.6	-41.8	-41.5	-36.1	
	JNGI 2022	7.9	-45.4	-44.4	-42.7	-40.6	-41.7	-41.4	-36.7	
	<i>difference</i>	0.04%	-0.04%	-0.05%	-0.06%	-0.05%	-0.12%	-0.24%	1.88%	

### 10.3. Implication for Emission Trends, including Time Series Consistency

Table 10-8 shows the changes made to the emission trends due to the recalculations indicated in “Section 10.1. Explanation and Justification for Recalculations”. The comparison between the 2021 submission and the 2022 submission is made through the comparison of values between FY1990 and FY2019.

#### 10.3.1. GHG Inventory

The change between FY1990 and FY2019 total emissions (excluding the LULUCF sector and including indirect CO<sub>2</sub>) in the 2022 submission decreased by approximately 0.2 million tonnes (in CO<sub>2</sub> equivalents) and decreased by 0.01 percentage points, compared to the data reported in the previous submission.

Table 10-8 Comparison of change between 1990 and 2019 total emissions (excluding the LULUCF sector, and including indirect CO<sub>2</sub>) between the inventories submitted in 2021 and 2022

	Emissions (2019) - Emissions (1990) [Mt-CO <sub>2</sub> eq.]			Emissions (2019) / Emissions (1990) - 1 [%]		
	JNGI 2021	JNGI 2022	Difference	JNGI 2021	JNGI 2022	Difference
CO <sub>2</sub>	-52.1	-52.1	0.0	-4.5%	-4.5%	0.00%
CH <sub>4</sub>	-15.4	-15.6	-0.2	-35.2%	-35.4%	-0.21%
N <sub>2</sub> O	-12.0	-12.1	-0.1	-37.8%	-37.4%	0.39%
HFCs	33.8	33.8	0.0	212.0%	212.1%	0.11%
PFCs	-3.1	-3.1	0.0	-47.7%	-47.7%	0.00%
SF <sub>6</sub>	-10.8	-10.8	0.0	-84.4%	-84.4%	0.00%
NF <sub>3</sub>	0.2	0.2	0.0	701.8%	701.8%	0.00%
Indirect CO <sub>2</sub>	-3.5	-3.5	0.0	-62.8%	-62.8%	-0.02%
<b>Total</b>	<b>-63.0</b>	<b>-63.2</b>	<b>-0.2</b>	<b>-4.94%</b>	<b>-4.96%</b>	<b>-0.01%</b>

### 10.4. Recalculations and improvement plan, including response to the review process

#### 10.4.1. Improvements after submission of the inventory

The major improvements carried out after the submission of the 2021 inventory are listed below.

##### 10.4.1.1. Methodology for estimating emissions and removals of GHGs

Changed calculation methods are provided in Table 10-9.



## 10.4.1.1.a. GHG Inventory

Table 10-9 Changes in estimation methods

Sector and category		Changes in estimation methods
1.B.1.a.i	Underground Mines	Although the production amount of salable coal was used as activity data until the previous submissions, the <i>2006 IPCC Guidelines</i> require to use the production amount of raw coal. Therefore, the production amount was revised for all years.
1.B.2.a.vi 1.B.2.b.vi	Oil (Other) Natural Gas (Other)	It is confirmed that there are no emissions from abandoned oil wells and abandoned gas wells in Japan.
2.C.1	Iron and Steel Production	CO <sub>2</sub> emissions from the flaring of by-product gas were newly estimated.
3.B.1 3.B.3 3.B.4	Manure Management – Cattle/ Swine/ Poultry	The Bo and MCF for composting and liquid system calculated for CH <sub>4</sub> emissions were revised to the 2019 Refinement.
3.B.4 3.B.5 3.D.a.2 3.D.b.1	Manure Management - Poultry Manure Management - Indirect N <sub>2</sub> O Emissions - Atmospheric Deposition Agricultural Soils - Direct N <sub>2</sub> O Emissions - Organic Fertilizer Agricultural Soils - Indirect N <sub>2</sub> O Emissions	The calculation method for amount of excretion and nitrogen content in excretion for poultry has been revised.
3.B.5 3.D.b.1 4.(IV)	Manure Management - Indirect N <sub>2</sub> O Emissions - Atmospheric Deposition Agricultural Soils - Indirect N <sub>2</sub> O Emissions Atmospheric Deposition	The emission factor for atmospheric deposition was revised.
3.D.a.5 3.D.b.2 4.(III)	Agricultural Soils/ Direct N <sub>2</sub> O Emissions/ Mineralization/Immobilization Associated with Loss/Gain of Soil Organic Matter Agricultural Soils - Indirect N <sub>2</sub> O Emissions	The N <sub>2</sub> O emission factor for mineralization/immobilization associated with loss/gain of soil organic matter was revised.
3.D.b.2 4.(IV)	Agricultural Soils - Indirect N <sub>2</sub> O Emissions	The emission factor for nitrogen leaching and run-off and fraction of leaching and run-off was revised.
4.A.1 4.A.2 4.(III) 4.(IV)	Each subcategory in Forest land, direct/indirect emissions from N mineralization associated with loss of soil organic matter	Due to revision of afforestation and reforestation area (AR area), areas of forest land converted from other land-use categories were recalculated. Accordingly, carbon stock changes in living biomass, dead organic matter and mineral soils in these subcategories and N <sub>2</sub> O emissions from mineralization associated with loss of soil organic matter in forest land were recalculated in all years.

Sector and category		Changes in estimation methods
4.B.1 4.B.2 4.C.1 4.C.2 4.D.2 4.E.1 4.E.2 4.F.2 4.(II) 4.(III) 4.(IV)	Each subcategory in cropland, grassland and other land and land converted to wetlands Direct/indirect emissions from drainage and other management of organic soils Direct/indirect emissions from N mineralization associated with loss of soil organic matter	Due to revision of deforestation area (D area), areas of land converted from forest land were recalculated. Accordingly, carbon stock changes in living biomass, dead organic matter and mineral soils in these subcategories were recalculated in all years. CH <sub>4</sub> emissions from drainage and other management of organic soils and N <sub>2</sub> O emissions from N mineralization associated with loss of soil organic matter in cropland and grassland were also recalculated in all years.
4.B.1	Cropland remaining cropland	By modifying the input data used in the Roth C model calculation, the amount of stock change per unit of area from FY2017 to FY2019 in each subcategory was recalculated. With this recalculation, carbon stock changes in mineral soils in rice field, upland fields and orchard were recalculated in all years.
4.B.1 4.(V)	Cropland remaining cropland Biomass burning	Due to the revision of some estimation method for orchard area, carbon stock changes of biomass and CH <sub>4</sub> and N <sub>2</sub> O emissions from burning of pruned branches from orchard trees from FY2017 to FY2019 were recalculated.
4.B.1 4.B.2 4.C.1 4.C.2 4.E.2 4.(II) 4.(IV)	Each subcategory in cropland, grassland and land converted to settlements Direct/indirect emissions from drainage and other management of organic soils	The minerals soil and organic soils areas in farmland and lands converted from/to farmland for the years between 1992, 2001, and 2010, when area data in soil groups were available, are estimated by an assumption. As there was an incompleteness in methodologies of estimating these areas in land-use conversion categories, estimation method of an assumption was modified. With this recalculation, the CO <sub>2</sub> emissions from organic soils were recalculated in all years.
4.E.1	Settlements remaining settlements	A revision was conducted on some area of urban green areas for all years. Due to this revision, carbon stock changes in living biomass, dead organic matter and mineral soils in this category were recalculated for all years.
4.G	Carbon stock changes in Harvested Wood Products	Since the activity data for sawnwood, wooden board, plywood, paper and paperboard was revised, the inflow values and outflow values were recalculated from FY2014 to FY2019.
5.A.1/5.C.1/1.A.4	Managed disposal site/Waste incineration/ Waste Incineration and Energy Use (Reported on Energy Sector)	By revising the fraction of carbon content and fossil fuel-derived content of paper/cardboard in industrial waste, CO <sub>2</sub> emissions (5.C.1/1.A.4) and CH <sub>4</sub> emissions (5.A.1) were recalculated.
5.C.1/1.A/4	Waste incineration/ Waste Incineration and Energy Use (Reported on Energy Sector)	By revising the fraction of synthetic textiles in MSW textiles, CO <sub>2</sub> emissions were recalculated.
5.C.1/1.A	Waste incineration/ Waste Incineration and Energy Use (Reported on Energy Sector)	By revisioning biomass-based plastic products data, CO <sub>2</sub> emissions were recalculated.

**10.4.1.1.b. KP-LULUCF Inventory**

Table 10-10 Changes in estimation methods

Sector and category	Changes in estimation methods
Afforestation (A), Reforestation (R), Deforestation (D)	With revision of ARD area, carbon stock changes in all carbon pools under AR and D for FY2013-FY2019 were recalculated. In addition, CH <sub>4</sub> and N <sub>2</sub> O emissions from biomass burning in AR were recalculated because of this revision in AR area. With the revision in D area, CH <sub>4</sub> and N <sub>2</sub> O emissions associated with drainage from organic soils in D area were recalculated. Moreover, N <sub>2</sub> O emissions associated with mineralization of soil organic matter in D also were recalculated because of revision of soil organic area in D area.
Forest Management (FM)	With revision of ARD area, carbon stock changes in all carbon pools under FM for FY2013-FY2019 were recalculated. In addition, CH <sub>4</sub> and N <sub>2</sub> O emissions from biomass burning in FM were recalculated because of this revision in AR area. N <sub>2</sub> O emissions associated with mineralization of soil organic matter in FM were also recalculated because of revision of soil organic area in D area.
Cropland Management (CM)	With revision of D area, carbon stock changes in all carbon pools under CM for FY2013-FY2019 were recalculated. With revisions of estimation method of coefficients used for the Roth C model, carbon stock changes in mineral soils in CM were also recalculated for FY2017-FY2019. In addition, with revisions of method for calculating the amount of N mineralized by the loss of carbon in CM soil organic matter, N <sub>2</sub> O emissions in CM were recalculated for all years. With revisions of estimation method of orchard areas in some prefectures from FY2017 to FY2019, carbon stock changes in living biomass, and CH <sub>4</sub> and N <sub>2</sub> O emissions from biomass burning in CM for FY2017-FY2019 were recalculated.
Grazing Land Management (GM)	With revision of D area, carbon stock changes in all carbon pools under GM for FY2013-FY2019 were recalculated. With revisions of estimation method of coefficients used for the Roth C model, carbon stock changes in mineral soils in GM were also recalculated for FY2017-FY2019. In addition, with revisions of method for calculating the amount of N mineralized by the loss of carbon in GM soil organic matter, N <sub>2</sub> O emissions in GM were recalculated for all years.
Revegetation (RV)	Carbon stock changes in all carbon pools under the RV activities for FY1990, FY2013-FY2019 were recalculated, due to the revision of ARD area.

**10.4.1.2. National Greenhouse Gas Inventory Report**

No major changes since the previous submission.

**10.4.1.3. Improvements by following UNFCCC-ERT recommendations**

Actions taken in response to recommendations from UNFCCC review are summarized below. See relative sections for details.

The Committee for Greenhouse Gas Estimation Methods (see “Committee for Greenhouse Gas Estimation Methods” (Chapter 1.2.1.2.)) address all the recommendations raised by ERT, and efforts have been made to tackle the issues and improve the national GHG inventory with due consideration of the priority.

Table 10-11 Summary of improvements made to the national inventory  
in response to recommendations from UNFCCC review

Sector/Category	Recommendations by ERT	Actions taken	NIR/CRF
LULUCF/ Forest land remaining forest land (4.A.1)	Improve the description of the methodology used to calculate carbon stock changes, including by adding specific information in the NIR on the parameters used to calculate carbon stock changes in living biomass for cutover forests and lesser stocked forests on the basis of expert judgment. (ARR 2020 L.12)	The parameters used for calculation of carbon stock changes in living biomass for cutover forests and lesser stocked forests were included in the NIR.	NIR Chapter 6 (6.5.1.b)1)) Table 6-16
LULUCF/ Forest land remaining forest land (4.A.1)	Explain in the NIR how observed changes in FM are taken into account in the CENTURY-jfos model on an ongoing basis (ARR 2020 L.13)	The assumptions in forest management scenarios for the Century-jfos model were included in the NIR.	NIR Chapter 6 (6.5.1.b)2))
LULUCF/ Emissions from drainage and other management of organic soils (4.(II))	Include in its NIR its assumptions that no N <sub>2</sub> O emissions occur from organic soils in forest land currently not included in the estimates, and include in its NIR its assumption that no CH <sub>4</sub> emissions occur from organic soils (forest land, cropland and grassland) currently not included in the estimates (ARR 2020 L.18)	The explanations were included in the NIR.	NIR Chapter 6 (6.13.a))

#### 10.4.2. Planned Improvements

The following improvements are continuously performed and reflect in an inventory preparation process accordingly. See relative sections for details.

1. Review of estimation methods, activity data, emission factors and other elements  
Japan holds meetings of a Committee for Greenhouse Gas Emission Estimation Methods and considers improvements of estimation methods, activity data, emission factors and other elements used in the current inventory. In case of implementation, Japan prioritizes highly important issues such as those relevant to key-categories and those pointed out in the past review reports.
2. Improvement of transparency  
Japan will further improve transparency of the inventory by examining descriptions of methodologies, assumptions, data, and other elements in NIR, and by adding necessary information to NIR.

## Chapter 11. Supplementary Information on LULUCF activities under Article 3, Paragraphs 3 and 4 of the Kyoto Protocol

### 11.1. Summary of removal related trends, and emissions and removals from KPLULUCF activities

In accordance with the decision 2/CMP.8 in paragraph 4 adopted by the Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol (COP/MOP8), Japan reports afforestation/reforestation (AR), deforestation (D), forest management (FM), cropland management (CM), grazing land management (GM) and revegetation (RV) as LULUCF activities under Article 3, paragraphs 3 and 4 of the Kyoto Protocol for the second commitment period. Table 11-1 shows the activity coverage and other information relating to activities under Article 3.3, forest management under Article 3.4 and elected activities under Article 3.4. The sum of emissions and removals in FY2020 by those activities were -34,472 kt-CO<sub>2</sub> eq. and the sum of the accounting quantity for Article 3.3 and 3.4 activities of the Kyoto Protocol for the second commitment period (after applying “the accounting rules”) was calculated to be -376,075 kt-CO<sub>2</sub> eq. (Table 11-2). Methodological tiers used are shown in Table 11-3.

Table 11-1 Activity coverage and other information relating to activities under Article 3.3 and elected activities under Article 3.4 (CRF-Table NIR 1)

Activity	Change in carbon pool reported							Greenhouse gas sources reported											
	Above-ground biomass	Below-ground biomass	Litter	Dead wood	Soil		HWP	Fertilization		Drained, rewetted and other soils		Nitrogen mineralization in mineral soils		Indirect N <sub>2</sub> O emissions from managed soil		Biomass burning			
					Mineral	Organic		N <sub>2</sub> O	CH <sub>4</sub>	N <sub>2</sub> O	N <sub>2</sub> O	N <sub>2</sub> O	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O				
Article 3.3 activities																			
Afforestation and reforestation	R	R	R	R	R	NO	NO	IE	NO	NO	NA	IE,NA	IE	R	R				
Deforestation	R	R	R	R	R	R	IO	IE	R	R	R	R	NO	NO	NO				
Article 3.4 activities																			
Forest management	R	R	R	R	R	NO	R	R	NO	NO	R	R	IE	R	R				
Cropland management	R	R	NR	NR	R	R					R		IE	R	R				
Grazing land management	R	R	NR	NR	R	R					R		NO	NO	NO				
Revegetation	R	R	R	IE	R	NO		IE	NO	NO	NA	IE,NA	NO	NO	NO				
Wetland drainage and rewetting	NA	NA	NA	NA		NA		NA	NA	NA		NA	NA	NA	NA				

Note: R: Reported; NR: Not reported; IO: Instantaneous oxidation;

Table 11-2 Accounting summary for activities under Articles 3.3 and 3.4 of the Kyoto Protocol

Greenhouse gas source and sink activities	Emissions/removals [kt CO <sub>2</sub> eq.]										Accounting parameters <sup>1), 3)</sup>	Accounting quantity <sup>2), 4)</sup>	
	1990 (Base Year)	2013	2014	2015	2016	2017	2018	2019	2020	Total			
A. Article 3.3 activities													
A.1. Afforestation/reforestation		-1,478	-1,483	-1,486	-1,488	-1,465	-1,375	-1,316	-1,245	-11,336		-11,336	
Excluded emissions from natural disturbances		NA	NA	NA	NA	NA	NA	NA	NA	NA		NA	
Excluded subsequent removals from land subject to natural disturbances		NA	NA	NA	NA	NA	NA	NA	NA	NA		NA	
A.2. Deforestation		2,005	2,007	2,317	2,316	1,827	1,819	1,683	1,696	15,669		15,669	
B. Article 3.4 activities													
B.1. Forest management													
Net emissions/removals		-51,174	-51,512	-49,255	-46,642	-46,353	-45,229	-41,259	-38,939	-370,363		-382,808	
Excluded emissions from natural disturbances		NA	NA	NA	NA	NA	NA	NA	NA	NA		NA	
Excluded subsequent removals from land subject to natural disturbances		NA	NA	NA	NA	NA	NA	NA	NA	NA		NA	
Any debits from newly established forest (CEF-ne)		NA	NA	NA	NA	NA	NA	NA	NA	NA		NA	
Forest management reference level (FMRL)		0	0	0	0	0	0	0	0	0		0	
Technical corrections to FMRL <sup>1)</sup>		1,044	1,220	1,366	1,499	1,635	1,762	1,899	2,019	12,446		1,556	
Forest management cap											355,669	-355,669	
B.2. Cropland management	7,561	5,490	6,230	5,749	5,525	4,712	4,130	4,747	4,759	41,341		-19,147	
B.3. Grazing land management	443	966	1,582	1,291	1,008	855	622	751	617	7,692		4,151	
B.4. Revegetation	-80	-1,230	-1,249	-1,270	-1,287	-1,310	-1,325	-1,350	-1,360	-10,381		-9,743	
B.5. Wetland drainage and rewetting (not elected)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA		NA	
Sum of emissions and removals from Article 3.3 and 3.4 activities for each year <sup>6)</sup>		-45,421	-44,425	-42,654	-40,570	-41,734	-41,357	-36,745	-34,472				
Sum of the accounting quantity for Article 3.3 and 3.4 activities of the Kyoto Protocol for the second commitment period <sup>5)</sup>												-376,075	

Note:

- 1) The technical corrections (TC) to forest management reference level (FMRL) to exclude emissions and removals caused by methodological changes from the time when the FMRL had been set for each year is shown in the table above. In

addition, the TC value in the accounting parameters column of the table above shows the annual average value of TC for the whole second commitment period of the Kyoto Protocol. In the CRF Reporter, we entered the average value of TC for the second commitment period of the Kyoto Protocol instead of the TC values for each year. This is because in the CRF Reporter, only FY2020 value will be referenced when calculating the accounted net removals from FM, and the correct accounting result cannot be obtained.

- 2) Regarding the accounted net removals from FM activity for the second commitment period of the Kyoto Protocol, the FMRL set as the baseline for accounting for FM and TC are considered. The value (-382,808 kt-CO<sub>2</sub> eq.) is considering the total TC value of the second commitment period of the Kyoto Protocol (8 times the average value of TC in the second commitment period).
- 3) The FM cap from FM activity for the whole second commitment period of the Kyoto Protocol is 3.5% of national total greenhouse gas emissions in the base year (excluding the LULUCF sector) for 8 years, as specified in paragraph 13 of the annex to Decision 2/CMP.7. Japan's total greenhouse gas emissions in the base year for calculating the FM cap are set as the total GHG emissions in the GHG inventory submitted in the year 2015 (1,270 Mt CO<sub>2</sub> eq.) and the FM cap was calculated to be -355,669 kt-CO<sub>2</sub> eq. Since the value indicated in Note 2) exceeded the FM cap, Japan accounted for the FM removals up to the FM cap.
- 4) The accounting quantity for emissions and/or removals resulting from CM, GM and RV were calculated by subtracting the emissions and removals in the base year times 8 (years) from the total emissions and removals during the second commitment period for each activity, respectively.
- 5) The sum of the accounting quantity for Article 3.3 and 3.4 activities of the Kyoto Protocol for the second commitment period after applying "the accounting rules" such as the accounting parameters in Note 1)-3) and the accounting approach in Note 4) is shown in here.
- 6) The sum of emissions and removals from Article 3.3 and 3.4 activities for each year before applying "the accounting rules" in Note 1)-4) is shown in here.
- 7) The total values and results of summing up each figure are not always the same because of the difference in display digit.

Table 11-3 Methodological tiers used under Articles 3.3 and 3.4 of the Kyoto Protocol

Activity	CO <sub>2</sub>		CH <sub>4</sub>		N <sub>2</sub> O		
	Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor	
Article 3.3 activities	Afforestation and reforestation	T2	CS	T1	D	T1	D
	Deforestation	T2	CS,D	T1	D	T1,T2	CS,D
Article 3.4 activities	Forest management	T2,T3	CS,D	T1	D	T1,T2	CS,D
	Cropland management	T2,T3	CS,D	T1	CS,D	T2,CS	CS,D
	Grazing land management	T2,T3	CS,D	T1	CS,D	T2,CS	CS,D
	Revegetation	T2	CS,D				
	Wetland drainage and rewetting						

D: IPCC default, T1: IPCC Tier1, T2: IPCC Tier2, T3: IPCC Tier3, CS: country-specific method or emissions factor

## 11.2. Information relating to the decision 3/CMP.11 in paragraph 8

Japan describes information about LULUCF activities under Article 3.4 of the Kyoto protocol for the second commitment period in accordance with decision 3/CMP.11 in paragraph 8, as follows:

- Japan reports CM and GM as activities under Article 3.4 of the Kyoto Protocol, in addition to FM which became mandatory in the second commitment period, and RV which was elected in the first commitment period.
- For the FM and the RV, the methodology on land identification, which was applied to the first commitment period, is also applied to the second commitment period; lands that have been accounted for the first commitment period are also included in the second commitment period. Regarding the CM and the GM added from the second commitment period, the lands are identified based on statistics which are applied for reporting of LULUCF under the Convention. Detailed information is described in relevant sections of each activity.

## 11.3. General information

### 11.3.1. Definition of forest and any other criteria

The definitions of forest in Japan are identified as the following, in accordance with decision 16/CMP.1,

paragraph 20 of the annex to decision 2/CMP.7 and the requirement from *the 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol* (hereafter *KP Supplement*).

- Minimum value for forest area: 0.3 [ha]
- Minimum value for tree crown cover: 30 [%]
- Minimum value for tree height: 5 [m]
- Minimum value for forest width: 20 [m]

The minimum forest area, minimum tree crown cover and the minimum forest width (mentioned above) are consistent with forests under the existing forest planning system in Japan. Although any minimum values for tree height is not defined under the existing forest planning system, forests with usual composition of tree species and under usual climate conditions in Japan usually reach a tree height of 5 m at maturity *in situ*. Each prefecture has surveyed and compiled information on forest resources under the forest planning system into Forest Registers, which are primarily intended to be prepared for establishing forest plans. Therefore, forests under the forest planning system are considered as forests under the Kyoto Protocol, and Forest Registers are suitable as basic data source for reporting. This is the same concept as the one used for reporting the LULUCF forest sector under the Convention. The definitions of forest used for the second commitment period are the same as the first commitment period.

The definitions of forest mentioned above are consistent with those in the Country Report under Global Forest Resources Assessment (FRA) by the Food and Agriculture Organization of the United Nation (FAO) (Table 11-4).

Table 11-4 Japan's forest categories and definition used in reporting to FAO

Category	Definition
Forest	Land on which trees and/or bamboo grow collectively, together with those trees and bamboo, or any other lands that are provided for collective growth of trees and/or bamboo covering 0.3 ha or more. Lands that are utilized mainly for agriculture, residential use or other similar purposes, and trees and bamboo on these lands, are not included.
Forest with standing trees	Forest that has a tree crown cover of 30 percent or higher (including young stands with the degree of stocking of 3 or higher).
Forest with less standing trees (Cut-over forest, lesser stocked forest)	Forest that does not fall under "forest with standing trees" or "bamboo forest".
Bamboo forest	Forest that does not fall under "forest with standing trees" and is mainly dominated by bamboo (excluding bamboo grass).

Note: See section 6.2. for a more detailed definition of each category

Before 1995, Japan classified forests with standing trees into two sub-categories, "intensively managed forests" and "semi-natural forests" in the Forestry Status Survey. Since 2002, Japan has conducted new sub-categories which are "ikusei-rin forest" and "tennensei-rin forest". In these new sub-categories, the degree of human-induced activities and stratification of forest have been taken into account. In ikusei-rin forests, intensively managed forests regenerated mainly by planting after felling and semi-natural forests regenerated by supplementary works such as site preparation are included. The definitions of intensively managed forest, semi-natural forest, ikusei-rin forest and tennensei-rin forest are shown below.

Table 11-5 Definitions of intensively managed forest, semi-natural forest, ikusei-rin forest and tennensei-rin forest<sup>1</sup>

Sub-categories by regeneration method		Sub-categories by management types	
Intensively managed forest	Forest regenerated by planting and so on.	Ikusei-rin Forest	Forest where practices for establishment and maintenance of single-storied forests have been carried out after clear-cutting (“ikusei-tansou-rin”), or forest where practices for establishment and maintenance of multi-storied forests have been carried out after selective cutting (“ikusei-fukusou-rin”).
Semi-natural forest	Forest which is not classified as intensively managed forest.		Tennensei-rin forest

### 11.3.2. Elected activities under Article 3, paragraph 4 of the Kyoto Protocol

Following the first commitment period, in accordance with paragraph 7 of the annex to decision 2/CMP.7, Japan continues to report FM which is mandatory in the second commitment period, and RV which has been reported in the first commitment period under Article 3, paragraph 4 of the Kyoto Protocol. In addition, Japan elected CM and GM defined by paragraph 6 of the annex to decision 2/CMP.7, as “additional human-induced activities related to changes in GHG emissions by sources and removals by sinks in the agricultural soils and the land-use change and forestry categories” defined by Article 3, paragraph 4 of the Kyoto Protocol for the second commitment period.

Japan interprets the definition of elected activities as follows by recalling *the KP Supplement* which the parties shall apply in accordance with decision 6/CMP.9, paragraph 9.

#### 11.3.2.1. Forest Management

FM is defined in paragraph 1 (f) of the annex to decision 16/CMP.1 as “a system of practices for stewardship and use of forest land aimed at fulfilling relevant ecological (including biological diversity), economic and social functions of the forest in a sustainable manner”. Japan interprets the definition of FM as the following.

- Activities for FM in ikusei-rin forests are appropriate forest practices including regeneration (land preparation, soil scarification, planting, etc.), tending (weeding, pre-commercial cutting, etc.), thinning and harvesting which have been carried out since 1990.
- Activities for FM in tennensei-rin forests are practices for protection or conservation of forests including controlling logging activities and land-use change which have been carried out by law.

#### 11.3.2.2. Cropland Management

CM is defined in paragraph 1 (g) of the annex to decision 16/CMP.1 as “a system of practices on land on which agricultural crops are grown and on land that is set aside or temporarily not being used for crop production”. Japan interprets the definition of CM as follows:

- Practices for cultivating in rice fields, upland fields and orchards<sup>2</sup>

<sup>1</sup> Explanations for Ikusei-rin forest and Tennensei-rin forest have been changed in accordance with the revision of the “Basic Plan for Forest and Forestry”. However, the coverage of those forests remains the same.

<sup>2</sup> dilapidated farmland which is included in cropland for reporting of LULUCF under the Convention, is not included in the CM because appropriate managements have not been carried out there.



### 11.3.2.3. Grazing Land Management

GM is defined in paragraph 1 (h) of the annex to decision 16/CMP.1 as “a system of practices on land used for livestock production aimed at manipulating the amount and type of vegetation and livestock produced”. Japan interprets the definition of GM as follows:

- Practices for meadow and grazing in pasture land<sup>3</sup>

### 11.3.2.4. Revegetation

RV is defined in paragraph 1 (e) of the annex to decision 16/CMP.1 as “a direct human-induced activity to increase carbon stocks on sites through the establishment of vegetation that covers a minimum area of 0.05 ha and does not meet the definitions of AR”. Japan interprets the definition of RV as follows:

- Practices for the creation of “parks and green space”, “public green space”, and “private green space guaranteed by administration” which have been carried out in settlements since 1990<sup>4</sup>. Activities which cover less than an area of 0.05 ha or meet the definitions of AR are not included.

### 11.3.3. Description of how the definitions of each activity under Article 3.3 and each elected activity under Article 3.4 have been implemented and applied consistently over time

The forest definition explained in section 11.3.1 has not changed over time. The same forest definition is used for AR and D under Article 3.3 as well as FM under Article 3.4. The definitions of FM, CM, GM and RV explained in section 11.3.2 above have been implemented and applied consistently over time.

### 11.3.4. Description of precedence conditions and/or hierarchy among elected Article 3.4 activities, and how they have been consistently applied in determining how land was classified

Japan interprets that FM activities occur only in forest land, and CM, GM, and RV activities occur only in non-forest land (cropland, grassland and settlements). Therefore, there is no overlap between FM and non-FM activities (CM, GM, and RV). The areas of CM and GM are not double counted, as they are identified by the different items in the same data source. However, there is a possibility that overlap may occur between CM, GM and RV when new planting is implemented in settlements converted from cropland and pasture land. In order to prevent double counting among activities under Article 3.4 of the Kyoto Protocol, Japan made arrangement that the converted land area and the emissions from carbon stock existed in original activities and lost due to conversion were reported under the original activities, but removals from the increase in carbon stock due to growth after conversion were reported under the current activities.

## 11.4. Land-related information

### 11.4.1. Spatial assessment unit used for determining the area of the units of land under Article 3.3

In accordance with the definition of forest explained in section 11.3.1, Japan determines the spatial

<sup>3</sup> As for grazed meadow and wild land that are included in grassland for reporting of LULUCF under the Convention, they are not included in GM because management practices changes have not been occurred in grazed meadow and wild land is not for use of grazing.

<sup>4</sup> In Japan, the urban green facilities subject to RV activities are: “urban parks”, “green areas on roads”, “green areas at ports”, “green areas around sewage treatment facilities”, “green areas by greenery promoting systems for private green space”, “green areas along rivers and erosion control sites”, “green areas around government buildings”, and “green areas around public rental housing”.

assessment unit used for determining the area of the units of land under Article 3.3 as 0.3 ha.

## 11.4.2. Methodology used to develop the land transition matrix

### 11.4.2.1. Description of land transition matrix (CRF-NIR Table 2)

Table 11-6 shows the land transition matrix related to the activities under Articles 3.3 and 3.4 of the Kyoto Protocol. The FM area in Japan is estimated by using the narrow approach concept described in section 2.7.1 of the *KP Supplement*. Therefore, new FM areas are identified every year due to the progress of FM practices in managed forests which previously had not been categorized as FM area. These areas are classified as land transition from “other” to FM in table 11-6. Also, areas where RV practices have been newly performed become new RV areas and are classified as land transition from “other” to RV in table 11-6.

Regarding CM and GM, Japan basically estimates emissions/removals for current cropland (except for dilapidated farmland) and current grazing land respectively; in accordance with paragraph 24 of the annex to the decision 2/CMP.7, cropland and pasture land converted to other land-use since 2013, were also included in CM and in GM with the following exceptions. The area of cropland or grassland converted to forest land is reported under “Afforestation and Reforestation”, the area of cropland or grassland converted to settlements with new planting is reported under “RV” land and newly created cropland or pasture land derived from the conversion of forests is reported under “Deforestation”. Moreover, the land conversion across CM and GM is reported as “IE”, because the changed areas between CM and GM from the previous year cannot be clearly separated from each other, although the spatially explicit data used in the tier 3 model itself considers the above-mentioned land use changes in its calculation.

As for the values of 2020 in the land transition matrix, changes from reported figures in 2019, are reported.

Table 11-6 Land transition matrix of Kyoto Protocol activities (CRF-Table NIR 2)

TO 2020 FROM 2019		Article 3.3 activities		Article 3.4 activities					Other	Total area at the end of the previous inventory year
		Afforestation and reforestation	Deforestation	Forest management	Cropland management	Grazing land management	Revegetation	Wetland drainage and rewetting (not elected)		
(kha)										
Article 3.3 activities	Afforestation and Reforestation	100.44	0.25							100.68
	Deforestation		321.87							321.87
	Forest management		3.18	16,026.53						16,029.71
Article 3.4 activities	Cropland management	NO		NA	3,947.66	IE	NO	NA		3,947.66
	Grazing land management	0.03		NA		614.30	NO	NA		614.33
	Revegetation	NO		NA	NA	NA	89.02	NA		89.02
	Wetland drainage and rewetting (not elected)	NA		NA	NA	NA	NA	NA		NA
Other		0.00	1.51	71.36	6.74	3.36	0.46	NA	16,610.83	16,694.26
Total area at the end of the current inventory year		100.46	326.80	16,097.89	3,954.39	617.66	89.48	NA	16,610.83	37,797.53

### 11.4.2.2. Overview of the procedures to estimate emissions and removals

This section gives an overview of the procedures to estimate emissions and removals for AR, D and FM activities in Japan. For AR and D activities, emissions and removals are estimated in AR and D areas which are detected for each prefecture based on sample survey data. For FM activity, emissions and removals are estimated by firstly subtracting emissions and removals in AR and D land from those in all managed forests for each prefecture, and then applying the FM ratio determined by the sample survey to the remaining emissions and removals.

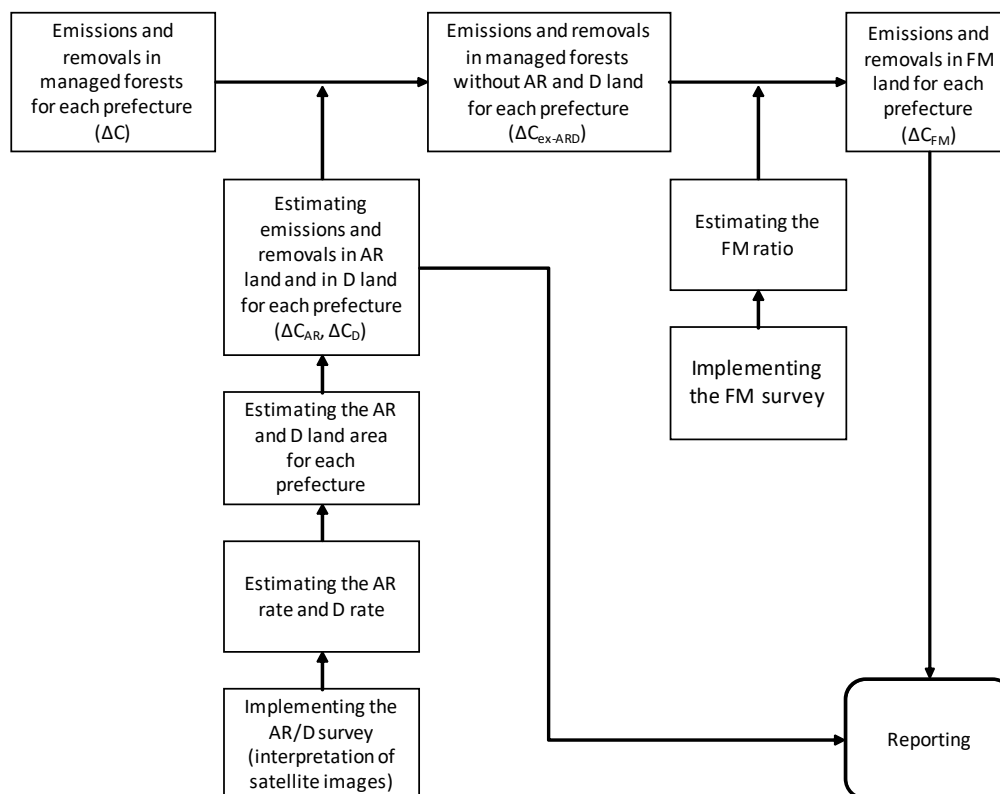


Figure 11-1 Procedures to estimate emissions and removals for AR, D and FM activities

### 11.4.2.3. Afforestation/Reforestation and Deforestation

#### 11.4.2.3.a. Methodology and Procedure

##### a) Plot design

Japan identifies the change of forest cover in each sample plot by using orthophotos taken at the end of 1989 and recent satellite images, considering the spatial assessment unit (area 0.3 ha and width 20 m). Plots identified as non-forest land converted to forest land due to human-induced forestation practice are categorized as AR plot, and plots identified as forest land converted to non-forest land are categorized as D plot (Hayashi et al., 2008). The plots on the whole country are set in a grid with an interval of 500 m, which are approximately 1,500 thousand plots in total. Satellite images since 2005 are used for the following time series to count the number of AR and/or D plots occurring from the end of 1989 up to recent images by comparing the orthophotos in 1989. Interpretation is annually done for the half of the total number of plots and it takes two years to complete one cycle of interpretation covering whole land area. AR and D land areas are calculated based on the results of the most recent two sets of interpretation work (Forestry Agency, 2020 and 2021). Plots which are difficult to interpret are excluded from “available sample plots” which are used for the estimation of AR or D rates. Furthermore, the land-use status before / after conversion from / to forest land is analyzed from satellite images at each plot point and these data are used for the estimation of previous land-use in AR land and/or of new land-use status in D land.

**b) Estimate land area of AR and D**

Estimate AR rate for FY1990-FY2020:

Plots recognized as AR from FY1990 to FY2020 are counted from the interpretation by comparison between orthophotos taken at the end of 1989 and the latest two satellite images of SPOT/7HRV-P taken in 2019 and 2020. And after that, the year when all AR plots occurred are detected, using the orthophotos taken at the end of 1989 and the images taken every 2 years since 2005 (see table 11-7 for the data used). For the AR plots occurred between FY1990 and FY2005, the total AR rate for FY1990-2005 was derived by dividing the total number of AR occurrence by the “available sample plots” (i). For those AR plots occurred from 2005 onward, the number of AR that occurred between two images photographed in two year intervals is divided by 2 to estimate the occurrence of AR in a single year and then divided by the “available sample plots”. This becomes the AR rate for each year (ii). As one interpretation cycle is completed with 2 works, the number of occurrences is summed up for these two. As it is mentioned above, one cycle is completed in two years, if that is the year when the latter half of interpretation work is not available yet, the results of the latter half interpretation of previous cycle is used to cover the entire land area. The AR rate in 2006 is not included in the calculation above, so the amount of the total AR rate for FY1990-2005 (i) divided into 16, counted the number of years from 1990 to 2005, is considered as the rate of 2006’s AR rate (iii). Finally, the rates from (i), (ii) and (iii) are aggregated to become the total AR rate for FY1990 to FY2020.

Estimate D rate for FY1990-FY2020:

The total D rate for FY1990-FY2020 is estimated based on the same procedure applied for AR explained above. But, the way of allocation for the rate for 2006 is different from the one in AR rate estimation. D rate for 2006 is estimated through dividing the number of D plots during FY1990-FY2005 by land conversion rate in each fiscal year provided by statistics. The rate for 2005 is alternatively used for 2006.

Estimate land area of AR and D for FY1990-FY2020:

The AR land area for each prefecture during FY1990-FY2020 is calculated by multiplying the land area for each prefecture by the total AR rate during FY1990-FY2020, which is obtained by summing the total AR rates as mentioned above. In the same way, the D land area for each prefecture during FY1990-FY2020 is calculated by multiplying the land area for each prefecture by the D rate during FY1990-FY2020, which is obtained by summing the increase of D rate in each year during FY1990-FY2020.

Japan’s national land area is gradually increasing due to land reclamation on the coastal areas, etc. However, it is considered that AR and D activities have hardly occurred in the reclaimed land on the coastal areas, and therefore newly expanded national areas are not included in the AR and D interpretation target areas. In order to do so, the national land area in FY2005, when the AR and D interpretation were started, is used for the whole time series, instead of the land area in each year, in the calculation of multiplying the land areas by the AR and D rates. This change was applied in the 2022 submission.

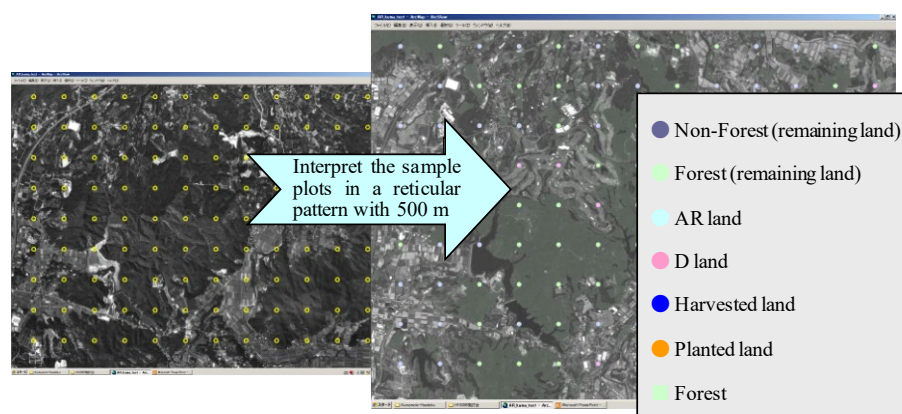


Figure 11-2 ARD land identification by interpreting remote sensing images

Although Forest Registers are used as basic data source for reporting since forests under the forest planning system are considered as forests under the Kyoto Protocol in Japan, orthophotos and satellite images are used for AR and D detection. This is because it is difficult to simulate the forest status during FY1990-FY2005 from the data in the Forest Registers, and to distinguish human-induced AR from forest expansion due to other causes.

With respect to possible over- or under-estimation of D rate based on orthophotos and satellite images, there is a possibility that the D rate may be over-estimated. The reason is that there is a possibility that plots on cut-over forests, which have lost forest cover but not classified as deforested, and those on areas of decreasing tree cover in land other than forest land may be misidentified as D plots. Hence, Japan has implemented field surveys on a part of plots identified as D plots thus far. As a result of the surveys so far, about 90% of plots identified as D plots was accurate, but about 10% was located on cut-over forests or on areas of decreasing tree cover in land other than forest land. In contrast, the result of double-checking a part of plots identified as not changed revealed that there were very few misidentifications; hence, possibility of under-estimation of D rate was extremely low. Therefore, it can be said that possibility of under-estimation of D rate is extremely low, but that the D rate may be over-estimated.

#### 11.4.2.3.b. Data

Japan determines the AR and D land area by using the following data.

Table 11-7 Data used in AR and D land detection

	Resolution [m]	Data format
Ortho air-photo (at the end of 1989)	1	Raster
SPOT5/HRV-P (2005, 2007 and 2009 - 2014)	2.5	Raster
SPOT6/7/HRV-P (2015 - 2020)	1.5	Raster

#### 11.4.2.3.c. Land-use change in deforested land

Japan determines the area of D land in accordance with the procedures mentioned in section 11.4.2.3.a. However, these procedures do not cover the continuous tracking of land-use change in D land. Therefore, the land-use change status in the D land has been assessed separately.

Japan has compiled land-use mesh data in the so called “Digital National Land Information” continuously over time. Although this mesh data cannot be used directly to monitor land-use change in the plots identified as D land because this mesh data is not absolutely consistent with the system

mentioned in section 11.4.2.3.a (e.g. definition, resolution and land identification method), it can detect the overall tendency of land-use transition in the D plot. The results of the analysis of this mesh data show that D land is seldom converted to other land use again. Therefore, Japan assumes that the status of land use after D will continue to be the same and secondary land-use change will not occur.

#### 11.4.2.4. Forest Management

##### 11.4.2.4.a. Procedure

Japan estimates the FM land area for ikusei-rin forests and tennensei-rin forests according to the following procedures. As explained in section 11.3.2.1., forests to which activities for FM have been implemented since 1990 are subject to FM. Hence, if forests do not fulfill this condition, they are not counted as the forests subject to FM even if they are reported as managed forests under the Convention. Therefore, areas of the forests subject to FM are not equivalent to those of the managed forests under the Convention.

Areas subject to forest management are extracted from the areas of remaining managed forests which are determined after the areas of deforestation have been subtracted from the area of the total managed forests of the previous year; hence, the area subject to forest management has reflects the decrease in forest management area resulting from deforestation. This means that the areas subject to forest management are not overestimated.

##### a) Ikusei-rin forests

1. A field survey in private forests and national forests is implemented each year to identify lands which have been subject to FM activities (the number of sample plots are systematically distributed by tree species and regions; then, sample plots are selected randomly from the National Forest Resource Database (NFRDB)).

Survey items: current status of forests (tree species, stand age, number of trees, etc.), status and contents of practices since 1990, etc.

2. The ratio of these FM land areas (FM ratio) is estimated according to the survey findings.
3. After the AR land area for each prefecture is subtracted from the total forest area, the remaining forest area for each prefecture is multiplied by the FM ratio for each tree species, region and age class.

Table 11-8 FM ratio for ikusei-rin forests (private forests / national forests)

Sub-category / Tree species		Region	Private forest	National forest
Intensively managed forest	Japanese cedar	Tohoku, Kita-kanto, Hokuriku, Tosan	0.89	0.92
		Minami-kanto, Tokai	0.74	0.88
		Kinki, Chugoku, Shikoku, Kyusyu	0.80	0.91
	Hinoki cypress	Tohoku, Kanto, Chubu	0.84	0.92
		Kinki, Chugoku, Shikoku, Kyusyu	0.88	0.93
	Japanese larch	All	0.89	0.85
Other	All	0.73	0.84	
Semi-natural forest / All		All	0.46	0.68

Note:

- 1) Data at the end of FY2020. About 22,400 sample plots are located all across the country.
- 2) These regions generally used broad boundaries which aggregated several prefectures.
- 3) FM ratios shown in this table are area-weighted average values of FM ratio for each age class.
- 4) Uncertainty for FM ratios is 5% for entire Japan.

**b) Tennensei-rin forests**

For tennensei-rin forests, forest lands subject to practices for protection or conservation such as controlling logging activities and land-use change which have been carried out under law are identified by the NFRDB. Tennensei-rin forests under Article 3.4 of KP consist of Protection Forests, Special Zones and Special Protection Zones of National Parks and other protected forests/zones as shown in Table 11-9 below. The Protection Forests are designated under article 25 of the Forest Law (legislation No. 249 of 26<sup>th</sup> June 1951) for the purpose of fulfilling forest multiple functions (such as headwater conservation and disaster prevention). In the Protection Forests, implementing cutting stands, changing land characteristics and related activities without pre-permission are prohibited. In addition, placing signs which show the Protection Forest area, conducting field inspection and monitoring by utilizing satellite images are implemented. With respect to the National Parks, the parks are protected by restriction of development and changing land characteristics, prohibition of hunting animals and harvesting plants, limitation of people's and vehicles' accesses, based on the National Parks Law (legislation No.161 of 1<sup>st</sup> June, 1957). These measures have been applied to the Tennensei-rin forests under Article 3.4 of KP continuously after FY1990.

Table 11-9 Area of protected/conserved tennensei-rin forests [kha]

Protected / Conserved forest type	Private forest	National forest	Total
Protection Forest	2,895	4,559	7,454
Area for Conservation facility installation project	1	0	1
Protected Forest	0	602	602
Special Protected Zones in National Parks	43	115	158
Class I Special Zones in National Parks	43	168	210
Class II Special Zones in National Parks	142	202	344
Special Protected Zones in Quasi-National Parks	9	37	47
Class I Special Zones in Quasi-National Parks	31	106	137
Class II Special Zones in Quasi-National Parks	96	88	184
Special Zone in National Environment Conservation Area	2	9	11
Special Seed Forest	1	1	1
Total	3,263	5,886	9,150
(excluding duplicate designations)	(2,787)	(4,316)	(7,103)

Reference: NFRDB (1<sup>st</sup> April 2021)

Note: This table includes forests with less standing trees.

**11.4.2.4.b. Data****a) Basic data for estimation**

The basic data sources for FM estimation are Forest Registers and yield tables developed by prefectures or regional forest offices. Some of the yield tables are developed by the Forestry and Forest Products Research Institute. These Forest Registers and yield tables are also used for reporting under the Convention. Detailed information on Forest Registers and yield tables is provided in section 6.5.1.b) 1), Chapter 6 of this report.

**b) Development of the National Forest Resources Database**

To estimate emissions from or removals by forests, the Forestry Agency has developed the NFRDB. In the NFRDB, Forest Registers which are the basic data source for estimation and report, administrative information including forest planning maps and geographical location data such as orthophotos and satellite images like Landsat-TM and SPOT are archived.

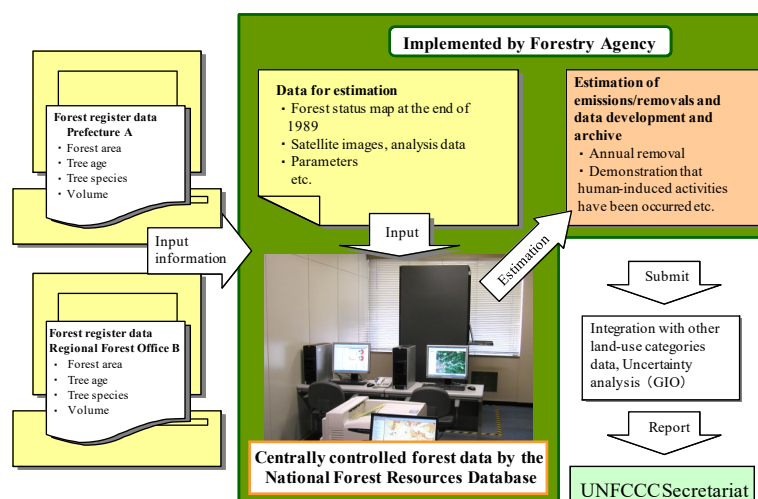


Figure 11-3 Summary of the National Forest Resources Database

#### 11.4.2.5. Cropland Management

Basically, current cropland is subject to CM, area of CM was obtained from *Statistics of Cultivated and Planted Area* by the MAFF in each prefecture for each land-use category (rice fields, upland fields and orchards). The data source and definition of land use are the same as reporting of LULUCF under the Convention (see section 6.6 in Chapter 6 in this NIR).

Since, land which was converted from forest land to cropland is classified as D activity, area of CM were calculated by subtracting the area of cropland converted from forest land since 1990 obtained from the D survey, from the current area of rice fields, upland fields and orchards in each prefecture.

The land converted from cropland between 1991 and 2012 was not been included in the estimation because the land is not subject to CM activity in accordance with *the KP Supplement*.

In accordance with paragraph 24 of the annex to the decision 2/CMP.7, the land converted from cropland in the second commitment period since 2013 is included in area of CM activity; hence, the annual decrease area of cropland for each land-use category (rice fields, upland fields and orchards) in each prefecture obtained from *Statistics of Cultivated and Planted Area* by the MAFF, etc. was included in area as “current non-cropland subject to CM activity”. However, as planting on cropland is classified as AR activity, the decrease of cropland area is calculated by subtracting annual area of afforestation (AR) in cropland since 2013, from the area subject to CM activity.

#### 11.4.2.6. Grazing Land Management

Method of determining and procedure for GM area are the same as the CM. Using the cultivation area of pasture in each prefecture obtained from *Statistics of Cultivated and Planted Area* by the MAFF as base data, GM area was calculated by identifying area of current pasture, current non-pasture converted from pasture since 2013, past-pasture area subject to D activity and subject to AR activity by using the same method as CM.

#### 11.4.2.7. Revegetation

##### 11.4.2.7.a. Procedure

Japan estimates the RV land area by types of urban green facilities according to the following procedures.



**a) Urban parks**

1. The information on the notification date and the establishment areas are sorted out as of the end of each corresponding fiscal year during the commitment period for all urban parks which are installed in our country.
2. The urban parks which have been notified since 1 January 1990 and whose establishment area is 500 m<sup>2</sup> or more are extracted.
3. The urban parks extracted in step 2 are sorted out by geographical boundaries (prefectures) are counted.
4. The area of land which was classified as forest land on 31 December 1989 is calculated by multiplying the establishment area estimated in step 3 by the sum of the area ratios of “Land that has been converted from forest land to settlements per annum” since 1990 until each corresponding fiscal year during the commitment period. This area is excluded from the establishment areas because it is classified as D. The remaining area is considered as RV land area.
5. The areas of “Remaining land (settlements remaining settlements)” and “Land converted from other land-use categories (cropland / grassland / wetlands / other land converted to settlements)” are calculated by multiplying the land area estimated in step 4 by the area ratio of “Land converted to settlements” in the single year<sup>5</sup>.

**b) Green areas on roads**

1. The number of tall trees at the end of each corresponding fiscal year during the commitment period is calculated by geographical boundaries (prefectures) based on the results of “Road Tree Planting Status Survey”.
2. The number of tall trees on 31 March 1990 is calculated by using linear regression of two surveyed data sets (1986 and 1991) from the “Road Tree Planting Status Survey”. Next, the number of tall trees for each prefecture on 31 March 1990 is calculated by multiplying these values by the ratio of the number of tall trees for each prefecture on 31 March 2007. The ratio of the number of tall trees on 31 March 1990 is fixed to the value on 31 March 2007.
3. The number of tall trees which have been planted since 1 April 1990 is calculated by subtracting the value estimated in step 1 from the value in step 2 (RV is considered to be an activity which takes place after 1 January 1990. However, Japan considers RV as an activity after 1 April 1990 because the “Road Tree Planting Status Survey” has been implemented on a fiscal year basis).
4. The ratio of the number of tall trees planted on roads with a planted area less than 500 m<sup>2</sup> is estimated by using data from the sampling survey implemented in 2006 (general road: 1.00%, expressway: 0.00%, significance level: 95%).
5. The land area per tall tree is estimated by using modeled data from the sampling survey implemented in 2006 (general road: 0.0062 ha/tree, expressway: 0.0008 ha/tree, significance level: 95%). (These modeled data are calculated by dividing randomly sampled RV land areas by the number of tall trees planted on the land).
6. The area of land planted with tall trees, which is 500 m<sup>2</sup> or more, is calculated by multiplying the

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<sup>5</sup> Land-use change from the previous year to each corresponding year is applied when the area ratio of “single year” is used.

values estimated in steps 4 and 5 by the number of tall trees for each geographical boundary (prefecture) estimated in step 3.

$$\begin{aligned} & \text{Area of land where tall trees have been planted since 1 April 1990 and whose size is 500 m}^2 \\ & \text{or more [ha]} \\ & = \text{Number of tall trees planted since 1 April 1990 [tree]} \\ & \quad \times \text{Ratio of the number of tall trees planted on land which is 500 m}^2 \text{ or more [\%]} \\ & \quad \times \text{Land area per tall tree [ha/tree]} \end{aligned}$$

7. The area of land which was classified as forest land on 31 December 1989 is calculated by multiplying the area estimated in step 6 by the sum of the area ratios of “Land that has been converted from Forest land to settlements per annum” since 1990 until each corresponding fiscal year during the commitment period. This area is excluded because it is classified as D area. The remaining area is considered as RV land area.
8. The areas of “Remaining land (settlements remaining settlements)” and “Land converted from other land-use categories (cropland / grassland / wetlands / other land converted to settlements)” are calculated by multiplying the land area estimated in step 7 by the area ratio of “Land converted to settlements” in the single year.

**c) Green areas at ports**

1. The green areas at ports which have been established since 1 January 1990 and which have a service area of 500 m<sup>2</sup> or more are extracted. Then, their areas are sorted out by geographical boundaries (All green areas at ports can be reported because they are considered not to be classified as forest land on 31 December 1989).
2. The areas of “Remaining land (settlements remaining settlements)” and “Land converted from other land-use categories (cropland / grassland / wetlands / other land converted to settlements)” are calculated by multiplying the land area estimated in step 1 by the area ratio of “Land converted to settlements” in the single year.

**d) Green areas around sewage treatment facilities**

1. The green areas around sewage treatment facilities which have been established since 1 January 1990 and which have a greening area of 500 m<sup>2</sup> or more are extracted. Then, their areas are sorted out by geographical boundaries.
2. The area of land which was classified as forest land on 31 December 1989 is calculated by multiplying the greening areas estimated in step 1 by the sum of the area ratios of “Land that has been converted from Forest land to settlements per annum” since 1990 until each corresponding fiscal year during the commitment period. This area is excluded because it is classified as D area. The remaining area is considered as RV land area.
3. The areas of “Remaining land (settlements remaining settlements)” and “Land converted from other land-use categories (cropland / grassland / wetlands / other land converted to settlements)” are calculated by multiplying the land area estimated in step 2 by the area ratio of “Land converted to settlements” in the single year.

**e) Green areas by greenery promoting systems for private green space**

1. The green areas by greenery promoting systems for private green space which have a greening area

(excluding wall green areas) of 500 m<sup>2</sup> or more are extracted and their areas are sorted out by geographical boundaries. All of them are activities which took place after 1 January 1990 because greenery promoting systems have been implemented since May 2001.

- All green areas by greenery promoting systems for private green space to be reported are “Remaining land (settlements remaining settlements)” because they were not classified as Forest land on 31 December 1989, and land-use conversion, if any in recent years, occurred only within settlements.

**f) Green areas along rivers and erosion control sites**

- The works of greening and erosion and sediment control including hillside works in river zones which have been established since 1 January 1990 and which have a greening area of 500 m<sup>2</sup> or more are extracted (greening works: (1) – (8), erosion and sediment control works: (9) – (11) in the following table).

Table 11-10 RV projects in green areas along rivers and erosion control sites and definition of planted land area

RV works in green areas along rivers and erosion control sites	Definition of planted land area
(1) Planting in inspection passage of excavated channel	Area of land from levee wall shoulder to private land
(2) Planting in face of river bank of excavated channel	Area of land from levee wall shoulder to private land
(3) Planting in backslope banquette	Area of embanked land
(4) Planting in levee marginal strip (second-class and third-class)	Area of marginal strip which is subject to greening works
(5) Planting in high water channel	Area of land from low-flow channel shoulder to foot of levee slope
(6) Planting in retarding basin	Area of retarding basin
(7) Planting in lake foreshore	Area of land from low-flow channel shoulder to foot of levee slope
(8) Planting in super levee	(Same as planting in excavated channel)
(9) Greening under erosion and sediment control works	Area of land which is subject to hillside works
(10) Greening under landslide control works	Area of land which is subject to hillside works
(11) Greening under steep slope failure prevention works	Area of land which is subject to hillside works

- The planted land area in green areas along rivers and erosion control sites for each geographical boundary (prefecture) extracted in step 1 is calculated. Double-counting between RV land and D land is prevented because forested land (on 1 January 1990) is not included in step 1.
- The land areas of “Remaining land (settlements remaining settlements)” and “Land converted from other land-use categories (cropland / grassland / wetlands / other land converted to settlements)” are calculated by multiplying the land area estimated in step 2 by the area ratio of “Land converted to settlements (excluding forest land converted to settlements)” in the single year.

**g) Green areas around government buildings**

- The green areas around government buildings which have been established since 1 January 1990 and whose RV land area (= total land area - building area) is 500 m<sup>2</sup> or more are extracted.
- The RV land area for each geographical boundary (prefecture) extracted in step 1 is calculated.
- The area of land which was classified as Forest land on 31 December 1989 is calculated by multiplying the land area estimated in step 2 by the sum of the area ratios of “Land that has been converted from Forest land to settlements per annum” since 1990 until each corresponding fiscal

year during the commitment period. This area is excluded because it is classified as D area. The remaining area is considered as RV land area.

4. The areas of “remaining land (settlements remaining settlements)” and “land converted from other land-use categories (cropland / grassland / wetlands / other land converted to settlements)” are calculated by multiplying the land area estimated in step 3 by the area ratio of “land converted to settlements” in the single year.

#### ***h) Green areas around public rental housing***

1. The green areas around public rental housing which have been established since 1 January 1990 and which have a RV land area (= total land area - building area) of 500 m<sup>2</sup> or more are extracted.
2. The RV land area for each geographical boundary (prefecture) extracted in step 1 are calculated.
3. The area of land which was classified as Forest land on 31 December 1989 is calculated by multiplying the land area estimated in step 2 by the sum of the area ratios of “Land that has been converted from Forest land to settlements per annum” since 1990 until each corresponding fiscal year during the commitment period. This area is excluded because it is classified as D area. The remaining area is considered as RV land area.
4. The areas of “Remaining land (settlements remaining settlements)” and “Land converted from other land-use categories (cropland / grassland / wetlands / other land converted to settlements)” are calculated by multiplying the land area estimated in step 3 by the area ratio of “Land converted to settlements” in the single year.

#### **11.4.2.7.b. Data**

The data applied in estimating RV land area are shown below.

Table 11-11 Data applied in estimating RV land area

Sub-division	Data type	Method for data collection
Urban parks	Area for each urban park	Urban Parks Status Survey (conducted every year since FY2008)
Green area on roads	Number of tall trees	Road Tree Planting Status Survey (conducted every year since FY2007)
	Land area per tall tree	Basic Data Collection Survey on Tall Tree Planting on Roads (February 2007)
Green areas at ports	Service area	Complete census (conducted every year since FY2008)
Green areas around sewage treatment facilities	Green area	Sewage Treatment Facility Status Survey (conducted every year since FY2009)
Green areas by greenery promoting systems for private green space	Greening area Wall greening area Number of tall trees	Application form for greenery promoting systems for private green space Urban Greening Status Survey (conducted every year since FY2008)
Green areas along river and erosion control sites	Planted land area	Survey on carbon dioxide absorption at source in river works (conducted every year since FY2008)
Green areas around government buildings	Total land area and building area	Complete census (conducted every year since FY2008)
Green areas around public rental housing	Total land area and building area	Progress survey on tree planting for public rental housing (conducted every year since FY2008)

### 11.4.3. Maps and/or database to identify the geographical locations, and the system of identification codes for the geographical locations

Section 2.2.2 of *the KP Supplement* shows two methods for identifying and reporting the units of land subject to Article 3.3 activities and lands subject to Article 3.4 activities. Reporting Method 1 entails delineating areas that include multiple land units subject to Article 3.3 and 3.4 activities by using legal, administrative, or ecosystem boundaries. Reporting Method 2 is based on the spatially explicit and complete geographical identification of all units of land subject to Article 3.3 activities and all lands subject to Article 3.4 activities.

Japan elects Reporting Method 1 in accordance with the decision tree indicated in Figure 2.2.2 in Chapter 4 of *the KP Supplement*, which means that the entire national land is stratified by using the geographic boundary of prefectures, and the total area of each “unit of land” subject to each Article 3.3 activity and each “land” subject to each Article 3.4 activity is reported within each boundary. The identification code is determined for each prefecture as shown in the following map (see Table 11-12). Each activity under Articles 3.3 and 3.4 is detected as described in sections 11.4.2.3-11.4.2.7 and the units of land or lands subject to it are identified within prefectural boundaries in accordance with Reporting Method 1.

This geographical boundary is applied for all units of land: units of land subject to activities under Article 3.3, units of land subject to activities under 3.3 which would otherwise be included in land subject to forest management or elected activities under Article 3.4, under the provisions of paragraph 9 of the annex to the decision 2/CMP.7, and lands subject to forest management and to nay elected activities under Article 3.4.



Figure 11-4 Japan's determination of identification codes

Table 11-12 Identification codes and prefectures

ID	Prefecture	ID	Prefecture	ID	Prefecture	ID	Prefecture	ID	Prefecture
01	Hokkaido	11	Saitama	21	Gifu	31	Tottori	41	Saga
02	Aomori	12	Chiba	22	Shizuoka	32	Shimane	42	Nagasaki
03	Iwate	13	Tokyo	23	Aichi	33	Okayama	43	Kumamoto
04	Miyagi	14	Kanagawa	24	Mie	34	Hiroshima	44	Oita
05	Akita	15	Niigata	25	Shiga	35	Yamaguchi	45	Miyazaki
06	Yamagata	16	Toyama	26	Kyoto	36	Tokushima	46	Kagoshima
07	Fukushima	17	Ishikawa	27	Osaka	37	Kagawa	47	Okinawa
08	Ibaraki	18	Fukui	28	Hyogo	38	Ehime		
09	Tochigi	19	Yamanashi	29	Nara	39	Kochi		
10	Gunma	20	Nagano	30	Wakayama	40	Fukuoka		

## 11.5. Activity-specific information

### 11.5.1. Methods for carbon stock change and GHG emission and removal estimates

#### 11.5.1.1. Description of the methodologies and the underlying assumptions used

##### 11.5.1.1.a. Afforestation/Reforestation

###### a) Above-ground biomass, Below-ground biomass

###### ● Methodology

The carbon stock change in living biomass in AR land ( $\Delta C_{AR\_LB}$ ) was calculated by summing the loss of carbon stock due to conversion ( $\Delta C_{LB\_conversion\_to\_AR}$ ) and the carbon stock change occurred after conversion ( $\Delta C_{AR\_LB\_SC}$ ).

$$\Delta C_{AR\_LB} = \Delta C_{LB\_conversion\_to\_AR} + \Delta C_{AR\_LB\_SC}$$

$\Delta C_{AR\_LB}$  : Annual carbon stock change in living biomass in AR [t-C/yr]

$\Delta C_{LB\_conversion\_to\_AR}$  : Annual carbon stock change due to land conversion to Forest land (loss) [t-C/yr]

$\Delta C_{AR\_LB\_SC}$  : Annual carbon stock change due to biomass growth, felling, fuelwood gathering, disturbance in living biomass in AR [t-C/yr] (see section 6.5.1.b.1))

The loss of carbon stock due to conversion ( $\Delta C_{LB\_conversion\_to\_AR}$ ) was calculated using the same method as “Land converted to Forest land (4.A.2)”.

$$\Delta C_{LB\_conversion\_to\_AR} = \sum_i \{ \Delta A_{i-AR} \times (B_{after} - B_{before\ i}) \times CF_i \}$$

$\Delta A_{i-AR}$  : Annual increase of land area that has been converted from land-use type  $i$  to forest [ha/yr]

$B_{after}$  : Dry matter weight per unit area immediately after conversion to forest [t-d.m./ha] (assumed to be zero)

$B_{before\ i}$  : Dry matter weight per unit area before conversion from land-use type  $i$  to forest [t-d.m./ha]

$CF_i$  : Carbon fraction of dry matter in land-use type  $i$  [t-C/t-d.m.]

$i$  : Type of land use (rice fields and upland fields grassland), (for conversions from wetlands, settlements and other land, carbon stock before conversion was assumed to be zero; carbon stock before conversion from orchards was included in the CM estimation)

Regarding the carbon stock change occurred after conversion ( $\Delta C_{AR\_LB\_SC}$ ), the same method of the Tier

2 stock difference method as “Forest land remaining Forest land (4.A.1)” was used. See section 6.5.1.b)1) for estimation equations and their parameters.

- **Parameters**

The biomass stock data for each land use category to estimate carbon stock change due to land conversion are provided in Table 6-8 and Table 6-9, Chapter 6 of this report.

- **Activity data**

The activity data is AR land area which was calculated by using the procedure described in section 11.4.2.3 of this report.

**b) Dead wood, Litter and Soils**

- **Methodology**

The carbon stock changes in dead wood, litter and soils in AR land were calculated using the same method as “Land converted to Forest land (4.A.2)” with the assumption that it takes 20 years to reach the average carbon stocks in forest land with linearly increase from carbon stock in land before conversion. See section 6.5.2.b)2) for estimation equations.

As mentioned in section 6.5.1.b).2), soil drainage activities for organic soil in forest land are not implemented in Japan, and it is considered as same for forests subject to AR activity. In Tier 1 and Tier 2 estimation methods provided in the *2006 IPCC Guidelines*, emissions from organic soils are estimated only when soil drainage is carried out, therefore it is considered that the emissions do not occur in undrained organic soils, and the emissions were reported as “NO”.

- **Parameters**

The parameters are determined based on the CENTURY-jfos model and relevant literature. See section 6.5.1.b)2) of this NIR for the key assumptions and parameters applied for the calculation by CENTURY-jfos model.

- **Activity data**

The AR land area is calculated by using the procedure described in section 11.4.2.3 of this report.

**c) Harvested Wood Products (HWP)**

HWP from forest land subject to AR activity was reported as “NO” because wood supply for HWP from AR land does not occur in Japan.

**d) Other gases**

**1) Direct and indirect N<sub>2</sub>O emissions from N fertilization**

The amount of nitrogen-based fertilizer applied in Forest land cannot be separated to those in AR and in FM. Hence, N<sub>2</sub>O emissions from N fertilization are reported in FM in a lump. Therefore, this category in AR has been reported as “IE”.

**2) N<sub>2</sub>O and CH<sub>4</sub> emissions from drainage of soils**

Soil drainage in forest land with organic soils is not implemented in Japan. According to the methodology of the *2006 IPCC Guidelines*, emissions do not occur in undrained organic soils. Therefore, N<sub>2</sub>O and CH<sub>4</sub> emissions were reported as “NO”.

### 3) N<sub>2</sub>O emissions from N mineralization/immobilization due to carbon loss/gain associated with land-use conversions and management change in mineral soils

Since soil carbon stock changes in AR are reported to be on the increases, according to method under Tier 2 described in *the 2006 IPCC Guidelines*, N<sub>2</sub>O emissions from N immobilization associated with gain of soil organic matter were not estimated. Therefore, N<sub>2</sub>O emissions from this subcategory in AR land were reported as “NA”. Since “NA” could not be entered in the CRF Reporter for this category, they were reported as “NO” in the CRF “Table NIR 1”.

### 4) Biomass burning

GHG emissions from wildfire exist in Japan as explained in section 6.16.b) 1), Chapter 6 of this report. Since there is no data which directly express biomass burning status in AR land, GHG emissions in AR land are estimated by multiplying GHG emissions due to fire for all forest land by the ratio of AR land area to all forest land area. Carbon released due to fire for all forest land (national forests and private forests) is estimated by multiplying the damaged timber volume due to fire by wood density, biomass expansion factor and carbon fraction of dry matter. Calculations only for non-CO<sub>2</sub> emissions are performed since CO<sub>2</sub> emissions are already included in the calculation of carbon stock change. Moreover, controlled burning activities in forests and land converted from land-use categories other than forest land to forest land are not implemented in Japan because of severe restrictions imposed by the “Waste Management and Public Cleansing Law” and the “Fire Defense Law”.

### e) Results

Table 11-13 Emissions and removals from AR activity

	2013	2014	2015	2016	2017	2018	2019	2020
	[kt-CO <sub>2</sub> eq.]	[kt-CO <sub>2</sub> eq.]	[kt-CO <sub>2</sub> eq.]	[kt-CO <sub>2</sub> eq.]	[kt-CO <sub>2</sub> eq.]	[kt-CO <sub>2</sub> eq.]	[kt-CO <sub>2</sub> eq.]	[kt-CO <sub>2</sub> eq.]
AR	-1477.60	-1483.34	-1485.66	-1488.04	-1464.61	-1375.40	-1316.24	-1245.26
Above-ground biomass	-845.96	-845.76	-847.52	-845.69	-824.13	-809.05	-806.16	-786.85
Below-ground biomass	-215.09	-214.96	-210.94	-210.56	-212.11	-207.99	-207.34	-202.29
Dead wood	-293.64	-303.72	-311.89	-319.51	-320.61	-261.95	-213.45	-172.68
Litter	-92.91	-89.56	-85.66	-81.66	-76.11	-63.58	-56.43	-51.25
Soils	-30.02	-29.46	-29.68	-30.62	-31.75	-32.84	-32.88	-32.21
Harvested wood products (HWP)	NO	NO	NO	NO	NO	NO	NO	NO
Other gases	0.02	0.10	0.03	0.01	0.11	0.01	0.02	0.01
Biomass burning (CH <sub>4</sub> )	0.02	0.10	0.03	0.01	0.10	0.01	0.02	0.01
Biomass burning (N <sub>2</sub> O)	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00

#### 11.5.1.1.b. Deforestation

##### a) Above-ground biomass, Below-ground biomass

###### ● Methodology

The carbon stock change in living biomass in D land ( $\Delta C_{D\_LB}$ ) was estimated by adding the living biomass loss in forests due to land conversion ( $\Delta C_{LB\_conversion\_to\_others}$ ) and carbon stock change due to growth of living biomass in D land after land conversion ( $\Delta C_{D\_LB\_SC}$ ).

The loss of living biomass of forest due to land conversion ( $\Delta C_{LB\_conversion\_to\_others}$ ) was estimated from data in the NFRDB taking into account the status of D land such as tree species and stand ages, and all carbon losses were allocated as emissions in the year of land conversion.

The carbon stock change due to growth of living biomass ( $\Delta C_{D\_LB\_SC}$ ) was estimated depending on land uses after conversion in D land. The land-use categories, where living biomass growth after conversion is calculated, were “land converted to cropland”, “land converted to grassland” and “land converted to settlements” as with reporting of LULUCF under the Convention. The growth of living biomass, which was increased after D practices, i.e. the carbon gain which was occurred under the land subject to both



Article 3.3 and 3.4 activities, was reported under D activity. The calculation was performed according to land-use status immediately after conversion in D land with the assumption that D land was seldom converted to other land uses again as explained in section 11.4.2.3.c.

$$\Delta C_{D\_LB\_SC} = \Delta C_{D-CL\_LB\_SC} + \Delta C_{D-GL\_LB\_SC} + \Delta C_{D-SL\_LB\_SC}$$

$$\Delta C_{D-CL\_LB\_SC} = \Delta A_{D-annualcrop} \times C_{annualcrop\_LB}$$

$$\Delta C_{D-GL\_LB\_SC} = \Delta A_{D-GL,5} \times b_{GL}$$

$$\Delta C_{D-SL\_LB\_SC} = \Delta C_{RV\_LB\_SC} \times RA_{D-RV}$$

$\Delta C_{D\_LB\_SC}$  : Annual carbon stock change due to living biomass growth after D activity [t-C/yr]

$\Delta C_{D-CL\_LB\_SC}$  : Carbon stock change due to living biomass growth in cropland subject to D activity [t-C/yr]  
(Estimated for annual crop only. All carbon stock change in Orchards is included in CM because of the applied method)

$\Delta C_{D-GL\_LB\_SC}$  : Carbon stock change due to living biomass growth in grassland subject to D activity [t-C/yr]

$\Delta C_{D-SL\_LB\_SC}$  : Carbon stock change due to living biomass growth in settlements subject to D activity [t-C/yr]

$\Delta A_{D-annualcrop}$  : Area of rice fields and upland fields in cropland subject to D activity within a year [ha/yr]

$C_{annualcrop\_LB}$  : Carbon accumulation in living biomass per area for annual crop in rice fields or upland fields in cropland [t-C/ha/yr]

$\Delta A_{D-GL,5}$  : Area of grassland subject to D activity within the past 5 years [ha]

$b_{GL}$  : Annual carbon stock change in living biomass per area in grassland [t-C/ha/yr]

$\Delta C_{RV\_LB\_SC}$  : Carbon stock change in living biomass due to all RV practices [t-C/yr] (see section 11.5.1.1.f)

$RA_{D-RV}$  : Ratio of the area subject to both D and RV activities within all areas subject to RV activities

### ● **Parameters**

Information relating to loss of forest biomass is obtained from the NFRDB. Table 6-9 in Chapter 6 of this report were used to calculate the carbon stock changes due to living biomass growth after D activity. The parameters for estimating carbon stock change due to RV practices are the same as those used for RV activity.

### ● **Activity data**

The D land area is calculated by the method described in section 11.4.2.3. The D land area where RV practices have been taken place is calculated by the method described in section 11.5.1.1.f.

### **b) Dead wood, Litter and Soils**

The carbon stock change in dead wood, litter and soils associated with D is calculated in accordance with the Tier 2 method in the *2006 IPCC Guidelines*. Japan assumes that all carbon stocks in dead wood and litter are emitted at the time when D activities occur. The carbon stock change in mineral soils is calculated under the assumption that it takes 20 years to reach the soil carbon stocks in non-forest land with linearly increase from carbon stocks in forest land. Carbon stocks before conversion were set by the data obtained from the CENTURY-jfos model and carbon stocks after conversion were established based on the data in Tables 6-10 to 6-12 in Chapter 6 of this report. See section 6.5.1.b)2) of this NIR for the key assumptions and parameters applied for the calculation by CENTURY-jfos model.

Land-use changes from forest land with organic soils hardly occur in Japan, however, the emissions from organic soils were reported in the case of forest conversion to settlements, as it was assumed that the emissions from organic soils would occur under the sites with constructions. As for estimation

method, the same estimation equations as section 6.6.1.b)2) in Chapter 6 in this NIR was used to estimate on-site CO<sub>2</sub> emissions from organic soils and off-site CO<sub>2</sub> emissions via waterborne carbon losses from drained inland organic soils.

### c) *Harvested Wood Products (HWP)*

The carbon stock change of HWP from D land was reported as “IO” because HWP from D land was accounted for on the basis of instantaneous oxidation in accordance with paragraph 31 of the annex to the decision 2/CMP.7.

### d) *Other gases*

#### 1) *Direct and indirect N<sub>2</sub>O emissions from N fertilization*

The fertilization in deforestation process has not been implemented in Japan. N<sub>2</sub>O emissions from N fertilization in land after conversion are included in the estimation of the Agriculture sector. Therefore, the emissions in this category were reported as “IE”.

#### 2) *N<sub>2</sub>O and CH<sub>4</sub> emissions from drainage of organic soils*

As in the case b) above, estimation was made only when land-use changes from forest land to settlements with organic soils occurred. CH<sub>4</sub> and N<sub>2</sub>O emissions from drainage of organic soils were estimated voluntarily by using Tier 1 and Tier 2 methods described in section 2.2.2.1 in the *Wetland Guidelines*, as described in Chapter 6, section 6.13.b) of this NIR.

#### 3) *N<sub>2</sub>O emissions from N mineralization/immobilization due to carbon loss/gain associated with land-use conversions and management change in mineral soils*

N<sub>2</sub>O emissions from nitrogen mineralization associated with loss of soil organic matter were calculated by using Tier 1 estimation method described in the *2006 IPCC Guidelines*. The estimation equation and parameters used are the same as section 6.14 in Chapter 6 in this NIR. All carbon losses due to deforestation are regarded as annual loss of soil carbon of N mineralized associated with land-use conversions in D area.

#### 4) *Biomass burning*

In Japan, controlled burning activities are not carried out in deforestation activities and on the lands after conversion because of severe restrictions imposed by the “Waste Management and Public Cleansing Law” and the “Fire Defense Law”. In addition, wildfires do not occur on all land after conversion. Therefore, CH<sub>4</sub>, N<sub>2</sub>O emissions from biomass burning in D land are reported as “NO”.

### e) *Results*

Table 11-14 Emissions and removals from D activity

	2013	2014	2015	2016	2017	2018	2019	2020
	[kt-CO <sub>2</sub> eq.]	[kt-CO <sub>2</sub> eq.]	[kt-CO <sub>2</sub> eq.]	[kt-CO <sub>2</sub> eq.]	[kt-CO <sub>2</sub> eq.]	[kt-CO <sub>2</sub> eq.]	[kt-CO <sub>2</sub> eq.]	[kt-CO <sub>2</sub> eq.]
D	2004.91	2006.85	2317.13	2315.61	1826.83	1819.38	1683.16	1695.62
Above-ground biomass	1046.16	1050.90	1214.23	1217.42	954.12	953.50	986.50	994.28
Below-ground biomass	255.81	258.33	302.51	302.94	235.04	236.52	245.84	249.40
Dead wood	495.86	494.74	565.03	562.61	441.49	440.20	313.33	312.34
Litter	199.76	199.86	229.02	229.22	180.50	180.57	128.71	128.76
Soils (mineral)	2.59	-1.33	1.40	-1.35	9.25	2.86	2.92	4.61
Soils (organic)	2.04	2.11	2.18	2.26	2.32	2.39	2.43	2.48
Harvested wood products (HWP)	IO	IO	IO	IO	IO	IO	IO	IO
Other gases	2.68	2.24	2.77	2.51	4.13	3.34	3.43	3.76
Organic soil (CH <sub>4</sub> )	0.44	0.45	0.47	0.48	0.50	0.51	0.52	0.53
Organic soil (N <sub>2</sub> O)	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.05
N mineralization (N <sub>2</sub> O)	2.20	1.74	2.26	1.98	3.58	2.78	2.85	3.18

### 11.5.1.1.c. Forest Management

#### *a) Above-ground biomass, Below-ground biomass*

##### ● *Methodology*

1. Emissions/removals in all forest lands are estimated from biomass stock data in the NFRDB (based on the stock difference method).
2. Emissions/removals relating to AR and D activities are subtracted from emissions/removals in all forest land. For ikusei-rin forest, emissions/removals in FM land are estimated by applying the FM ratio for each tree species, region and age class<sup>6,7</sup>. For tennensei-rin forest, the areas of forest land with standing trees subject to practices for protection or conservation activities such as controlling logging activities and land-use change which have been implemented under laws are identified by using the NFRDB, and emissions/removals are estimated.

##### ● *Parameters*

The parameters are the same as those used for AR.

#### *b) Dead wood, Litter and Soils*

##### ● *Methodology*

The carbon stock changes in dead wood, litter and mineral soil pools were estimated by using the same method of the Tier 3 method as “Forest land remaining Forest land (4.A.1)”. It was estimated by multiplying carbon emissions/removals per area in each pool, which were calculated by the CENTURY-jfos model for each type of forest management, by the land area of each type of forest management and then summing them. For estimation equations, see section 6.5.1.b)2) of this NIR for key assumptions and parameters applied for the calculation by CENTURY-jfos model.

As described in section 6.5.1.b)2), soil drainage activities for organic soil in forest land were not implemented in Japan. In Tier 1 and Tier 2 estimation methods provided in the *2006 IPCC Guidelines*, emissions from drainage of organic soils are estimated only when soil drainage is carried out. Therefore, it is considered that emissions do not occur in undrained organic soils, and the emissions were reported as “NO”.

##### ● *Parameters*

Detailed explanation of the CENTURY-jfos model and its parameters are provided in section 6.5.1.b)2), Chapter 6 of this report.

#### *c) Harvested Wood Products (HWP)*

HWP under FM is the same as the HWP reporting of LULUCF under the Convention; carbon stock change in sawnwood, wooden board and plywood used in buildings were estimated by using the Tier 3 country-specific method. As for wood used for other than buildings (sawnwood, wooden board,

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<sup>6</sup> Only a part of stock losses may be accounted for as FM removals/emissions, when carbon stock changes obtained through the stock change method are multiplied by the FM ratios. In order to avoid this, all stock losses resulted from harvesting are included in the estimation of FM removals/emissions.

<sup>7</sup> When prefectures and Regional Forest Offices update the Forest Registers, the Registers' data like tree species or areas may be revised in order to reflect the current status of forests. In this case, FM removals/emissions are modified to obtain values based on appropriate carbon stock changes. Without modification, the difference between carbon stock without revision at a time point and carbon stock with revision at another time point would be regarded as the carbon stock change between the two points of time under the stock change method, and it would not reflect the correct removals or emissions.

plywood) and paper and paperboard (including waste paper), the Tier 2 method described in *the KP Supplement* was used for calculation. The estimation equations, parameters used and activity data are the same as those described in section 6.11 of Chapter 6 in this NIR.

#### d) Other gases

##### 1) Direct and indirect N<sub>2</sub>O emissions from N fertilization

The amount of nitrogen-based fertilizer applied in Forest land cannot be separated to those in AR and in FM. Hence, N<sub>2</sub>O emissions from N fertilization are reported in FM in a lump. With respect to the methodology and parameters applied to this category, see section 6.12, Chapter 6, of this report.

##### 2) N<sub>2</sub>O and CH<sub>4</sub> emissions from drainage of soils

Soil drainage activity for organic soils in forest land does not occur in Japan. According to the methodology of the *2006 IPCC Guidelines*, emissions do not occur in undrained organic soils. Therefore, N<sub>2</sub>O and CH<sub>4</sub> emissions were reported as “NO”.

##### 3) N<sub>2</sub>O emissions from N mineralization/immobilization due to carbon loss/gain associated with land-use conversions and management change in mineral soils

N<sub>2</sub>O emissions from N mineralization associated with loss of soil organic matter is estimated by using Tier 1 method described in the *2006 IPCC Guidelines*. The estimation method and parameters are the same as section 6.14 and section 6.15 in Chapter 6 in this NIR. The activity data is gross loss of soil carbon in FM which was extracted from land that soil carbon has reduced by each tree age and tree species in each prefecture.

#### 4) Biomass burning

Emissions due to biomass burning are estimated in the same way as in the case of AR by multiplying GHG emissions due to fire for all forest land by the ratio of FM land area to all forest land area. Calculations are performed only for non-CO<sub>2</sub> emissions since CO<sub>2</sub> emissions are already included in the calculation of carbon stock change (reported as “IE”). Moreover, controlled burning activities in forests are not implemented in Japan because of severe restrictions imposed by the “Waste Management and Public Cleansing Law” and the “Fire Defense Law”.

#### e) Results

Table 11-15 Emissions and removals from FM activity

	2013	2014	2015	2016	2017	2018	2019	2020
	[kt-CO <sub>2</sub> eq.]	[kt-CO <sub>2</sub> eq.]	[kt-CO <sub>2</sub> eq.]	[kt-CO <sub>2</sub> eq.]	[kt-CO <sub>2</sub> eq.]	[kt-CO <sub>2</sub> eq.]	[kt-CO <sub>2</sub> eq.]	[kt-CO <sub>2</sub> eq.]
FM	-51,173.74	-51,512.15	-49,255.20	-46,642.40	-46,352.62	-45,228.61	-41,259.00	-38,938.83
Above-ground biomass	-41,427.48	-40,837.24	-38,909.70	-36,870.76	-36,367.72	-35,327.03	-32,185.89	-31,017.02
Below-ground biomass	-10,472.96	-10,345.91	-9,830.36	-9,439.25	-9,300.87	-8,968.59	-8,109.58	-7,870.70
Dead wood	2,020.01	2,088.88	2,141.01	2,174.90	2,141.55	2,069.87	1,961.24	1,883.64
Litter	-202.16	-197.80	-186.44	-166.22	-162.64	-152.46	-130.11	-114.32
Soils	-1,514.43	-1,452.67	-1,390.74	-1,328.12	-1,275.07	-1,209.53	-1,145.45	-1,096.44
Harvested wood products (HWP)	325.01	-881.11	-1,182.74	-1,115.79	-1,508.31	-1,748.17	-1,760.25	-833.82
Other gases	98.26	113.69	103.76	102.85	120.44	107.29	111.04	109.82
N fertilization (N <sub>2</sub> O)	0.94	0.90	0.85	0.86	0.86	0.86	0.86	0.86
N mineralization (N <sub>2</sub> O)	94.50	96.55	98.54	101.01	102.61	104.65	106.44	107.04
Biomass burning (CH <sub>4</sub> )	2.60	15.01	4.04	0.90	15.68	1.65	3.47	1.78
Biomass burning (N <sub>2</sub> O)	0.21	1.23	0.33	0.07	1.29	0.14	0.28	0.15

### 11.5.1.1.d. Cropland Management

#### a) Above-ground biomass, Below-ground biomass

##### ● Methodology

The carbon stock change in living biomass under CM ( $\Delta C_{CM\_LB}$ ) was calculated for the changes of carbon stock in perennial crop (orchards) and annual crop ( $\Delta C_{orchard\_LB\_SC}$  and  $\Delta C_{annualcrop\_LB\_SC}$ ) as well as the loss of carbon stock in living biomass due to conversion from cropland (rice fields, upland fields) ( $\Delta C_{LB\_conversion\_to\_others}$ ). Carbon stock changes in living biomass in orchards were estimated by using the same method of Tier 2 stock-difference method as “Cropland remaining Cropland (4.B.1)”. The carbon stock change in annual crop is estimated only when land conversion from and to cropland. No carbon stock change was assumed when annual cropland remaining annual cropland. Thus, when land conversion to rice fields or upland fields occurred (except for deforestation), the increase to the average in carbon stock associated with the growth of annual crops due to those conversions ( $\Delta C_{annualcrop\_LB\_SC}$ ) was estimated. When rice fields or upland fields are converted to other land-use categories (except for afforestation or reforestation), the loss in carbon stock associated with loss of annual crops due to those land conversion ( $\Delta C_{LB\_conversion\_to\_others}$ ) were included under CM calculation as it was described in section 11.3.4.

The estimation equations were described below and see Table 6-8, Table 6-9 and section 6.6.1.b)1) of the report for the parameters and activity data used.

$$\Delta C_{CM\_LB} = \Delta C_{orchard\_LB\_SC} + \Delta C_{annualcrop\_LB\_SC} - \Delta C_{LB\_conversion\_to\_others}$$

$$\Delta C_{annualcrop\_LB\_SC} = \Delta A_{others-annualcrop} \times C_{annualcrop\_LB}$$

$$\Delta C_{LB\_conversion\_to\_others} = \Delta A_{annualcrop-others} \times C_{annualcrop\_LB}$$

$\Delta C_{CM-LB}$	: Carbon stock change in living biomass in CM [t-C/yr]
$\Delta C_{orchard\_LB\_SC}$	: Carbon stock change in living biomass in orchards [t-C/yr] (see 6.6.1.b)1))
$\Delta C_{annualcrop\_LB\_SC}$	: Carbon stock change (gain) in living biomass of annual crops in rice fields and upland fields [t-C/yr]
$\Delta C_{LB\_conversion\_to\_others}$	: Carbon stock change (loss) due to land conversion from cropland [t-C/yr]
$\Delta A_{others-annualcrop}$	: Annual area converted from other non-forest land-use category to cropland (rice fields or upland fields) [ha/yr]
$\Delta A_{annualcrop-others}$	: Area converted from rice fields and upland fields to other non-forest land-use categories[ha/yr]
$C_{annualcrop\_LB}$	: Carbon stocks in living biomass of annual crops per unit area in rice fields and upland fields [t-C/ha]

#### b) Dead Wood, Litter

Dead wood and litter in rice fields and in upland fields do not occur. In orchards, the practices that accumulate dead organic matter on the soil are not implemented. Therefore, carbon stocks are not changed over time and are not net sources. Hence, the carbon stock changes are treated as “NA” and reported as “NR” in the CRF “Table NIR 1”.

**c) Soils**● **Methodology****1) Mineral soil**

Carbon stock changes in mineral soils in CM were estimated by applying the tier 3 model (Roth C) estimation method. As described in section 6.6.1.b) 2) in Chapter 6 in this NIR, mesh data have been used as input data of Roth C model and carbon stock changes were calculated by Roth C model in each grid (100m x 100m). From the result of grid level calculation, the average carbon stock changes per unit area were estimated by prefecture and by land use subcategory (rice fields, upland fields and orchards). This output (carbon stock change per unit area) was multiplied by the area in each prefecture and land use subcategory from statistics, and then the final results of carbon stock change were obtained. For the parameters and carbon input data applied for the calculation of Roth C model, annual fluctuation of soil carbon stock change in mineral soil in CM and its main drivers, see section 6.6 in Chapter 6 in this NIR.

**2) Organic soil**

On-site CO<sub>2</sub> emissions from organic soils in rice fields and in upland fields were estimated by applying Tier 1, 2 described in the *2006 IPCC Guidelines*. Off-site CO<sub>2</sub> emissions via waterborne carbon losses from drained inland organic soils in rice fields and upland fields were estimated by applying Tier 1 described in section 2.2.1.2 in the *Wetlands Guidelines*. In Japan, orchard land is rarely located on organic soil (0.3 % of the total area of organic soils in cropland, see table 6-27) due to its growth conditions. In addition, for orchard land on organic soil, its tillage and drainage are not implemented in the common practices (clean cultivation system and sod culture) for growing fruit trees in Japan. Therefore, the emissions were considered as “NO”. When those area is converted to settlements, emissions from drainage of organic soils converted from cropland to settlements during the second commitment periods were also reported under CM. For detailed information on the method, see section 11.5.1.1.b.b) and 6.6.1.b) 2) in Chapter 6 in this NIR.

● **Parameters**

Parameters used are the same as section 6.6.1.b) 2) in Chapter 6 in this NIR.

● **Activity data**

Regarding area subject to CM activity in current cropland obtained by using method described in section 11.4.2.6, areas of mineral soil and organic soil were estimated by the ratio of organic soil in each prefecture, and were regarded as activity data, respectively. The emissions from drainage of organic soils under land converted to settlements reported under CM activity were estimated at the cumulative areas of conversion during the second commitment period in each sub-category level that “the area converted from rice fields, upland and orchards to settlements” multiplied by the ratio of organic soils in each sub-category. For calculation of ratio of organic soil in cropland, see section 6.6.1.b)2) in Chapter 6 in this NIR.

**d) Other gases****1) CH<sub>4</sub> emissions from drainage of organic soils**

CH<sub>4</sub> emissions from drainage of organic soils in upland fields were estimated by applying Tier 1 method described in section 2.2.2.1 in the *Wetlands Guidelines*. The estimation equation and parameters used are the same as section 6.13 in Chapter 6 in this NIR. The activity data is the same as section 6.6.1.b) 2) in Chapter 6 in this NIR.

## 2) N<sub>2</sub>O emissions from N mineralization/immobilization due to carbon loss/gain associated with land-use conversions and management change in mineral soils

Since the emissions from cropland converted from other-land use is subject to CM, the emissions calculated for reporting of LULUCF under the Convention are reported. The estimation equation and parameters used and activity data are the same as section 6.14 in Chapter 6 in this NIR.

## 3) Biomass burning

Since CO<sub>2</sub> emissions are already included in the calculation of carbon stock change, CH<sub>4</sub> and N<sub>2</sub>O emissions from burning of pruned branches from orchards trees were reported as part of the GHG emissions in CM land. In addition, emissions from wildfires are not reported, as it is considered almost impossible that wildfires occur under our farmland management system. The estimation method, parameters and activity data are the same as section 6.16.b) 2) in Chapter 6 in this NIR.

## e) Results

Table 11-16 Emissions and removals from CM activity

	1990	2013	2014	2015	2016	2017	2018	2019	2020
	[kt-CO <sub>2</sub> eq.]	[kt-CO <sub>2</sub> eq.]	[kt-CO <sub>2</sub> eq.]	[kt-CO <sub>2</sub> eq.]	[kt-CO <sub>2</sub> eq.]	[kt-CO <sub>2</sub> eq.]	[kt-CO <sub>2</sub> eq.]	[kt-CO <sub>2</sub> eq.]	[kt-CO <sub>2</sub> eq.]
CM	7,561.05	5,489.54	6,230.07	5,748.61	5,524.92	4,712.38	4,130.08	4,746.50	4,758.93
Above-ground biomass	157.89	156.85	190.20	233.47	260.50	240.54	256.21	231.69	279.51
Below-ground biomass	118.80	54.45	51.86	66.36	65.42	62.24	76.88	67.46	84.11
Dead wood	NA	NA	NA	NA	NA	NA	NA	NA	NA
Litter	NA	NA	NA	NA	NA	NA	NA	NA	NA
Soils (mineral)	5,941.93	4,055.51	4,765.52	4,227.51	3,979.60	3,187.35	2,571.04	3,217.67	3,162.45
Soils (organic)	1,249.70	1,172.11	1,171.72	1,170.59	1,168.80	1,170.92	1,173.72	1,176.80	1,179.37
Other gases	92.72	50.63	50.77	50.68	50.60	51.32	52.22	52.88	53.49
Organic soil (CH <sub>4</sub> )	24.27	24.19	24.40	24.62	24.85	25.18	25.61	26.05	26.47
N mineralization (N <sub>2</sub> O)	36.32	4.11	4.33	4.39	4.44	5.18	6.06	6.63	7.23
Biomass burning (CH <sub>4</sub> )	24.54	17.06	16.83	16.55	16.28	16.01	15.70	15.43	15.12
Biomass burning (N <sub>2</sub> O)	7.58	5.27	5.20	5.12	5.03	4.95	4.85	4.77	4.67

### 11.5.1.1.e. Grazing Land Management

#### a) Above-ground biomass, Below-ground biomass

##### ● Methodology

The carbon stock change in living biomass under GM ( $\Delta C_{GM\_LB}$ ) was calculated from the carbon stock change occurred after conversion ( $\Delta C_{GM\_LB\_SC}$ ) and the loss of carbon stock in living biomass due to conversion from pasture land ( $\Delta C_{LB\_conversion\_to\_others}$ ). No carbon stock change is assumed when Grazing land is remaining Grazing land. The estimation equation, parameters and activity data used were the same as Table 6-8, Table 6-9 and sections 6.7.2.b) 1) in Chapter 6 and 11.4.2.6 in Chapter 11 in this NIR.

#### b) Dead Wood, Litter

It is assumed that carbon stocks in dead wood and litter in grassland do not change in Japan, according to the 2006 IPCC Guidelines. Therefore, the carbon stock changes are treated as “NA” and are reported as “NR” in the CRF “Table NIR 1” because these carbon pools are not net sources of GHGs.

#### c) Soils

##### ● Methodology

##### 1) Mineral soil

Carbon stock changes in mineral soils in GM were estimated by applying the tier 3 model (Roth C) estimation method. For detailed information on the method, see section 6.6.1 b 2) in Chapter 6 in this

NIR. For the annual fluctuation and main drivers of soil carbon stock change in mineral soil in GM, see section 6.7 in Chapter 6 in this NIR.

## **2) Organic soil**

On-site CO<sub>2</sub> emissions from organic soils in pasture land were estimated by applying the Tier 1 estimation method described in section 6.2.3.1 in the *2006 IPCC Guidelines*. The estimation method is the same as cropland remaining cropland. Off-site CO<sub>2</sub> emissions via waterborne carbon losses from drained inland organic soils were estimated by applying Tier 1 estimation method described in the *Wetlands Guidelines*. Emissions from drainage of organic soils, whose areas were converted from GM during the second commitment periods and currently used as non-pasture land, were also reported under GM. For detailed information on the method, see section 11.5.1.1.b.b) and section 6.7.1.b) 2) in Chapter 6 in this NIR, as described in CM section.

### ● **Parameters**

Parameters used are the same as section 6.7.1.b) 2) in Chapter 6 in this NIR.

### ● **Activity data**

Regarding area subject to GM activity in current pasture land obtained by using method described in section 11.4.2.6, areas of mineral soil and organic soil were estimated by using the ratio of organic soil by prefecture, and were used for estimating as activity data, respectively. As explanation described in Box1.1 in *the KP Supplement*, since emissions and removals are treated as zero, the area subject to GM activity in current non-pasture land is not included in activity data to be used for the estimation. For calculation of ratio of organic soil in pasture land, see section 6.7.1.b) 1) in Chapter 6 in this NIR.

## **d) Other gases**

### **1) CH<sub>4</sub> emissions from drainage of organic soils**

CH<sub>4</sub> emissions from drainage of organic soils in pasture land were estimated by applying Tier 1 method described in section 2.2.2.1 in the *Wetlands Guidelines*. The estimation equation and parameters used are the same as section 6.13 in Chapter 6 in this NIR. The activity data is the same as section 6.7.1.b) 1) in Chapter 6 in this NIR.

### **2) N<sub>2</sub>O emissions from N mineralization/immobilization due to carbon loss/gain associated with land-use conversions and management change in mineral soils**

Estimation equation, parameters used and activity data are the same as section 6.14 in Chapter 6 in this NIR.

## **3) Biomass burning**

Emissions from biomass burning in GM were reported as “NO” because open burning in pasture land do not occur in Japan.



## e) Results

Table 11-17 Emissions and removals from GM activity

	1990	2013	2014	2015	2016	2017	2018	2019	2020
	[kt-CO <sub>2</sub> eq.]	[kt-CO <sub>2</sub> eq.]	[kt-CO <sub>2</sub> eq.]	[kt-CO <sub>2</sub> eq.]	[kt-CO <sub>2</sub> eq.]	[kt-CO <sub>2</sub> eq.]	[kt-CO <sub>2</sub> eq.]	[kt-CO <sub>2</sub> eq.]	[kt-CO <sub>2</sub> eq.]
GM	442.58	965.72	1,582.39	1,291.21	1,007.76	854.62	621.85	751.17	617.02
Above-ground biomass	-10.74	13.49	17.72	14.77	16.45	21.10	20.36	17.84	17.00
Below-ground biomass	-42.96	53.95	70.86	59.07	65.82	84.39	81.45	71.35	68.00
Dead wood	NA	NA	NA	NA	NA	NA	NA	NA	NA
Litter	NA	NA	NA	NA	NA	NA	NA	NA	NA
Soils (mineral)	464.51	861.03	1,450.28	1,171.31	890.75	713.75	484.01	625.29	494.66
Soils (organic)	27.44	31.46	37.37	39.71	30.03	30.56	31.10	31.65	32.21
Other gases	4.34	5.79	6.17	6.35	4.71	4.82	4.93	5.04	5.15
Organic soil (CH <sub>4</sub> )	2.15	2.53	3.08	3.35	2.67	2.79	2.90	3.02	3.14
N mineralization (N <sub>2</sub> O)	2.19	3.25	3.09	3.00	2.04	2.03	2.02	2.02	2.01

## 11.5.1.1.f. Revegetation

Methodologies for estimating GHG emissions and removals from RV activity are described in two cases: when RV activity is performed on the land where no land conversion has occurred (remaining land) and on the land where land conversion has occurred (Conversion Land).

## a) Remaining land: Above-ground biomass, Below-ground biomass

Japan estimates the carbon stock change in above-ground biomass and below-ground biomass of tall trees planted in RV lands. Tall trees are consistent with the definition in “Standards for the quality and size of planted trees for the public (draft)”<sup>8</sup>.

## ● Methodology

The carbon stock change in living biomass under “remaining land” was estimated by using the same equation of the Tier 2b as described in “Settlements remaining Settlements (4.E.1.)”. See section 6.9.1.b)1) of this NIR.

● Parameters<sup>9</sup>

The parameters at each type of urban green facility were described below.

## ➤ Urban parks

Carbon stock changes due to the loss of living biomass in urban parks are assumed to be zero based on Tier 2b method in the *2006 IPCC Guidelines* (p. 8.9), because the average age of trees is found to be less than or equal to 30 years in the tree survey for sample urban parks<sup>10</sup> (*Parks, Green Spaces and Landscape Division, Ministry of Land, Infrastructure, Transport and Tourism (MLIT), 2014*).

The annual living biomass growth of trees in urban parks is calculated by using the country-specific value for annual growth rate of living biomass per tree, which was developed by combining the default values (0.0033-0.0142 t-C/tree/yr) provided in the *2006 IPCC Guidelines* (p. 8.10, Table 8.2) and the

<sup>8</sup> “Standards for the quality and size of planted trees for the public (draft)” was decided by the Ministry of Land, Infrastructure, Transport and Tourism in order to promote proper enforcement of projects such as greening in public spaces. Tall tree is defined in the standards as tree which reaches 3 ~ 5 m in height.

<sup>9</sup> The Tier 1b method described in the *2006 IPCC Guidelines* and the Tier 2b method with country-specific annual biomass growth rates are applied for the estimation of the annual growth rate of living biomass per tree. Japan will further improve the accuracy of this estimation.

<sup>10</sup> 129 samples were randomly extracted from the urban parks notified after 1 January 1990 and located in Kanagawa prefecture, which is located in Japan’s typical climate zone and has various types of urban parks. In addition, the same survey was implemented in 3 urban parks in Chiba prefecture, which is located next to Kanagawa prefecture, in order to cover the park types that did not exist in Kanagawa prefecture.

country specific annual growth rates of living biomass for the trees in Japan (0.0204 for Japanese zelkova, 0.0103 for ginkgo, 0.0095 for bamboo-leaf oak and 0.0122 t-C/tree/yr for camphor tree) by taking into account the distribution ratio of tree species in sample urban parks<sup>11</sup>. The annual growth rates of living biomass for Japanese zelkova, ginkgo, bamboo-leaf oak and camphor tree are calculated by using the growth curve for each tree species (Matsue et al., 2009), which were developed based on the results of surveys conducted by the National Institute for Land and Infrastructure Management (NILIM) of the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) and the average trunk diameter at breast height for each tree species (Parks and Green Spaces Division of the MLIT, 2005), which were determined from the results of surveys in urban parks.

For the ratio of above-ground biomass/below-ground biomass, the default value (root-to-shoot ratio: 0.26) provided in the *2006 IPCC Guidelines* (p. 8.9) is applied.

➤ ***Green areas on roads***

Carbon stock changes due to the loss of living biomass in green areas on roads are assumed to be zero, because the average age of trees is found to be less than or equal to 30 years for those trees planted in randomly extracted green areas on roads.

The annual living biomass growth in green areas on roads is calculated by using the country-specific value for annual growth rate of living biomass per tree, which was developed by combining the default values and the annual growth rates of living biomass for the trees in Japan (4 species), which were also used for the urban parks, taking into account the distribution ratio of tree species indicated by the surveys in green areas on roads<sup>12</sup>.

For the ratio of above-ground biomass/below-ground biomass, the same value used for urban parks is applied.

➤ ***Urban green areas other than Urban parks, Green areas on roads and Green areas by greenery promoting systems for private green space***

Carbon stock changes due to the loss of living biomass in these green areas are assumed to be zero, because the standard of planted trees, tree types and their distribution are applied in the same manner as in urban parks.

The annual living biomass growth and the ratio of above-ground biomass/below-ground biomass are the same parameters as for urban parks.

➤ ***Green areas by greenery promoting systems for private green space***

Carbon stock changes due to the loss of living biomass in these green areas are assumed to be zero, because the standard of planted trees is selected in the same manner as in urban parks and all facilities have been certified since 2002.

The annual living biomass growth and the ratio of above-ground biomass/below-ground biomass are the same parameters as for urban parks.

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<sup>11</sup> The distribution ratio of tree types was calculated by using tree registers and plantation maps for all urban parks in Kushiro city and Yubari city in Hokkaido and for 321 randomly extracted urban parks in the other prefectures.

<sup>12</sup> The distribution ratio of tree types is taken from the *Road Tree Planting Status Survey (The Street tree of Japan VI)*, which covered green areas on roads throughout Japan.

● **Activity data<sup>13</sup>**

➤ **Urban parks**

The area of land remaining urban parks is calculated by multiplying the area of urban parks by the area ratio of land conversion for the whole country. The activity data for carbon stock changes in living biomass in urban parks is the number of tall trees planted in urban parks which is calculated by multiplying the area of urban parks obtained from the “Urban Parks Status Survey” by the number of tall trees per area (Hokkaido: 329.5 tree/ha, the other prefectures: 222.3 tree/ha). The number of tall trees per area is calculated based on the number of tall trees and the land areas of sample urban parks. Sample number was intended to satisfy the significance level of 95%.<sup>14</sup>

Table 11-18 Areas of urban parks which were not classified as forest land on 31 December 1989

At the end of FY2020

	Land-use category	Area ratio of land which has been converted from forest land to settlements from FY1990 to FY2020	Area [ha]	Classified as RV land
Urban parks which have been notified since 1st January 1990 and whose establishment area is 500 m <sup>2</sup> or more	Forest	5.58%	3,628.40	No
	Non-forest	94.42%	61,378.60	Yes
	Total	100.00%	65,007.00	-

Table 11-19 Areas of urban parks which were classified as RV and activity data (remaining land / converted land)

At the end of FY2020

	Land-use category	Area ratio of land which has been converted in the current year	Area [ha]	Activity data [Number of tall trees]
Urban parks which have been notified since 1st January 1990 and whose establishment area is 500 m <sup>2</sup> or more (classified as RV land)	Converted (except land converted from forest land)	0.25%	152.91	37,149
	Remaining	99.75%	61,225.69	14,318,709
	Total	100.00%	61,378.60	14,355,858

➤ **Green areas on roads**

The activity data (the number of tall trees) in “Remaining green areas on roads” is calculated by the following procedures.

1. The number of tall trees in all green areas on roads on 31 March 1990 and in the end of each corresponding fiscal year during the commitment period is estimated by using data from the “Road Tree Planting Status Survey” which have been implemented in FY1987, FY1992 and each corresponding fiscal year.
2. The number of tall trees planted after 1 April 1990 was calculated by subtracting the number at 31 March 1990 from the number for the end of each corresponding fiscal year (RV is an activity which takes place after 1 January 1990. However, Japan considers it an activity after 1 April 1990 because it is impossible to estimate the number of tall trees which have been planted between 1 April 1990 and 31 March 1990).

<sup>13</sup> The areas shown in the tables of this section present the values of activity data actually used in the calculation of removals occurred in RV areas.

<sup>14</sup> The number of tall trees per area in urban parks was calculated by using data from tree registers and planting maps for randomly extracted 176 sample urban parks in Hokkaido and 321 sample urban parks in the other prefectures.

3. The number of tall trees calculated in step 2 is multiplied by the ratio of the number of tall trees planted on roads whose planted area is more than 500 m<sup>2</sup>.
4. The number of tall trees calculated in step 3 is multiplied by the area ratio of green areas on roads, which were classified as “Forest land” on 31 December 1989.
5. The number of tall trees calculated in step 4 is multiplied by the area ratio of “Land remaining settlements”.

Table 11-20 Areas of green areas on roads which were classified as RV

At the end of FY2020

	Area of green areas on roads per tall tree [ha/tree]	Number of planted tall trees [tree]			Area ratio of planted lands which are 500 m <sup>2</sup> or more [%]	Area ratio of land which was classified as forest land on 31st December 1989 [%]	Area of green areas on roads which was classified as RV land [ha]	Activity data [Number of tall trees]
		31st March 1990	31st March 2021	FY1990 - FY2020				
		a	b	c-b				
General roads (managed by the MLIT, Prefectures, local authorities, public corporations)	0.006237	4,342,070	6,673,813	2,331,743	99.00%	5.58%	13,594	2,179,506
Expressway (managed by now-defunct public corporation)	0.000830	1,096,380	9,473,661	8,377,281	100.00%	5.58%	6,564	7,909,699
Total	-	5,438,450	16,147,474	10,709,024	-	-	20,158	10,089,205

Note: MLIT: Ministry of Land, Infrastructure, Transport and Tourism

Table 11-21 Areas of green areas on roads which were classified as RV and activity data [number of tall trees] (remaining land / converted land)

At the end of FY2020

	Land-use category	Area ratio of land which has been converted in the current year	Activity data [Number of tall trees]	Area [ha]
Green areas on roads which have been notified since 1st January 1990 and whose establishment area is 500 m <sup>2</sup> or more (classified as RV land)	Converted	0.25%	25,135	50.22
	Remaining	99.75%	10,064,070	20,107.64
	Total	100.00%	10,089,205	20,157.86
General roads	Converted	0.25%	5,430	33.87
	Remaining	99.75%	2,174,076	13,559.71
	Total	100.00%	2,179,506	13,593.58
Expressway	Converted	0.25%	19,705	16.35
	Remaining	99.75%	7,889,994	6,547.93
	Total	100.00%	7,909,699	6,564.28

Note: “Converted”: except land converted from forest land.

### ➤ Green areas at ports

The activity data for carbon stock changes in living biomass in green areas at ports is the number of tall trees planted in green areas at ports. The activity data is calculated by multiplying the service area obtained from complete census by the number of tall trees per unit area of urban parks (329.5 trees/ha for Hokkaido and 222.3 trees/ha for the other prefectures). These values were adopted by taking into account the similarities between the urban parks and the green areas at ports as mentioned above. All green areas at ports are located in “settlements” and judged not being classified as “Forest land” on 31 December 1989.

Table 11-22 Areas of green areas at ports and activity data (remaining land / converted land)

At the end of FY2020

Land-use category	Area ratio of land which has been converted in the current year	Area [ha]	Activity data [Number of tall trees]
Converted	0.25%	4.82	1,095
Remaining	99.75%	1,930.97	438,293
Total	100.00%	1,935.79	439,388

➤ **Green areas around sewage treatment facilities**

The area of land remaining green areas around sewage treatment facilities is calculated in the same manner as for urban parks. The activity data for carbon stock change in living biomass in green areas around sewage treatment facilities are obtained from the “Sewage Treatment Facility Status Survey” for each fiscal year during the commitment period. The number of tall trees planted in green areas around sewage treatment facilities is calculated by multiplying the greening areas by the number of tall trees per greening area (129.8 tree/ha for Hokkaido and 429.2 tree/ha for the other prefectures).<sup>15</sup> All green areas around sewage treatment facilities are located in “settlements”.

Table 11-23 Areas of green areas around sewage treatment facilities which were not classified as “Forest land” on 31 December 1989

At the end of FY2020

Land-use category	Area ratio of land which has been converted from forest land to settlements from FY1990 to FY2020	Area [ha] (Green areas)	Classified as RV land
Forest	5.58%	39.03	No
Non-forest	94.42%	660.16	Yes
Total	100.00%	699.19	-

Table 11-24 Areas and activity data of “Green areas around sewage treatment facilities” [number of tall trees] (remaining land / converted land)

At the end of FY2020

Land-use category	Area ratio of land has been converted for the current year	Area [ha] (Green areas)	Activity data [Number of tall trees]
Converted (except land converted from forest land)	0.25%	1.64	669
Remaining	99.75%	658.52	267,821
Total	100.00%	660.16	268,490

➤ **Green areas by greenery promoting systems for private green space**

Activity data (the number of tall trees) is available for each facility. Therefore, the total number of tall trees is used as activity data.

<sup>15</sup> The number of tall trees per area for green areas around sewage treatment facilities was established by using data on the number of tall trees and greening areas measured in 59 green areas.

Table 11-25 Activity data and areas of “Green areas by greenery promoting systems for private green space”

Certification year	Location	Area [m <sup>2</sup> ]	Breakdown of area [m <sup>2</sup> ]			Area Wall green area by greenery promoting system for private green space [m <sup>2</sup> ]	Activity data Number of tall trees [tree]
			Ground	Roof	Wall		
2002	Minato-ku, Tokyo	17,244	1,314	2,042	106	3,356	335
2002	Minato-ku, Tokyo	19,708	3,285	736	0	4,021	147
2002	Minato-ku, Tokyo	52,766	10,679	0	0	10,679	672
2002	Minato-ku, Tokyo	84,780	8,846	9,386	0	18,232	813
2003	Minato-ku, Tokyo	5,519	1,374	280	0	1,654	167
2003	Osaka City	22,282	1,527	3,164	110	4,691	500
2005	Kawaguchi City	1,995	586	164	18	750	153
2006	Kyoto City	3,857	1,271	0	0	1,271	90
2006	Hiroshima City	4,453	130	783	0	913	1
2007	Hiroshima City	14,353	4,058	0	0	4,058	261
2007	Fukuoka City	5,689	773	799	0	1,572	19
2008	Ishikawa Prefecture	7,281	682	1,411	0	2,093	19
2009	Setagaya-ku, Tokyo	5,526	1,116	0	0	1,116	51
2009	Setagaya-ku, Tokyo	6,459	1,370	0	0	1,370	15
Total		251,912	37,011	18,765	234	55,776	3,243

Note: There were no areas certified from FY2010 to FY2020.

#### ➤ Green areas along rivers and erosion control sites

The area of land remaining green areas along rivers and erosion control sites is calculated by multiplying the area of this green area by the area ratio of land conversion for the whole country. The activity data for living biomass (the number of tall trees) is calculated by multiplying this area by the number of tall trees per area (Hokkaido: 1470.8 tree/ha, the other prefectures: 339.0 tree/ha).<sup>16</sup>

The green areas along rivers and erosion control sites exclude lands, which were classified as Forest land at the time of survey. Therefore, land conversion from Forest land is not taken into account for the estimation of activity data.

Table 11-26 Activity data and areas of “Green areas along rivers and erosion control sites” (remaining land / converted land)

At the end of FY2020				
	Land-use category	Area ratio of land which has been converted in the current year	Area [ha]	Activity data [Number of tall trees]
Green areas along rivers and erosion control sites which have been established since 1st January 1990 and whose establishment area is 500 m <sup>2</sup> or more (classified as RV land)	Converted (except land converted from forest land)	0.25%	4.35	2,235
	Remaining	99.75%	1,740.92	964,192
	Total	100.00%	1,745.27	966,427

#### ➤ Green areas around government buildings

The area of land remaining green area around government buildings is calculated by multiplying the area of this green area by the area ratio of land conversion for the whole country. The activity data for living biomass (the number of tall trees) is calculated by multiplying this area by the number of tall trees

<sup>16</sup> For green areas along rivers and erosion control sites, the number of tall trees was measured in approximately 95% of this green area. Based on these data, the number of planted trees per area was estimated in order to simplify the estimation of the number of tall trees in all green areas.

per area (all prefecture: 108.8 tree/ha).<sup>17</sup>

Table 11-27 Areas of “Green areas around government buildings” which were not classified as “Forest land” on 31 December 1989

At the end of FY2020

	Land-use category	Area ratio of land which has been converted from forest land to settlements from FY1990 to FY2020	Area (Green areas) [ha]	Classified as RV land
Green areas around government buildings which have been established since 1st January 1990 and whose establishment area is 500 m <sup>2</sup> or more	Forest	5.58%	21.28	No
	Non-forest	94.42%	359.98	Yes
	Total	100.00%	381.26	-

Table 11-28 Areas and activity data of “Green areas around government buildings” (remaining land / converted land)

At the end of FY2020

	Land-use category	Area ratio of land which has been converted in the current year	Area [ha]	Activity data [Number of tall trees]
Green areas around government buildings which have been established since 1st January 1990 and whose establishment area is 500 m <sup>2</sup> or more (classified as RV land)	Converted (except land converted from forest land)	0.25%	0.90	98
	Remaining	99.75%	359.08	39,068
	Total	100.00%	359.98	39,166

### ➤ Green areas around public rental housing

The area of land remaining green areas around public rental housing is calculated by multiplying the area of this green area by the area ratio of land conversion for the whole country. The activity data for living biomass (the number of tall trees) is calculated by multiplying this area by the number of tall trees per area (all prefecture: 219.9 tree/ha).<sup>18</sup>

Table 11-29 Areas of “Green areas around public rental housing” which were not classified as “Forest land” on 31 December 1989

At the end of FY2020

	Land-use category	Area ratio of land which has been converted from forest land to settlements from FY1990 to FY2020	Area (Green areas) [ha]	Classified as RV land
Green areas around public rental housing which have been established since 1st January 1990 and whose establishment area is 500 m <sup>2</sup> or more	Forest	5.58%	191.58	No
	Non-forest	94.42%	3,240.89	Yes
	Total	100.00%	3,432.47	-

<sup>17</sup> For green areas around government buildings, the number of tall trees per area was estimated by dividing the number of tall trees by the “total land area – building area” (these data were based on 30 facilities where planting maps were available). The common value is used for all prefectures, since the sample data were not sufficient enough to set values for Hokkaido and the other prefectures, respectively.

<sup>18</sup> For green areas around public rental housing, the number of tall trees per area was estimated for 33 facilities, where planting maps were available, by dividing the number of tall trees by the area “total land area – building area”. The common value is used for all prefectures, since the sample data were not sufficient enough to set values for Hokkaido and the other prefectures, respectively.

Table 11-30 Areas and activity data of “Green areas around public rental housing”  
(remaining land / converted land)

At the end of FY2020

	Land-use category	Area ratio of land which has been converted in the current year	Area [ha]	Activity data [Number of tall trees]
Green areas around public rental housing which have been established since 1st January 1990 and whose establishment area is 500 m <sup>2</sup> or more (classified as RV land)	Converted (except land converted from forest land)	0.25%	8.07	1,775
	Remaining	99.75%	3,232.81	710,895
	Total	100.00%	3,240.89	712,670

**b) Remaining land: Dead wood****➤ Urban parks**

The number of tall trees per land area used in the estimation of activity data for living biomass includes trees which have died and have been complementary planted since the establishment of the park. Thus, the carbon stock changes in dead wood are thought to be included in the carbon stock changes in living biomass. Therefore, this category is reported as “IE”.

**➤ Green areas on roads**

The number of tall trees used in the estimation of activity data for living biomass is obtained in the survey every 5 years (implemented every year since 2007). These data include the effects of dead wood and complementary planting, thus the carbon stock change in dead wood is included in the carbon stock changes in living biomass. Therefore, this category is reported as “IE”.

**➤ Urban green facilities other than Urban parks and Green areas on roads**

These categories are reported as “IE” based on the same assumption as urban parks.

**c) Remaining land: Litter**

Carbon stock changes in litter are estimated for urban parks and green areas at ports.

The carbon stock change in litter under “remaining land” was estimated by using the same equation as described in “Settlements remaining Settlements (4.E.1.)”. See section 6.9.1.b)2) of this NIR.

**● Parameters**

The parameters at each type of urban green facility were described below.

**➤ Urban parks and Green areas at ports**

Carbon stock changes in litter were estimated only in branches and leaves dropped naturally from tall trees. The carbon stock changes in litter per urban park area are calculated by using the annual accumulation of litter per tall tree (all prefectures: 0.0006 t-C/tree/yr) based on the results of a field survey in urban parks<sup>19</sup>, the number of tall trees per area and the ratio of litter moved to off-site due to management including cleaning (54.4%). As a result, carbon stock change in litter per urban park area

<sup>19</sup> The annual accumulation of litter dropped naturally was measured for some tree types by using litter traps installed in Takino Suzuran Kyuryo National Government Park (Hokkaido) and Showa Kinen National Government Park (Tokyo). Litter is defined as branches and leaves dropped on the surface. In the selection of parks for the survey, large-sized and intensively managed national government parks in which continuous monitoring is available and different types of trees have been planted are considered to meet the measurement requirements. In addition, it is also considered that the distribution of tree types differs between Hokkaido and other prefectures. Therefore, Japan selected two parks for the survey, one in Hokkaido and the other in a typical climate zone excluding Hokkaido.



is calculated to be 0.0882 t-C/ha/yr for Hokkaido and 0.0594 t-C/ha/yr for other prefectures. In addition, the carbon fraction in litter is assumed to be 0.4 t-C/t-d.m., which is a default value provided in the 2006 IPCC Guidelines (p.8.21).

➤ **Urban green facilities other than urban parks and green areas at ports**

Litter in these urban green facilities includes branches and leaves dropped naturally and dead roots. A part of the litter remains on-site and leads to an increase in carbon stocks, although other litter is moved to off-site due to management such as cleaning (such litter is dropped from trees planted after the establishment of green areas). Dead roots also lead to an increase in carbon stocks because they are not moved to off-site.

It is clear that the litter in the urban green facilities other than urban parks and green areas at ports because the input of fallen branches and leaves and dead roots into these facilities increases carbon stocks as mentioned above. However, it is difficult to accurately estimate the carbon stock changes in litter in these urban green facilities because of limited information on various managements (such as cleaning). Therefore, as a conservative treatment, these sub-categories are not subject to reporting because they are not sources of GHGs.

● **Activity data**

The activity data is the same as for living biomass.

**d) Remaining land: Soils**

Urban parks, for which the carbon stock changes in soils per area were determined, and green areas at ports, whose management practices are similar to those for urban parks, are the subject of estimation. In general, soils in RV land are not organic soils (peat soils and muck soils). Therefore, organic soils are reported as “NO”, and only mineral soils are estimated.

● **Methodology**

The carbon stock change in soils under “remaining land” was estimated by using the same equation as described in “Settlements remaining Settlements (4.E.1.)”. See section 6.9.1.b)3) of this NIR.

● **Parameters**

The parameters at each type of urban green facility were described below.

➤ **Urban parks and Green areas at ports**

Carbon stock changes in soils per area of RV land are estimated based on the results of surveys<sup>20</sup> conducted in urban parks which have been established within 30 years (1.28t-C/ha/yr for 0~20 years and 1.38t-C/ha/yr for 21~30 years) (Tonosaki et al., 2013; Parks, Green Spaces and Landscape Division, Ministry of Land, Infrastructure, Transport and Tourism (MLIT), 2015)<sup>21</sup>.

<sup>20</sup> Soil carbon stocks (at 30 cm depth) were measured for areas with different types of vegetation cover in urban parks (planted: 31 areas, lawn: 29 areas, bare: 21 areas), which are located in Tokyo and were established in different years.

<sup>21</sup> Since urban parks are generally established by turning entire sites into urban parks, soil carbon stocks within the site immediately after establishment are assumed to be uniform irrespective of previous types of vegetation cover. The soil carbon stocks of the area, where basically carbon is not supplied by plants (bare area), are assumed to be the same as soil carbon stocks of sites immediately after conversion. Based on the soil carbon stocks in the areas with different types of vegetation cover (planted, lawn and bare) in urban parks, which were established in different years, “carbon accumulation rates in planted areas” and “carbon accumulation rates in lawn areas” are calculated:

- Carbon accumulation rates in planted areas = “Difference in soil carbon stocks between planted and bare areas” / “Average years after establishment of surveyed planted areas”

This value is applicable to land, which is the subject of revegetation activity and was established within 30 years, because the value is based on the results of surveys conducted in urban parks which have been established within 30 years.

➤ **Urban green facilities other than Urban parks and Green areas at ports**

It is assumed that the patterns of carbon stock changes in soils in these urban green facilities are similar to those in urban parks, because planting, establishment and management practices are implemented in a similar way. The slopes on the expressway, where different plantation practices are applied, are assumed to be a sink, because field surveys have revealed that the carbon stocks keep increasing for at least 20 years after establishment.

However, it is difficult to accurately estimate the carbon stock changes in soils in these urban green facilities because of limited available data. Therefore, as a conservative treatment, these sub-categories are not subject to reporting because they are not sources of GHGs. The estimation for urban green facilities other than urban parks and green areas at ports will be further considered in the future.

● **Activity data**

The area is as obtained for estimating the activity data for living biomass.

**e) Remaining land: Other gases**

**1) Direct and indirect N<sub>2</sub>O emissions from N fertilization**

It is assumed that the volume of nitrogen-based fertilizer applied to urban parks is included in the demand for nitrogen-based fertilizers in the Agriculture sector, although fertilization in urban parks has been conducted in Japan. Therefore, these sources have been reported as “IE”.

**2) N<sub>2</sub>O and CH<sub>4</sub> emissions from drainage of soils**

Because soil drainage activity for organic soils in RV does not occur in Japan, this category is reported as “NO”.

**3) N<sub>2</sub>O emissions from N mineralization/immobilization due to carbon loss/gain associated with land-use conversions and management change in mineral soils**

Since soil carbon stock changes in RV are reported to be on the increases, according to method under Tier 2 described in *the 2006 IPCC Guidelines*, N<sub>2</sub>O emissions from immobilization associated with gain of soil organic matter were not estimated. Therefore, N<sub>2</sub>O emissions in this subcategory is reported as “NA”.

**4) Biomass burning**

In settlements subjected to RV activities, burning of residues is restricted by the “Waste Management and Public Cleansing Law” and the “Fire Defense Law”. In addition, wildfires do not usually occur in lands subjected to RV activities because these lands are managed. Therefore, biomass burning activities which lead to carbon emissions do not occur and Japan reports this category as “NO”.

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• Carbon accumulation rates in lawn areas = “Difference in soil carbon stocks between lawn and bare areas” / “Average years after establishment of surveyed lawn areas”

Furthermore, changes in soil carbon stocks per area are determined by taking the weighted average based on the typical area ratio among planted, lawn and bare sites in urban parks. The soil carbon stocks of bare area are about 38 t-C/ha when converted from the sample data.

**f) Land converted from other land-use categories: Above-ground biomass, Below-ground biomass**● **Methodology**

For RV activities, land conversion occurs due to the establishment or building of “facilities” and all living biomass is basically replaced in one year. In Japan’s basic estimation principles for land converted to RV land, the facilities newly established by land conversion in the reporting year are defined as “Land converted to RV land”. The estimation was made by summing the loss of carbon stock due to conversion ( $\Delta C_{LB\_conversion\_to\_RV}$ ) and the carbon stock change occurred after conversion ( $\Delta C_{RV\_LB\_SC}$ ). However, in the case of land conversion that crosses the activities under Article 3.4, the loss of carbon stock due to the conversion was reported under the original activities, as described in section 11.3.4. So, the loss of carbon stock due to conversion from cropland and pasture land was estimated under CM and GM and not reported under RV. Those were estimated by using the same equation as described in “Land converted to Settlements (4.E.2.)”. See section 6.9.2.b)1) of this NIR. Moreover, there is no land conversion from RV to other land-use.

● **Parameters**➤ **Urban parks**

The loss of the carbon stocks in living biomass immediately before conversion were estimated under the original activities under Kyoto protocol, as mentioned above. And those in the land conversion from non-Kyoto protocol activities was not estimated due to the parameters set. The carbon stocks in living biomass immediately after conversion are assumed to be zero (When urban parks classified as RV land are established, planting activities occur and living biomass is stocked. It is assumed that these biomass stocks are zero because they are carried from other fields and they are grown by the RV activities). In addition, it is assumed that all living biomass before conversion is lost due to the establishment of RV land. The other parameters are assumed to be the same as the ones for “Remaining urban parks”.

➤ **Urban green facilities other than Urban parks**

The carbon stocks in living biomass immediately before and after conversion [t-C/ha] are the same as those for urban parks converted from other land uses.

The other parameters are assumed to be the same as the ones for “Remaining green area on roads”, “Remaining green area at ports”, “Remaining green area around sewage treatment facilities”, “Remaining green area along rivers and erosion control sites”, “Remaining green area around public rental housing” and “remaining green area around government buildings”.

● **Activity data**➤ **Urban parks**

The area of land converted to urban parks is calculated by multiplying the area of urban parks by the area ratio of land conversion for the whole country. The activity data for living biomass (the number of tall trees) is estimated in the same manner as for “remaining urban parks”.

Table 11-31 Areas of “Urban parks” and activity data (remaining land /converted land)

At the end of FY2020

	Land-use category before conversion	Area ratio of land which has been converted in the current year	Area [ha]	Activity data [Number of tall trees]
Urban parks which have been notified since 1st January 1990 and whose establishment area is 500 m <sup>2</sup> or more	Remaining land	99.75%	61,225.69	14,318,709
	Cropland	0.21%	130.70	30,566
	Grassland	0.04%	22.21	5,195
	Wetlands	IE	IE	IE
	Other land	IE	IE	IE
	Total	100.00%	61,378.60	14,354,470

➤ **Green areas on roads**

The area of land converted to green area on roads is calculated by multiplying the area of green areas on roads by the area ratio of land conversion for the whole country. The activity data for living biomass (the number of tall trees) is estimated in the same manner as for “remaining green area on roads”.

Table 11-32 Areas of “Green areas on roads” and activity data for each land-use category

At the end of FY2020

	Land-use category before conversion	Area ratio of land which has been converted in the current year	Area [ha]	Activity data [Number of tall trees]
Green areas on roads which have been notified since 1st January 1990 and whose establishment area is 500 m <sup>2</sup> or more	Remaining	99.75%	20,107.64	10,064,070
	Cropland	0.21%	42.92	21,484
	Grassland	0.04%	7.29	3,651
	Wetlands	IE	IE	IE
	Other land	IE	IE	IE
	Total	100.00%	20,157.86	10,089,205

➤ **Green areas at ports**

The area of land converted to green areas at ports is calculated by multiplying the service area of green areas at ports by the area ratio of land conversion for the whole country. The activity data for living biomass (the number of tall trees) is estimated in the same manner as for “remaining green areas at ports”.

Table 11-33 Areas of “Green areas at ports” and activity data for each land-use category

At the end of FY2020

Land-use category before conversion	Area ratio of land which has been converted in the current year	Area [ha]	Activity data [Number of tall trees]
Remaining land	99.75%	1,930.97	438,293
Cropland	0.21%	4.12	936
Grassland	0.04%	0.70	159
Wetlands	IE	IE	IE
Other land	IE	IE	IE
Total	100.00%	1,935.79	439,388

➤ **Green areas around sewage treatment facilities**

The area of land converted to green areas around sewage treatment facilities is calculated by multiplying the green areas around sewage treatment facilities by the area ratio of land conversion for the whole country. The activity data for living biomass (the number of tall trees) is estimated in the same manner

as for “remaining green area around sewage treatment facilities”.

Table 11-34 Areas of “green areas around sewage treatment facilities” and activity data for each land-use category

At the end of FY2020

Land-use category before conversion	Area ratio of land which has been converted in the current year	Area [ha]	Activity data [Number of tall trees]
Remaining land	99.75%	658.52	267,821
Cropland	0.21%	1.41	572
Grassland	0.04%	0.24	97
Wetlands	IE	IE	IE
Other land	IE	IE	IE
Total	100.00%	660.16	268,490

➤ **Green areas along rivers and erosion control sites**

The area of land converted to green areas along rivers and erosion control sites is calculated by multiplying the planted land area by the area ratio of land conversion for the whole country. The activity data for living biomass (the number of tall trees) is estimated in the same manner as for “remaining green area along rivers and erosion control sites”.

Table 11-35 Areas of “green areas along rivers and erosion control sites” and activity data for each land-use category

At the end of FY2020

Land-use category before conversion	Area ratio of land which has been converted in the current year	Area [ha]	Activity data [Number of tall trees]
Remaining land	99.75%	1,740.92	964,192
Cropland	0.21%	3.72	2,058
Grassland	0.04%	0.63	350
Wetlands	IE	IE	IE
Other land	IE	IE	IE
Total	100.00%	1,745.27	966,600

➤ **Green areas around government buildings**

The area of land converted to green areas around government buildings is calculated by multiplying the “total land area – building area” by the area ratio of land conversion for the whole country. The activity data for living biomass (the number of tall trees) is estimated in the same manner as for “remaining green area around government buildings”.

Table 11-36 Areas of “green areas around government buildings” and activity data for each land-use category

At the end of FY2020

Land-use category before conversion	Area ratio of land which has been converted in the current year	Area [ha]	Activity data [Number of tall trees]
Remaining land	99.75%	359.08	39,068
Cropland	0.21%	0.77	83
Grassland	0.04%	0.13	14
Wetlands	IE	IE	IE
Other land	IE	IE	IE
Total	100.00%	359.98	39,165

➤ **Green areas around public rental housing**

The area of land converted to green areas around public rental housing is calculated by multiplying the “total land area – building area” by the area ratio of land conversion for the whole country. The activity data for living biomass (the number of tall trees) is estimated in the same manner as for “remaining green area around public rental housing”.

Table 11-37 Areas of “green areas around public rental housing” and activity data for each land-use category

At the end of FY2020

Land-use category before conversion	Area ratio of land which has been converted in the current year	Area [ha]	Activity data [Number of tall trees]
Remaining land	99.75%	3,232.81	710,895
Cropland	0.21%	6.90	1,518
Grassland	0.04%	1.17	258
Wetlands	IE	IE	IE
Other land	IE	IE	IE
Total	100.00%	3,240.89	712,671

**g) Land converted from other land use categories: Dead wood**

When a RV activity following land-use conversion is implemented, dead wood is removed off-site and supplemental planting is implemented before conversion because almost all of such lands are managed and trees are assumed to be “property”. Therefore, dead wood is not left on the ground immediately before land-use conversion. The carbon stocks in dead wood immediately after conversion are assumed to be zero, the same as living biomass. Therefore, the carbon stocks in dead wood before and after conversion are assumed to be zero.

The carbon stocks in dead wood accumulated for a year after conversion are reported as “IE”, the same as for “Remaining land”.

**h) Land converted from other land-use categories: Litter**

Likewise the “remaining land”, Japan estimates carbon stock changes in litter in urban parks and green areas at ports only. The other urban green facilities (green areas on roads, green areas around sewage treatment facilities, green areas along rivers and erosion control sites, green areas around public rental housing and green areas around government buildings) are not the subject of estimation and are not reported (NR), since these facilities are not net sources.

- **Methodology**

- **Urban parks and Green areas at ports**

When urban parks are converted from cropland, grassland or wetlands, soils before conversion are not moved to off-site and in general, these soils are used continuously after conversion or covered by additional soils. Therefore, litters and dead roots accumulated before conversion do not decrease due to the land-use conversion.

In addition, litter in urban parks immediately following conversion is very little, because the parks are newly planted. Therefore, carbon stock changes in litter due to land conversion are assumed to be zero.

The amount of carbon in litter accumulated for a year after conversion is estimated in the same manner as for “Remaining urban parks”. See section 11.5.1.1.f.b) for estimation methods.

- **Urban green facilities other than Urban parks and Green areas at ports**

The carbon stock changes in litter due to land-use conversion are assumed to be zero for the same reasons as for urban parks. With respect to after conversion, it is clear that the litter in the urban green facilities other than urban parks and green areas at ports because the input of fallen branches and leaves and dead roots into these facilities increases carbon stocks likewise the “remaining green area on roads”, “remaining green area around sewage treatment facilities”, “remaining green area along rivers and erosion control sites”, “remaining green area around public rental housings” and “remaining green area around government buildings” mentioned above. However, it is difficult to accurately estimate the carbon stock changes in litter in these urban green facilities because of limited information on various managements (such as cleaning). Therefore, as a conservative treatment, these sub-categories are not subject to reporting because they are not sources of GHGs.

- **Activity data**

The activity data is the same as for living biomass.

- i) **Land converted from other land-use categories: Soils**

Likewise the “remaining land”, urban parks and green areas at ports, whose management practices are similar to those in urban parks, are the only subject of estimation.

- **Methodology**

- **Urban parks and Green areas at ports**

As mentioned in the section for litter, when urban parks are converted from cropland, grassland or wetlands, soils before conversion are almost never moved to off-site (even if moved to off-site, carbon in these soils are not emitted due to combustion). In general, these soils are used after conversion continuously or covered by additional soils.

Therefore, soil carbon stocks do not change due to land-use conversion (the carbon stocks may increase due to additional soils. However, Japan assumes that soil carbon stocks do not change because additional soils do not lead to carbon sequestration from the atmosphere).

Carbon stock changes in soils within a year after conversion is estimated in the same manner as for the remaining urban parks and green areas at ports. See section 11.5.1.1.f.c) for estimation methods.

- **Urban green areas other than Urban parks and Green areas at ports**

The urban green facilities other than urban parks and green areas at ports are not sources of GHGs

because of the same reasons as for the “Land converted to urban parks”. Therefore, as a conservative treatment, these sub-categories are not subject to reporting because they are not sources of GHGs.

- **Activity data**

The area is as used for living biomass.

**j) Land converted from other land-use categories: Other gases**

For reporting each GHG emission, the same way as the RV remaining RV is used.

**k) Results**

Table 11-38 Emissions and removals from RV activity

	1990	2013	2014	2015	2016	2017	2018	2019	2020
	[kt-CO <sub>2</sub> ]	[kt-CO <sub>2</sub> ]	[kt-CO <sub>2</sub> ]	[kt-CO <sub>2</sub> ]	[kt-CO <sub>2</sub> ]	[kt-CO <sub>2</sub> ]	[kt-CO <sub>2</sub> ]	[kt-CO <sub>2</sub> ]	[kt-CO <sub>2</sub> ]
RV	-79.76	-1,229.97	-1,249.14	-1,270.02	-1,287.42	-1,310.19	-1,324.54	-1,350.48	-1,359.67
Above-ground biomass	-47.89	-752.34	-761.91	-772.26	-781.07	-795.37	-801.96	-819.37	-822.82
Below-ground biomass	-12.45	-195.61	-198.10	-200.79	-203.08	-206.80	-208.51	-213.04	-213.93
Dead wood	IE	IE	IE	IE	IE	IE	IE	IE	IE
Litter	-0.92	-12.96	-13.23	-13.56	-13.79	-13.95	-14.18	-14.32	-14.50
Soils	-18.50	-269.07	-275.90	-283.41	-289.49	-294.07	-299.89	-303.76	-308.41
Other gases	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO

For RV activities, various parameters (annual living biomass growth of trees, number of tall trees per area, etc.) which corresponding to specific characteristic of types of urban green facilities (sub-categories) and climatic division (Hokkaido, areas other than Hokkaido), have been applied.

Hence, the total removals per unit of revegetation area in each year are not the same because of composition of the sub-categories are different in each year.

**11.5.1.2. Justification when omitting any carbon pool or GHG emissions/removals from activities under Article 3.3, forest management and elected activities under Article 3.4**

Some carbon pools under RV activities (litter and soils: green areas on roads, green areas around sewage treatment facilities, green areas by greenery promoting systems for private green space, green areas along river and erosion control sites, green areas around public rental housing and green areas around government buildings) are not included in the reporting. Some intermediate results of the ongoing research project relating to RV land by the MLIT show a clear tendency that those carbon pools have been increasing although more research and analysis are necessary to quantify carbon stock changes in these carbon pools (Handa et al., 2008). This does not lead to over-estimation of removals because these carbon pools are not sources of GHGs, although further information and data are needed for estimating carbon stock changes in these carbon pools.

Carbon pools of dead wood and litter in CM and in GM are not included in the reporting. As described in the relevant sections, carbon stock changes in dead wood and litter in CM and in GM were estimated as zero. This does not lead to over-estimation of removals because these carbon pools are not sources of GHGs.

**11.5.1.3. Information relating to exclusions of emission from natural disturbances**

Japan does not apply to exclusion of emissions from natural disturbances.



#### 11.5.1.4. Information relating to Harvest Wood Products (HWP)

- **Overview and methodologies used**

As described in 11.5.1.1.c), for HWP of the reporting of LULUCF under the Convention, carbon stock changes in sawnwood, wooden board, and plywood used in buildings were estimated by using the Tier 3 country-specific method. Carbon stock changes in wood used for other than buildings (sawnwood, wooden board, plywood) and paper and paperboard (including waste paper) were calculated by using the Tier 2 method described in *the KP Supplement*. The estimation equations, parameters used and activity data are the same as those described in section 6.11 in Chapter 6 in this NIR.

In the reporting under the Kyoto Protocol, the values were estimated by deducting the HWP resulting from deforestation as instantaneous oxidation.

- **Information on reporting HWP before the second commitment period of the Kyoto Protocol**

As shown in the CRF “Table 4(KP-I) B.1.1”, the forest management reference level (FMRL) is not based on a projection in Japan. Therefore, carbon stock changes in the HWP pool before the second commitment period of the Kyoto Protocol were included in the estimation in Japan. The FMRL for reporting five carbon pools (not including HWP) was set as zero in Japan. For the reporting of HWP, the HWP reference level was set newly based on a projection and reported as technical corrections. For detailed information on setting of the HWP reference level, see section 11.7.5.

- **Information on emissions from HWP already accounted for during the first commitment period**

In Japan, emissions from the HWP pool already accounted for during the first commitment period of the Kyoto Protocol on the basis of instantaneous oxidation have not been excluded either from the accounting for the second commitment period of the Kyoto Protocol, or from the HWP reference level. This is because the HWP reference level was set based on a projection as mentioned above. As a result, emissions from the HWP pool that have been accounted for during the first commitment period of the Kyoto Protocol on the basis of instantaneous oxidation has been canceled out to be zero.

- **Information on HWP resulting from D land**

HWP resulting from D land have been accounted for on the basis of instantaneous oxidation (see section 11.5.1.1.b). For detailed information on methodology, see section 11.5.1.7.

- **Information on CO<sub>2</sub> emissions from HWP in SWDS and logged wood for energy purpose**

The methodologies used for calculating carbon stock changes in HWP are explained in section 6.11 in chapter 6 and the same methodologies are applied for reporting of LULUCF under the Kyoto Protocol. CO<sub>2</sub> emissions from HWP in solid waste disposal sites (SWDS) are considered to be similar to incineration and are not included in the HWP pool. Also, logged wood for energy purpose is not included in the HWP pool subject to accounting; those emissions from HWP have been accounted for on the basis of instantaneous oxidation.

- **Information on imported HWP**

As the Production Approach is applied for calculating carbon stock changes in HWP, emissions and removals resulting from changes in the HWP pool accounted for do not include imported HWP (see section 6.11 Chapter 6 in this NIR).

#### 11.5.1.5. Information on whether or not indirect and natural GHG emissions and removals have been factored out

Japan does not factor out indirect, natural and pre-1990 effects specified in paragraph 3 in the annex II to decision 2/CMP.8 in estimating emissions/removals from activities under Articles 3.3 and 3.4.

#### 11.5.1.6. QA/QC and verification

- **General inventory QA/QC procedure**

As for reporting of LULUCF under the Kyoto Protocol, general inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines* as with reporting of LULUCF under the Convention. The focus of general inventory QC is on the checking of the parameters for activity data and emissions factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

- **Verification of Tier 3 estimation method**

For the calculation using Tier 3 method, the following verification activities have been carried out when applying the Roth C model in Japan.

- **Information on activities of calibration and validation**

Although calibration for Roth C estimation method has not been carried out, it was confirmed that the simulation results of Roth C matched well the measured data with selectively using the three modified versions of the Roth C model adopting to different land uses and soil types (Paddy soils, Andosols and non-Andosols). Regarding the suitability of Roth C model for estimating carbon stock changes in mineral soils in CM and GM, the modification and the verification of plot scale using the measured data in long-term field experiments have been carried out.

- **Demonstration that sites of calibration and validation have covered all of soil species and activities**

First of all, it is necessary to divide soils broadly into paddy soils and non-paddy soils depending on whether or not the soils are waterlogged due to the characteristics of soil carbon dynamics. Furthermore, for non-paddy soils, it is appropriate to divide them into Andosols and non-Andosols from the characteristics of soil carbon dynamics. As a result, it is considered appropriate that all agricultural soils to be divided into these three types above.

- **More detailed information on input data**

More detailed information on input data of Roth C model for estimating was described in a research paper listed below.

For detailed information on calibration and validation and input data of Roth C model, see references; Shirato Y, 2006, Shirato.Y & Taniyama.I, 2003, Shirato. Y et al., 2004, Shirato.Y & Yokozawa.M., 2005, Takata.Y et al., 2011, Shirato. Y et al., 2011, Yagasaki. Y et al., 2014 listed in this chapter.

#### 11.5.1.7. Changes in data and methods since the previous submission (recalculations)

For reporting of LULUCF under the Kyoto Protocol, recalculation described below was carried out. For the impact of the recalculation, refer to Chapter 10.

- **Revision of AR and D areas**

In this submission, the ARD ratio was revised. As a result, the AR and D areas were recalculated. Due

to this revision, carbon stock changes in above-ground biomass, below-ground biomass, litter, dead wood and mineral soils in AR, D and FM from FY2013 to FY2019 were also recalculated.

Due to this revision, the areas of CM, GM and RV were recalculated, so, carbon stock changes in all carbon pools in CM, GM and RV were also recalculated.

Moreover, CH<sub>4</sub> and N<sub>2</sub>O emissions from biomass burning in AR and FM were recalculated because of this revision in AR area. In addition, N<sub>2</sub>O emissions associated with mineralization of soil organic matter in FM were also recalculated because of the revision of soil organic area in the D area.

- **Revisions of coefficients used for the Roth C model**

Since the Roth C model calculation uses the 5-year moving average of the plowing rate in each region for carbon input data (rice straw), the input amount of rice straw after FY2017 was corrected due to updating the data for 2019. In addition, climate change scenarios were used instead of AMeDAS (Automated Meteorological Data Acquisition System) observations for 2019 weather data. With these data changes, carbon stock changes per unit area in rice fields, upland fields, orchards and pasture lands were recalculated for FY2017-FY2019. As a result, carbon stock changes in mineral soils in CM and GM were also recalculated for FY2017-FY2019.

- **Revisions of the method for calculating the amount of N mineralized by the loss of carbon in CM and GM soil organic matter**

A new study by Shirato et al. (2021) has made it possible to calculate the amount of carbon loss in soil organic matter in line with the methodology provided in the *2006 IPCC Guidelines*. This leads to recalculation in the respective N<sub>2</sub>O emissions associated with mineralization of soil organic matter in CM and GM for all years.

- **Update of indirect N<sub>2</sub>O emission factors**

The default parameters of the N<sub>2</sub>O emission factors from atmospheric deposition of N volatilized, fraction of N that volatilized as NH<sub>3</sub> and NO<sub>x</sub>, the N<sub>2</sub>O emission factors from N leaching and runoff, and fraction of N leaching/runoff provided in the *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories* (hereafter *2019 Refinement*) were applied instead of the default parameters for these values of the *2006 IPCC Guidelines*. With this revision, N<sub>2</sub>O emissions in D, FM, CM and GM were recalculated for all years.

- **Revisions of organic soil areas in cropland**

Since there were some inconsistencies in the interpolated values of organic soil areas in each land use change category from/to cropland and grassland for the years between 1992, 2001, and 2010 for which data on agricultural organic soil area were available, these inconsistencies were corrected. This recalculation resulted in minor revisions to organic soil and mineral soil area. As a result, the carbon stock changes in mineral soil in CM and GM, CO<sub>2</sub> and CH<sub>4</sub> emissions from drainage of organic soil, and N<sub>2</sub>O emissions associated with soil mineralization were also recalculated for all years.

- **Revisions of orchard areas**

Due to the revision of estimation methods for the orchard areas in some prefectures for FY2017-FY2019, carbon stock changes in living biomass, and CH<sub>4</sub> and N<sub>2</sub>O emissions from biomass burning in CM for FY2017-FY2019 were recalculated.

- **Revisions of activity data, parameters and equations used for calculating carbon stock change in HWP**

Carbon stock changes in sawnwood for buildings were recalculated due to updated activity data of sawnwood for buildings for 2017-2019 in the *Survey of Construction Materials and Labor Demand*, etc. by the Ministry of Land, Infrastructure, Transport and Tourism. In addition, with update of density data for wooden board and plywood from 2014 to 2019 and the update of FAOSTAT for plywood from 2018 to 2019, carbon stock changes for wooden board and plywood in the wood used for other than buildings for those years were recalculated. Moreover, carbon stock changes in paper products were recalculated due to the update of FAOSTAT for 2019.

- **Revisions of HWP reference level**

The HWP reference level was projected by using the average value of D area from 2008 to 2012 and deducting the inflow resulting from D. Due to the revision of D area as well as some revisions related to activity data and parameters mentioned above, the HWP reference level for FY2013 - FY2019 were recalculated.

#### 11.5.1.8. Uncertainty estimates

The uncertainty of the total emissions/removals from activities under Articles 3.3 and 3.4 in FY2020 has been assessed to be -17% to +17%.

See relevant sections of chapters 6 and 11 for uncertainties of respective parameters of the LULUCF sector. Specifically, see Table 11-39 to 11-43 below for detailed information on disaggregated uncertainties on emission factors and activity data used for estimating GHG emissions from and removals by each KP-LULUCF activity.

Table 11-39 Uncertainty of emissions/removals from activities under Articles 3.3 and 3.4 of KP

Greenhouse gas source and sink activities	GHGs	Emissions/Removals [kt CO <sub>2</sub> eq.]	Emissions/Removals Uncertainty [%]		Emissions/Removals Uncertainty as % of net removals [%]	
			(-)[%]	(+)[%]	(-)[%]	(+)[%]
Article 3.3 activities Afforestation and Reforestation	CO <sub>2</sub> , N <sub>2</sub> O, CH <sub>4</sub>	-1,245	-36%	36%	-1%	1%
Article 3.3 activities Deforestation	CO <sub>2</sub> , N <sub>2</sub> O, CH <sub>4</sub>	1,696	-23%	23%	-1%	1%
Article 3.4 activities Forest management	CO <sub>2</sub> , N <sub>2</sub> O, CH <sub>4</sub>	-38,939	-14%	14%	-16%	16%
Article 3.4 activities Cropland management	CO <sub>2</sub> , N <sub>2</sub> O, CH <sub>4</sub>	4,759	-24%	24%	-3%	3%
Article 3.4 activities Grazing land management	CO <sub>2</sub> , N <sub>2</sub> O, CH <sub>4</sub>	617	-9%	9%	0%	0%
Article 3.4 activities Revegetation	CO <sub>2</sub> , N <sub>2</sub> O, CH <sub>4</sub>	-1,360	-33%	33%	-1%	1%
Total		-34,472	-17%	17%		

##### 11.5.1.8.a. Uncertainties of emissions/removals of afforestation/reforestation activities

Uncertainties of emissions/removals in living biomass resulting from AR activities were estimated by

applying Tier 1 – error propagation equation – based on uncertainties in accuracy of AR area identification (activity data), in estimation of carbon stock changes in living biomass in forest land, and in carbon stocks before land conversion. Uncertainties of emissions/removals in litter, dead woods and soils were estimated by applying Monte Carlo Analysis in the CENTURY-jfos model. As a result, the uncertainty of emissions/removals from AR activities in FY2020 has been assessed to be -36% to +36%.

Table 11-40 Uncertainty of emissions and removals from afforestation and reforestation activities

Greenhouse gas source and sink activities		GHGs	Emissions/ Removals [kt CO <sub>2</sub> eq.]	AD Uncertainty [%]		EF/RF Uncertainty [%]		Combined Uncertainty [%]		Combined Uncertainty as % of emissions/ removals [%]		
				(-)[%]	(+)[%]	(-)[%]	(+)[%]	(-)[%]	(+)[%]	(-)[%]	(+)[%]	
Article 3.3 activities  Afforestation and Reforestation	Change in carbon pool reported											
		Above-ground biomass	CO <sub>2</sub>	-786.85	-12%	12%	-43%	43%	-45%	45%	-36%	36%
		Below-ground biomass	CO <sub>2</sub>	-202.29	IE	IE	IE	IE	IE	IE	IE	IE
		Litter	CO <sub>2</sub>	-172.68	-	-	-	-	-51%	51%	-7%	7%
		Dead wood	CO <sub>2</sub>	-51.25	-	-	-	-	-22%	22%	-1%	1%
		Soil	CO <sub>2</sub>	-32.21	-	-	-	-	-20%	20%	-1%	1%
		Harvested wood products (HWP)	CO <sub>2</sub>	NO	-	-	-	-	-	-	-	-
		Greenhouse gas sources reported										
		Fertilization	N <sub>2</sub> O	IE	IE	IE	IE	IE	IE	IE	IE	IE
		N <sub>2</sub> O emissions from drainage of soils	N <sub>2</sub> O	NO	-	-	-	-	-	-	-	-
		N <sub>2</sub> O emissions from N mineralization associated with loss of soil organic matter	N <sub>2</sub> O	NA	-	-	-	-	-	-	-	-
		Biomass burning	CO <sub>2</sub>	IE	IE	IE	IE	IE	IE	IE	IE	IE
			CH <sub>4</sub>	0.01	-	-	-	-	-51%	51%	0%	0%
			N <sub>2</sub> O	0.001	-	-	-	-	-53%	53%	0%	0%
		Total		-1,245.26					-36%	36%		

#### 11.5.1.8.b. Uncertainties of emissions/removals of deforestation activities

Uncertainties of emissions/removals in living biomass resulting from D activities were estimated, as same as AR activities, by applying Tier 1 – error propagation equation – based on uncertainties in accuracy of D area identification (activity data), in estimation of carbon stock changes in living biomass in forest land, and in growth of living biomass after land conversion. Uncertainties of emissions/removals in litter, dead woods and soils were estimated by applying Monte Carlo Analysis in the CENTURY-jfos model. As a result, the uncertainty of emissions/removals from D activities in FY2020 has been assessed to be -23% to +23%.

Table 11-41 Uncertainty of emissions and removals from deforestation activities

Greenhouse gas source and sink activities		GHGs	Emissions/ Removals [kt CO <sub>2</sub> eq.]	AD Uncertainty [%]		EF/RF Uncertainty [%]		Combined Uncertainty [%]		Combined Uncertainty as % of emissions/ removals [%]		
				(-)[%]	(+)[%]	(-)[%]	(+)[%]	(-)[%]	(+)[%]	(-)[%]	(+)[%]	
Article 3.3 activities	Change in carbon pool reported											
	Deforestation	Above-ground biomass	CO <sub>2</sub>	994.28	-12%	12%	-26%	26%	-28%	28%	-21%	21%
Below-ground biomass		CO <sub>2</sub>	249.40	IE	IE	IE	IE	IE	IE	IE	IE	
Litter		CO <sub>2</sub>	312.34	-	-	-	-	-51%	51%	-9%	9%	
Dead wood		CO <sub>2</sub>	128.76	-	-	-	-	-22%	22%	-2%	2%	
Mineral soil		CO <sub>2</sub>	4.61	-	-	-	-	-20%	20%	0%	0%	
Organic soil		CO <sub>2</sub>	2.48	-1%	1%	-90%	90%	-90%	90%	0%	0%	
Harvested wood products (HWP)		CO <sub>2</sub>	IO	-	-	-	-	-	-	-	-	-
Greenhouse gas sources reported												
Deforestation	Fertilization	N <sub>2</sub> O	IE	IE	IE	IE	IE	IE	IE	IE	IE	
	Drainage of soils under forest management	CH <sub>4</sub>	0.53	-	-	-	-	-71%	71%	0%	0%	
	Drainage of soils under forest management	N <sub>2</sub> O	0.05	-	-	-	-	-71%	71%	0%	0%	
	N <sub>2</sub> O emissions from N mineralization associated with loss of soil organic matter	N <sub>2</sub> O	2.51	-	-	-	-	-75%	202%	0%	0%	
	Indirect N <sub>2</sub> O emissions (from N mineralization)	N <sub>2</sub> O	0.66	-	-	-	-	-118%	288%	0%	0%	
	Biomass burning	CO <sub>2</sub>	NO	-	-	-	-	-	-	-	-	-
		CH <sub>4</sub>	NO	-	-	-	-	-	-	-	-	-
N <sub>2</sub> O		NO	-	-	-	-	-	-	-	-	-	
Total			1,695.62					-23%	23%			

### 11.5.1.8.c. Uncertainties of emissions/removals of forest management activities

Uncertainties of emissions/removals in living biomass resulting from FM activities were estimated by applying Tier 1 – error propagation equation – based on uncertainties in data on forest areas and FM ratio and in estimation of carbon stock changes in living biomass in forest land. Uncertainties of emissions/removals in litter, dead woods and soils were estimated by applying Monte Carlo Analysis in the CENTURY-jfos model. As a result, the uncertainty of emissions/removals from FM activities in FY2020 has been assessed to be -14% to +14%.

Table 11-42 Uncertainty of emissions/removals from forest management activities

Greenhouse gas source and sink activities		GHGs	Emissions/ Removals [kt CO <sub>2</sub> eq.]	AD Uncertainty [%]		EF/RF Uncertainty [%]		Combined Uncertainty [%]		Combined Uncertainty as % of emissions/ removals [%]		
				(-)[%]	(+)[%]	(-)[%]	(+)[%]	(-)[%]	(+)[%]	(-)[%]	(+)[%]	
Article 3.4 activities	Change in carbon pool reported											
	Forest management	Above-ground biomass	CO <sub>2</sub>	-31,017.02	-12%	12%	-8%	8%	-14%	14%	-14%	14%
Below-ground biomass		CO <sub>2</sub>	-7,870.70	IE	IE	IE	IE	IE	IE	IE	IE	
Litter		CO <sub>2</sub>	1,883.64	-	-	-	-	-51%	51%	-2%	2%	
Dead wood		CO <sub>2</sub>	-114.32	-	-	-	-	-22%	22%	0%	0%	
Soil		CO <sub>2</sub>	-1,096.44	-	-	-	-	-20%	20%	-1%	1%	
Harvested wood products (HWP)		CO <sub>2</sub>	-833.82	-	-	-	-	-30%	30%	-1%	1%	
Greenhouse gas sources reported												
Forest management	Direct N <sub>2</sub> O emissions (N fertilization)	N <sub>2</sub> O	0.51	-	-	-	-	-31%	31%	0%	0%	
	Indirect N <sub>2</sub> O emissions (N fertilization)	N <sub>2</sub> O	0.35	-	-	-	-	-143%	493%	0%	0%	
	Drainage of soils under forest management	N <sub>2</sub> O	NO	-	-	-	-	-	-	-	-	
	N <sub>2</sub> O emissions from N mineralization associated with loss of soil organic matter	N <sub>2</sub> O	84.68	-	-	-	-	-75%	202%	0%	0%	
	Indirect N <sub>2</sub> O emissions (N mineralization)	N <sub>2</sub> O	22.36	-	-	-	-	-118%	288%	0%	0%	
	Biomass burning	CO <sub>2</sub>	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
		CH <sub>4</sub>	1.78	-	-	-	-	-29%	29%	0%	0%	
N <sub>2</sub> O		0.15	-	-	-	-	-32%	32%	0%	0%		
Total			-38,938.83					-14%	14%			

#### 11.5.1.8.d. Uncertainties of emissions/removals of cropland management

For the uncertainties of activity data for living biomass in orchards, the uncertainties of statistics and the default values given in the *2006 IPCC Guidelines* are applied. For the uncertainties of mineral soil, the comparison of simulation results and actual measurement, when both data are available, revealed that the uncertainty due to model structure was estimated about 10%. The uncertainties caused by input values have not been quantified yet and remain as an issue to be solved. For the uncertainties of organic soil, the uncertainties of statistical data and default values given in the *Wetlands Guidelines* are used. For the uncertainties related to soil mineralization and biomass burning, the uncertainty of N<sub>2</sub>O emission associated with soil mineralization and uncertainty of burning of agricultural residues in the Agriculture sector were applied. As a result, the uncertainty of emissions and removals accompanied by cropland management was evaluated to be -24% to +24%.

#### 11.5.1.8.e. Uncertainties of emissions/removals of grazing land management

The description of method used in GM is omitted as uncertainties of carbon stock changes in mineral soil are the same as that in CM. Uncertainties of existing statistics and the default values described in the *Wetlands Guidelines* were applied to the estimation of emissions from organic soil. For the uncertainties related to soil mineralization, the uncertainty of N<sub>2</sub>O emission associated with soil mineralization in the Agriculture sector was applied. As a result, the uncertainty of emissions and removals accompanied by grazing land management was evaluated to be -9% to +9%.

#### 11.5.1.8.f. Uncertainties of emissions/removals of revegetation activities

Uncertainties of emissions/removals resulting from RV activities were estimated by following processes of estimating carbon stock changes in 8 sub-categories. First, uncertainties of each carbon pool (living biomass, litter and soils) in the 8 sub-categories were estimated by combining uncertainties of parameters and activity data (areas and the number of tall trees) used for estimating carbon stock changes. Next, an uncertainty of emissions/removals resulting from RV activities as a whole was estimated by applying Tier 1 – error propagation equation – based on the carbon stock changes in the 8 sub-categories. As a result, the uncertainty of emissions/removals from RV activities in FY2020 has been assessed at -33% to +33%.

Table 11-43 Uncertainty of emissions/removals from revegetation activities

Greenhouse gas source and sink activities		GHGs	Emissions/ Removals [kt CO <sub>2</sub> eq.]	AD Uncertainty [%]		EF/RF Uncertainty [%]		Combined Uncertainty [%]		Combined Uncertainty as % of emissions/ removals [%]		
				(-)[%]	(+)[%]	(-)[%]	(+)[%]	(-)[%]	(+)[%]	(-)[%]	(+)[%]	
Article 3.4 activities	Change in carbon pool reported											
	Revegetation	Above-ground biomass	CO <sub>2</sub>	-822.82	-	-	-	-	-42%	42%	-32%	32%
		Below-ground biomass	CO <sub>2</sub>	-213.93	IE	IE	IE	IE	IE	IE	IE	IE
		Litter	CO <sub>2</sub>	-14.50	-	-	-	-	-61%	61%	-1%	1%
		Dead wood	CO <sub>2</sub>	IE	IE	IE	IE	IE	IE	IE	IE	IE
		Soil	CO <sub>2</sub>	-308.41	-	-	-	-	-38%	38%	-9%	9%
Total		-1,359.67					-33%	33%				

### 11.5.1.9. Information on other methodological issues (methods dealing with the effects of natural disturbances<sup>22</sup>)

#### 11.5.1.9.a. Afforestation/Reforestation and Deforestation

The effects of natural disturbances have been reflected in forest resources data when Forest Registers are updated every 5 years in each planning area.

#### 11.5.1.9.b. Forest Management

The effects of natural disturbances have been reflected in forest resources data when Forest Registers are updated every 5 years in each planning area.

#### 11.5.1.9.c. Revegetation

It is considered that windstorms, floods and insects are natural disturbances which have a considerable impact on carbon stock changes in RV land. However, all land classified as RV is under human-induced management by administration etc. In addition, when tall trees disappear and outflow of soils occur in RV land located in settlements, the business budget is often appropriated and urgent restoration measures are administered from the viewpoint of safety and view.

Consequently, the effects of natural disturbances are not considered in the estimation because it looks that carbon stocks do not change. Furthermore, carbon stock change due to post-disaster restoration practices which are not implemented in the year when the disaster occurred does not lead to double-counting because it is not considered in this reporting.

#### 11.5.1.10. The year of the onset of an activity

In this submission, all units of land and lands which start to be subject to activities under Article 3.3, Article 3.4 and any elected activities under Article 3.4 until 2020 are reported. The emissions and removals from the units of land and the lands which activities started in FY2020 for the first time are not included in the calculated emissions and removals in FY2019. The areas of such lands are shown below.

Table 11-44 Areas of afforestation/reforestation, deforestation and forest management

Area of activities	Afforestation/ Reforestation [kha]	Deforestation [kha]	Forest Management [kha]		
			Ikusei-rin forest	Tennensei- rin forest	Total
FY1990-2020	100.5	326.8	8,993.1	7,104.8	16,097.9
(FY2020)	—	4.9	—	—	—

<sup>22</sup> Including fires, windstorms, insects, droughts, flooding and ice storms, etc.



Table 11-45 Areas of revegetation

Categories	Urban parks [ha]	Green areas on roads [ha]	Green areas at ports [ha]	Green areas around sewage treatment facilities [ha]	Green areas by greenery promoting systems for private green space [ha]
FY1990	3,743	1,623	198	44	0
FY1990-FY2020	61,379	20,158	1,936	660	6
(FY2020)	760	-375	19	6	0
Categories	Green areas along rivers and erosion control sites [ha]	Green areas around government buildings [ha]	Green areas around public rental housing [ha]	Total [ha]	
FY1990	51	13	239	5,911	
FY1990-FY2020	1,745	360	3,241	89,484	
(FY2020)	3	3	43	459	

## 11.6. Article 3.3

### 11.6.1. Information that demonstrates that activities under Article 3.3 began on or after 1 January 1990 and before 31 December 2020 and are direct human-induced

Japan identifies AR and D by detecting changes of the forest cover which has occurred since 1 January 1990 using orthophotos taken at the end of 1989 and recent satellite images. At that time, AR and forest restoration through natural succession are distinguished by judging through imagery interpretation whether each forest cover change is human-induced or not. This judgement is based on whether any signs of human activities such as uniform tree species and uniform tree height, artificial forestation blocks, or work roads for forestation are observed or not.

### 11.6.2. Information on how harvesting or forest disturbance that is followed by the re-establishment of forest is distinguished from deforestation

In Japan, land conversion from forest land to other land use means exclusion of the land from forest plans. Therefore, as far as the area of harvested forest would remain included in forest plans, the area would be considered to be subject not to D but to temporary loss of biomass stock, and in Forest Registers would be distinguished from D which means conversion to other land use.

Japan identifies forest cover change as D only in the case when land form transformation or artificial construction are observed or obvious conversion to non-forest land such as cropland are detected through imagery interpretation using aerial photos and satellite images. By this methodology, D is distinguished from temporary loss of biomass stock in forest land such as clear-cut under ongoing forestry activities.

Sample field surveys are conducted at plots which are interpreted as D areas in several prefectures every year, and accuracy of D interpretation is approximately 90% on average.

The total area of forest land that has temporarily lost forest cover due to harvesting or disturbance and which are not classified as deforested but as “cut-over forests” in Forest Registers was about 100 thousand ha in 2020.

The period for tree planting after a harvest event is determined as being within two years at the latest under the standard based on the Forest Law. In the case of natural regeneration, it is expected that trees are established within five years following a harvest event.

## **11.7. Article 3.4**

### **11.7.1. Information that demonstrates that activities under Article 3.4 have occurred since 1 January 1990 and are human-induced**

#### **11.7.1.1. Forest Management**

The status of FM activities since 1 January 1990 has been investigated since FY2007 by sample surveys including field surveys, interviews with forest owners' associations and detection of administrative information on subsidies for forest practices, of ikusei-rin forests throughout the country. The results of the survey have been used to estimate the FM ratio.

With respect to Tennensei-rin forests, the measures described in detail in section 11.4.2.4.a.b) have been applied to the Tennensei-rin forests continuously after January 1, 1990.

#### **11.7.1.2. Cropland Management**

Cropland is land which anthropogenic management practices such fertilization management is implemented and CM land is subject to direct human induced activities from January 1, 1990 onward.

#### **11.7.1.3. Grazing Land Management**

Pasture land is land which anthropogenic management practices such fertilization management is implemented and GM land is subject to direct human induced activities from January 1, 1990 onward.

#### **11.7.1.4. Revegetation**

Japan demonstrates that RV activities have occurred since 1990 and are human induced based on the following reasons.

Table 11-46 Information that demonstrates that revegetation activities have occurred since 1 January 1990 and are human induced

Urban green facilities	Information that demonstrates that Revegetation activities have occurred since 1 January 1990 and are human induced
Urban parks	<p><u>Extraction of activities which have occurred since 1 January 1990</u> MLIT has implemented the “Urban Parks Status Survey” and has collected data on the notification year of urban parks. In the reporting, only urban parks which have been notified since 1 January 1990 are included. Although some urban parks were established before the notification year, Japan considers that RV activities have occurred since the notification year under the “Urban Park Act”. <u>Demonstration that activities are human induced</u> Activity data (the number of tall trees) is calculated based on the number of tall trees per land area (tree/ha) which is developed by using data on planted tall trees. Its calculation procedure ensures that Japan extracts human-induced activities.</p>
Green areas on roads	<p><u>Extraction of activities which have occurred since 1 January 1990</u> MLIT has implemented the “Road Tree Planting Status Survey” every 5 years (implemented every year since 2007) and has collected data on the number of planted tall trees. Activity data after 1990 is calculated by extrapolating or interpolating these data. <u>Demonstration that activities are human induced</u> In the “Road Tree Planting Status Survey”, only planted tall trees have been measured. Their measurement procedure ensures that Japan extracts human induced activities.</p>
Green areas at ports	<p><u>Extraction of activities which have occurred since 1 January 1990</u> MLIT has implemented complete census since 2006 and has collected relevant data (year of establishment and service area) for green areas at ports which had been established since 1990. <u>Demonstration that activities are human induced</u> Activity data (the number of tall trees) is calculated by using parameters of urban parks which are based on human-induced activities data.</p>
Green areas around sewage treatment facilities	<p><u>Extraction of activities which have occurred since 1 January 1990</u> MLIT has implemented the “Sewage treatment Facility Status Survey” since 2006 and has collected relevant data (year of establishment and greening area) for green areas around sewage treatment facilities which had been established since 1990. <u>Demonstration that activities are human induced</u> Activity data (the number of tall trees) is calculated based on the number of tall trees per land area (tree/ha) which is developed by using data on planted tall trees. Its calculation procedure ensures that Japan extracts human-induced activities.</p>
Green areas by greenery promoting systems for private green space	<p><u>Extraction of activities which have occurred since 1 January 1990</u> It is clear that all green areas by greenery promoting systems for private green space have been established since 1 January 1990 because greenery promoting systems have been implemented since 2001. Existing tall trees before 1990 in some green areas are reported when it have been notified by the local authority mayor. They are excluded from RV land area. <u>Demonstration that activities are human induced</u> All green areas by greenery promoting systems for private green space have been established by human-induced activities.</p>
Green areas along rivers and erosion control sites	<p><u>Extraction of activities which have occurred since 1 January 1990</u> MLIT has implemented the “Survey on carbon dioxide absorption at source in river works” since 2007 and has collected relevant data (name, location, year of establishment, planted land area [projected area] and the number of tall trees) for river works and erosion and sediment control works which had been implemented since 1990. <u>Demonstration that activities are human induced</u> Activity data (the number of tall trees) is calculated based on the number of tall trees per land area (tree/ha) which is developed by using data on planted tall trees. Its calculation procedure ensures that Japan extracts human-induced activities</p>
Green areas around government buildings	<p><u>Extraction of activities which have occurred since 1 January 1990</u> MLIT has implemented complete census since 2007 and has collected relevant data (name, location, year of establishment, total land area and building area) for government buildings which had been established since 1990. <u>Demonstration that activities are human induced</u> Activity data (the number of tall trees) is calculated based on the number of tall trees per land area (tree/ha) which is developed by using data on planted tall trees. Its calculation procedure ensures that Japan extracts human-induced activities.</p>

Urban green facilities	Information that demonstrates that Revegetation activities have occurred since 1 January 1990 and are human induced
Green areas around public rental housing	<u>Extraction of activities which have occurred since 1 January 1990</u> MLIT has implemented the “Progress survey on tree planting for public rental housing” since 2007 and has collected relevant data (name, location, year of establishment, total land area and building area) for public rental housing which had been established since 1990. <u>Demonstration that activities are human induced</u> Activity data (the number of tall trees) is calculated based on the number of tall trees per land area (tree/ha) which is developed by using data on planted tall trees. Its calculation procedure ensures that Japan extracts human-induced activities.

### 11.7.2. Information relating to cropland management, grazing land management and revegetation for the base year and the commitment period

The anthropogenic greenhouse gas emissions/removals in “Cropland management”, “Grazing land management” and “Revegetation” for the base year are those from CM, GM and RV area in 1990. The anthropogenic greenhouse gas emissions/removals in “Cropland management”, “Grazing land management” and “Revegetation” for the commitment period are those from CM, GM and RV area in each year. Those emissions/removals are reported within the relevant geographical location. The data and the methodologies used are provided in sections 11.4.2.5 through 11.4.2.7 and 11.5.1.1.d through 11.5.1.1.f.

### 11.7.3. Information that demonstrates the emissions and removals resulting from elected Article 3.4 activities are not accounted for under activities under Article 3.3 activities

#### 11.7.3.1. Information on emissions and removals by FM activities are not accounted for under Article 3.3 activities

AR and D are of higher hierarchy than FM in the land classification system of Articles 3.3 and 3.4 in Japan. Emissions and removals by AR and D are estimated in the first step, then emissions and removals by FM are estimated by subtracting emissions and removals by AR and D from emissions and removals in managed forests as explained in section 11.4.2.2 (see Figure 11-1). Therefore, emissions and removals by FM could not be included in those by AR nor D.

#### 11.7.3.2. Information on emissions and removals from CM activities are not accounted under Article 3.3 activities

As described in definition of CM in section 11.3.2.2 and identifying method of CM area in section 11.4.2.5, the land that does not fall under AR can be classified as CM. In addition, in the cropland, the land that fall under D was excluded from land subject to CM.

#### 11.7.3.3. Information on emissions and removals from GM activities are not accounted under Article 3.3 activities

As described in definition of GM in section 11.3.2.3 and identifying method of GM area in section 11.4.2.6, land that does not fall under AR can be classified as GM. In addition, in the pasture land, the land that fall under D was excluded from land subject to GM.

#### 11.7.3.4. Information on emissions and removals from RV activities are not accounted under Article 3.3 activities

RV land is defined as the land which is not included in AR land as described in the definition section 11.3.2.4. Therefore, emissions and removals from RV could not be included in those from AR theoretically.

The area of D land which would otherwise be included in RV lands is reported in the CRF “Table 4(KP-I) A.2.1”. Since this land is classified as D land and is not included in RV land, all emissions and removals from this land are reported under D activity as described in the explanation of methodologies of D in section 11.5.1.1.b and those of RV in section 11.5.1.1.f. Therefore, there is no double count between D and RV and emissions and removals from RV could not be included in those from D.

#### **11.7.4. Information relating to the conversion of natural forests to planted forests**

Since the conversion of natural forests to planted forests are accounted as practices subject FM activity if such activities occur, emissions arising from the conversion of natural forests to planted forests are all included in FM estimation.

#### **11.7.5. Information on forest reference level (Consistency)**

As for reporting FM, forest management reference level (FMRL) was set as zero in Japan. For estimating five carbon pools and GHG emissions and treatment of natural disturbances, methodological consistency between the FMRL and actual calculation is ensured.

Japan set its FMRL as zero because Japan maintains gross-net accounting for the five forest carbon pools using the narrow approach, which had been adopted in the first commitment period of the Kyoto Protocol. The narrow approach is a method for identifying FM area and therefore the narrow approach applies only to those five carbon pools existing in the forest land and does not apply to the HWP pool which exists outside the forest land. Therefore, regarding the setting of the HWP pool reference level, Japan considered the provisions relating to RL of the HWP pool in decision 2/CMP.7 and the *KP Supplement* and discussed them under several committees inside Japan. In order to ensure the consistency of the methodology, the difference between the total FMRL which includes both the five forest carbon pools and the HWP pool and the FMRL value for the five forest carbon pools adopted in 2/CMP.7 has been reported as a technical correction.

With respect to the HWP pool reference level specifically, prediction values by sub-categories based on the historical trend until 2012 were applied. The prediction values from 2013 to 2020 were estimated by extrapolating the trend or using an average over 20 years from 1993 to 2012 for the floor area of construction and the production of wooden board, and over 10 years from 2003 to 2012 for the floor area of demolished buildings, the production of sawnwood and the production of paper and paper board. As for the ratio of domestic wood, the average values of 10 years from 2003 to 2012 were applied. The periods referenced for the past trend for prediction vary among the activity data and parameters, because the trend which showed a high correlation was applied for each activity data and parameter. The average values for 10 years were applied where the past trend was not clear.

The HWP inflow resulting from D from 2013 to 2020, which was estimated from the average value of deforestation area from 2008 to 2012, was deducted from HWP reference level.

#### **11.7.6. Information relating forest management reference (technical correction)**

In reporting carbon stock changes of the HWP pool in FM, technical correction was submitted.

#### **11.7.7. Information on newly established forest will reach at least the equivalent carbon stock**

Japan does not apply the provision of Carbon Equivalent Forests (in paragraphs 37-39 of Annex to Decision/CMP.7).

## 11.8. Other information

### 11.8.1. Key category analysis for Article 3.3 activities and any elected activities under Article 3.4

In accordance with section 2.3.6 of *the KP Supplement* as well as section 4.3.3 in Volume 1 of the 2006 *IPCC Guidelines*, the activity which meets the following requirements is considered as a key category.

- The activities that associated categories identified as key under the UNFCCC inventory.
- The activities that of emissions/removals are greater than the smallest category identified as key in the tier 1 level assessment under the UNFCCC inventory.

- **Corresponding key categories under the UNFCCC**

Japan's LULUCF key categories under the UNFCCC for FY2020 (Annex 1 of this report) are as follows;

- 4.A.1. Forest land remaining forest land (CO<sub>2</sub>)
- 4.A.2. Land converted to Forest land (CO<sub>2</sub>)
- 4.B.1. Cropland remaining cropland (CO<sub>2</sub>)
- 4.E.2. Land converted to settlements (CO<sub>2</sub>)

In accordance with the *KP Supplement*, AR, D, FM, CM and RV may be identified as key categories under the Kyoto Protocol.

Table 11-47 Relationship between UNFCCC categories and Kyoto Protocol activities

UNFCCC category under the Convention	Kyoto Protocol category
4.A.1. Forest land remaining forest land	FM
4.A.2. Land converted to forest land	AR
4.B.1. Cropland remaining cropland	CM
4.B.2. Land converted to cropland	D
4.C.1. Grassland remaining grassland	GM
4.C.2. Land converted to grassland	D
4.D.1. Wetlands remaining wetlands	-
4.D.2. Land converted to wetlands	D
4.E.1. Settlements remaining settlements	RV
4.E.2. Land converted to settlements	D, RV
4.F.1. Other land remaining other land	-
4.F.2. Land converted to other land	D
4.G. Harvest Wood Products	FM

Note: The relationship between the Convention categories and the Kyoto categories in this table is based on the Table 2.1.1 of the *KP Supplement*, and the definitions of Articles 3.3 and 3.4 activities in Japan. Shade indicates the key categories under the UNFCCC.

- **Comparison with the smallest key category under the UNFCCC**

The smallest category for the UNFCCC (Approach 1 level assessment) for FY2020 was 2.A.2 Lime Production (CO<sub>2</sub>). As a result of the comparison, only FM activity was greater than this category.

Therefore, AR, D, FM, CM and RV activities (CO<sub>2</sub>) are identified as key activities for FY2020.

### 11.8.2. Further improvements

Methodological issues relating to Articles 3.3 and 3.4 are identified under the committee for greenhouse gas emissions estimation methods- breakout group on LULUCF. They are updated every year along with the progress of the inventory-related work and issues identified by the expert review team. Many of the improvement plans on LULUCF reporting under the Convention described in Chapter 6 of this

report are closely linked to activities under Articles 3.3 and 3.4 of the Kyoto Protocol. Therefore, both the reporting under the Convention and the reporting under the Kyoto Protocol are discussed together. Major issues to be improved are as follows:

- Improvement of methodology and data to estimate carbon stock change in soil due to land-use conversion which reflects changes in management practices more properly is under discussion in Japan.
- With regard to the annual growth rate of living biomass per tree in RV land, Japan plans to improve the accuracy when new country-specific data by tree species become available.
- Except for urban parks and green areas at ports, carbon stock change in soils is not included in the reporting because soils are not sources of GHGs under RV activities. Collecting fundamental information on soil carbon and development estimation methods will be continued.
- With respect to uncertainties on KP-LULUCF activities, disaggregated uncertainties area shown in section 11.5.1.8 in chapter 11, and additional information in description on each category in Chapter 6 are provided. The method to show more detailed information on uncertainties systematically than in current NIR is regarded as a long-term issue.

### 11.9. Information relating to Article 6

Japan has not carried out any projects under Article 6 of the Kyoto Protocol. Therefore, a special indication of whether the boundary of the geographical location encompasses land subject to the Article 6 project is not prepared.

### 11.10. Information on the reporting status of the Annex II to decision 2/CMP.8

The requirements for reporting about Articles 3.3 and 3.4 which are set out in the annex II to decision 2/CMP.8 are provided in sections shown in Table 11-48.

Table 11-48 List of reference sections for the requirements set in the annex II to decision 2/CMP.8

Checklist for KP reporting (paragraphs 1-5 in the annex to decision 2/CMP.8)	Paragraph	Main sections of Chapter 11 providing relevant information
Information on how inventory methodologies have been applied taking into account <i>the KP Supplement</i> and decision 16/CMP.1	2 (a)	Detailed information is provided in each section
Information on the geographical location of the boundaries of areas that encompass:	2 (b)	11.4.2, 11.4.3
Units of land subject to activities under Article 3.3	2 (b) (i)	11.4.2, 11.4.3
Units of land subject to activities under Article 3.3, which would otherwise be included in land subject to elected activities under Article 3.4	2 (b) (ii)	11.4.2, 11.4.3 and CRF "Table 4(KP-I) A.2.1"
Land subject to elected activities under Article 3.4	2 (b) (iii)	11.4.2, 11.4.3
Information on the spatial assessment unit for determining the area of accounting for ARD	2 (c)	11.4.1
GHG emissions by sources and removals by sinks from LULUCF activities under Articles 3.3 and 3.4:		
Emissions by sources and removals by sinks are clearly distinguished from emissions from Annex A sources	1	11.5.1: Methodology
Emissions by sources and removals by sinks are reported for all geographical locations reported in current and previous years	2 (d)	11.4.2.3, 11.4.2.4, 11.4.2.5, 11.4.2.6, 11.4.2.7
Emissions/removals from Articles 3.3 or (elected) 3.4 activities are reported since the beginning of the commitment period or the onset of the activity	2 (d)	11.5.1.10
Information on which pools (above-ground / below-ground biomass, litter, dead wood and soil organic carbon) were not accounted for	2 (e)	11.5.1.2

Checklist for KP reporting (paragraphs 1-5 in the annex to decision 2/CMP.8)		Paragraph	Main sections of Chapter 11 providing relevant information
Information on how emissions from natural disturbance are considered	2 (f)	11.5.1.3	
Information on GHG emissions /removals from the harvested wood products pool	2 (g)	11.5.1.4	
Activity data for the HWP categories used for estimating the pool removed from domestic forests, for domestic consumption and for export	2(g)(i)	11.5.1.4	
Half-lives used in estimating emissions/removals for the HWP categories when the first-order decay method was used	2(g)(ii)	11.5.1.4	
Whether emissions from HWP originating from forests prior to the start of the second commitment period have been included in the accounting, if the forest management reference level is based on a projection	2(g)(iii)	11.5.1.4	
How emissions from the HWP pool accounted for in the first commitment period on the basis of instantaneous oxidation have been excluded from the accounting for the second commitment period	2(g)(iv)	11.5.1.4	
How the HWP resulting from deforestation have been accounted on the basis of instantaneous oxidation	2(g)(v)	11.5.1.4	
How CO <sub>2</sub> emissions from HWP in SWDS and from wood harvested for energy purposes have been accounted on the basis of instantaneous oxidation	2(g)(vi)	11.5.1.4	
How emissions/removals from changes in the HWP pool accounted for do not include imported harvested wood products	2(g)(vii)	11.5.1.4	
Information on whether Articles 3.3 and (elected) 3.4 emissions/removals factor out removals from (i) elevated CO <sub>2</sub> concentrations above pre-industrial levels; (ii) indirect N deposition; and (iii) dynamic effects of age structure resulting from pre-1 January 1990 activities	3	11.5.1.5	
Specific information to be reported for Article 3.3 activities			
Information that activities under Article 3.3 began on or after 1 January 1990 and before 31 December of the last year of the commitment period	4 (a)	11.6.1	
Information on how harvesting or forest disturbance that is followed by the re-establishment of forest is distinguished from deforestation	4 (b)	11.6.2	
Specific information to be reported for Article 3.4 activities			
Information that activities under Article 3.4 occurred since 1 January 1990 and are human induced.	5 (a)	11.7.1	
CM, GM, RV: emissions/removals reported for each year of the commitment period and for the base year for each of the elected activities on the geographical locations reported	5 (b)	11.4.2.5, 11.4.2.6, 11.4.2.7, 11.5.1.1.d, 11.5.1.1.e, 11.5.11.f, 11.7.2	
Information that emissions/removals from Article 3.4 activities are not accounted for under activities under Article 3.3	5 (c)	11.7.3	
Information how all emissions arising from the conversion of natural forests to planted forests are accounted for	5 (d)	11.7.4	
Information that demonstrates methodological consistency between the reference level and reporting for FM during the second commitment period	5 (e)	11.7.5	
Information on technical corrections between the reference level and reporting for FM during the second commitment period	5 (f)	11.7.6	
Information on newly established forest will reach at least the equivalent carbon stock	5 (g)	11.7.7	



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## Chapter 12. Information on accounting of Kyoto units

In line with paragraph 10 of the annex to decision 15/CMP.1 and paragraph 14 of decision 3/CMP.11, Japan reports the information on holdings and transactions of Kyoto units (ERUs, CERs, ICERs, tCERs, AAUs and RMUs)<sup>1</sup>. For the reporting, in accordance with paragraph 11 of annex of decision 15/CMP.1, Japan uses Standard electronic format (SEF) defined in the annex of decision 14/CMP.1. Apart from this NIR, SEF is submitted to the UNFCCC Secretariat with the file name “RREG1\_JP\_2021\_1\_2.xlsx”.

### 12.1. Summary of information reported in the SEF tables

For information on Kyoto units in Japan’s National Registry, see the annex of the NIR “Standard Electric Format for Reporting of Information on Kyoto Protocol Units” (RREG1\_JP\_2021\_1\_2.xlsx) submitted on the basis of Decision 14/CMP. 1.

Japan also submits “RREG1\_JP\_2021\_2\_1.xlsx”.

### 12.2. Discrepancies and notifications

Regarding Japan’s national registry, discrepancies and notifications to be reported in accordance with paragraphs 12-17 of annex to decision 15/CMP.1 are as follows.

Table 12-1 Discrepancies and notifications

Reporting item	Description
Para. 12 of the annex to decision 15/CMP.1 Discrepancies	There was no discrepancy to be reported.
Para. 13 of the annex to decision 15/CMP.1 Notification from Executive Board of CDM	There was no notification regarding ICERs to be replaced due to a reversal of storage.
Para. 14 of the annex to decision 15/CMP.1 Failure of certification	There was no notification regarding ICERs to be replaced due to non-submission of certification report.
Para. 15 of the annex to decision 15/CMP.1 List of non-replacements	There was no record of non-replacement identified by the transaction log.
Para. 16 of the annex to decision 15/CMP.1 Invalid Kyoto units	There were no units that are invalid for use towards compliance with commitments.
Para. 17 of the annex to decision 15/CMP.1 Discrepant transaction that needs actions to correct problem	There was no discrepant transaction that needs actions to correct problem.

### 12.3. Publicly accessible information

As presented in the section IV of Part 2 of “Report on Japan’s Assigned Amount”, a list of the information publicly accessible by means of the user interface to the national registry is as below:

- Account information as required by paragraph 45, annex, Decision 13/CMP.1

<sup>1</sup> Kyoto units are: emission reduction units (ERUs) from joint implementation (JI) projects, certified emission reductions (CERs) from clean development mechanism (CDM) projects, temporary certified emission reductions (tCERs) and long-term certified emission reductions (ICERs) from afforestation/reforestation CDM projects, assigned amount units (AAUs) and removal units (RMUs) from KP-LULUCF activities within Annex I Parties.

- Article 6 project information as required by paragraph 46, annex, Decision 13/CMP.1
- Kyoto units information as required by paragraph 47, annex, Decision 13/CMP.1
- Legal entities as required by paragraph 48, annex, Decision 13/CMP.1
- The serial numbers of the units in the retirement account at the end of the true-up period as required by paragraph 49(b), annex, Decision 13/CMP.1
- The serial numbers of the units requested to be carried over as required by paragraph 49(c), annex, Decision 13/CMP.1

The information is provided in “Publicly Accessible Information” of Japan’s national registry website.

- URL of the Japan’s national registry system: [http://www.registry.go.jp/index\\_e.html](http://www.registry.go.jp/index_e.html)
- Publicly Accessible Information: [http://www.registry.go.jp/public\\_info\\_en.html](http://www.registry.go.jp/public_info_en.html)

The following information is not published due to confidentiality concerns:

- Unit holdings at an individual account level
- Identity of accounts to which Japan’s national registry transferred units and those from which it acquired units.

In addition, for better readability, information on units is not associated with their respective serial numbers.

#### **12.4. Calculation of the commitment period reserve (CPR)**

Since Japan does not have a quantified emission limitation or reduction commitment for the second commitment period, it does not have a commitment period reserve.

## Chapter 13. Information on changes in national system

In line with paragraph 50 (J) of the UNFCCC Inventory Reporting Guidelines, and paragraph 21 of the annex to decision 15/CMP.1, Japan reports the changes in its national system from the previous inventory submission.

- The Sub-breakout Group on Carbon Capture and Utilization (CCU) was established under the Breakout Group on Energy and Industrial Processes of the Committee for the Greenhouse Gas Emissions Estimation Methods.





## Chapter 14. Information on changes in national registry

In line with paragraph 22 of the Annex to decision 15/CMP.1 and paragraph 14 of decision 3/CMP.11, Japan reports changes in the national registry of Japan from the previous inventory submission.

### 14.1. Summary of changes made on national registry of Japan in 2021

Table 14-1 Summary of changes made on national registry of Japan in 2021

Reporting Items	Descriptions of Changes
15/CMP.1, annex II, para 32. (a) Change of name or contact	No change
15/CMP.1, annex II, para 32. (b) Change of cooperation arrangement	No change
15/CMP.1, annex II, para 32. (c) Change to database or the capacity of national registry	No change
15/CMP.1, annex II, para 32. (d) Change of conformance to technical standards	No change
15/CMP.1, annex II, para 32. (e) Change of procedures to minimize discrepancies	No change
15/CMP.1, annex II, para 32. (f) Change of security measures	No change
15/CMP.1, annex II, para 32. (g) Change of a list of publicly accessible information	Information on unit holdings and transactions is made publicly available on the basis of Standard Electronic Format (SEF) to meet the requirement specified in decision 14/CMP.1. In May 2021, the information for 2020 was published. The following information was not published due to confidentiality concerns: - Unit holdings at an individual account level - Identity of accounts to which national registry of Japan transferred units and those from which it acquired units. In addition, for better readability, information on units was not associated with their respective serial numbers.
15/CMP.1, annex II, para 32. (h) Change of the internet address	No change
15/CMP.1, annex II, para 32. (i) Change of measures for ensuring data integrity	No change
15/CMP.1, annex II, para 32. (j) Change of test results	No change

### 14.2. Information relevant to the changes made on national registry of Japan

Following changes were made to national registry of Japan. There was no impact on the functions of the ITL and other national registries.

- In March 2021, the network device was updated with security patches.
- In March 2021, the server was changed.
- In May 2021, public information on the unit holdings and transactions conducted was updated on the basis of the SEF for 2020, for the purpose of meeting the requirement specified in decision 13/CMP.1. The following information, which is requested to be made publicly available in decision 13/CMP.1, has not been made so due mostly to confidentiality concerns (relevant paragraph numbers of the annex to decision 13/CMP.1 are indicated in parentheses):

- The full name of the representative of the account holder (paragraph 45(e))
  - Serial numbers of ERUs, CERs, AAUs and RMUs those are subject of this public information (paragraph 47)
  - The total quantity of ERUs, CERs, AAUs and RMUs in each account at the beginning of the year (the total quantity is only available by account type) (paragraph 47(a))
  - The identity of the transferring accounts from which ERUs, CERs, AAUs and RMUs were acquired by national registry of Japan during the year (the identity of the transferring registries is available) (paragraph 47(d))
  - The identity of the acquiring accounts to which ERUs, CERs, AAUs and RMUs were transferred from national registry of Japan during the year (the identity of the acquiring registries is available) (paragraph 47(g))
  - Current holdings of ERUs, CERs, AAUs and RMUs in each account (the current holdings are only available by account type) (paragraph 47(l))
- In May 2021, the network device was updated with security patches.

## Chapter 15. Information on minimization of adverse impacts in accordance with Article 3, paragraph 14

In line with paragraphs 23-25 of the Annex to decision 15/CMP.1 and paragraph 4 of Annex III to decision 3/CMP.11, Japan reports the following information on minimization of adverse impacts in accordance with Article 3, paragraph 14. Changes made since the last submission are indicated with underlines.

### 15.1. Overview

Japan takes actions while taking into account the importance of making efforts to minimize adverse impacts in accordance with Article 3, Paragraph 14 of the Kyoto Protocol. On the other hand, it should be noted that we have difficulty in accurately assessing specific adverse impacts due to the implementation of response measures to address climate change issues. For example, the fluctuations in crude oil prices are caused by the balance between supply and demand, as well as various other factors (e.g., trends in crude oil futures market or economic fluctuations), and direct causality and its extent between climate change measures and adverse impacts thereof remain uncertain.

Furthermore, for the genuine resolution of climate change problems, it is essential to change the perception related to response measures, and in such a light sustainable growth may become a key. For instance, it should be underlined that the introduction of renewable energy has aspects not only to contribute to GHG emission reductions but also to improve energy access, disaster preparedness, benefit the job creation through the development of new industries.

In October 2020, the Prime Minister SUGA declared in his Policy Speech that by 2050 Japan will aim to reduce greenhouse gas emissions, that is, to realize a carbon-neutral. He expressed Japan's strong determination that proactive climate change measures bring transformation of industrial structures as well as our economy and society, and Japan will lead the green industry globally and realize a virtuous cycle of the economy and the environment.

### 15.2. Actions to minimize adverse impacts in accordance with Article 3, paragraph 14

Japan has as a priority taken the following measures, taking into consideration of the importance to minimize adverse social, environmental, and economic impacts on developing country Parties, particularly those identified in Article 4, paragraphs 8 and 9, of the Convention in implementing the commitments under Article 3, paragraph 1, of the Kyoto Protocol.

At the same time, it should be added that since there is no internationally established methodology for evaluating efforts related to the minimization of above-mentioned adverse impacts, it is impossible to carry out such evaluations.

- ***Technical assistance in the energy and environmental sectors***

Japan has continued to contribute to the sustainable economic growth of developing countries, based on their needs, through the provision of technical assistance in the field of energy and the environment

throughout the world. For example, Japan has provided assistance for the development and operation of institutions related to energy savings and renewable energy, through cooperation in human resource development, such as inviting trainees from and sending experts to developing countries, including in the Middle East region and Asian countries.

● ***Development of Carbon Capture, Utilization and Storage (CCUS) and carbon recycling technologies***

Japan will work on CCUS/ Carbon Recycling which is an important technology for addressing global warmings from the viewpoint of the policy decisions based on the Strategic Energy Plan, the Long-term Greenhouse Gas Emission Strategy as requested in the Paris Agreement and Japan's Green Growth Strategy Through Achieving Carbon Neutrality in 2050. In particular, Japan has been implementing large-scale demonstration projects in the pursuit of aiming for the practical use by around 2020. As a result, in November 2019, the initial target of 300,000 tons of injection was achieved, and the domestic CCS technology is considered to have been put into practical use. Also, the following projects have been continuing research and development for cost reductions and safety improvements, evaluations of environmental impacts due to the CO<sub>2</sub> capture process, and geological surveys to identify potential CO<sub>2</sub> offshore storage sites in Japan. In addition to the above activities, Japan has actively conducted information exchanges with stakeholders in European countries, the United States and Australia regarding technologies pertaining to CCUS. Japan has carried out feasibility studies on CCS with application of Japanese leading CCS technologies in Indonesia.

## Annex 1. Key Categories

### A1.1. Outline of Key Category Analysis

The *UNFCCC Inventory Reporting Guidelines*<sup>1</sup> require the application of the *2006 IPCC Guidelines*, and the key category analysis given in the Guidelines. The key category analyses were done for both data of FY2020 (the latest reported year) and of FY1990 (the base year for the UNFCCC). Their results are presented here.

### A1.2. Results of Key Category Analysis

#### A1.2.1 Key Categories

Key categories were assessed in accordance with the *2006 IPCC Guidelines* assessment methods (Approach 1 level assessment, Approach 1 trend assessment, Approach 2 level assessment, and Approach 2 trend assessment).

The key categories were identified by first conducting the key category analysis excluding LULUCF, and then conducting the key category analysis for the whole inventory including the LULUCF sector.

As a result, 42 and 40 sources and sinks were detected as the key categories for FY2020 and FY1990, respectively (Table A1-1 and A1-2).

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<sup>1</sup> Revision of the UNFCCC reporting guidelines on annual inventories for Parties included in Annex I to the Convention (Decision 24/CP.19)

Table A1-1 Japan's key categories (FY2020)

A IPCC Code	B IPCC Category	C GHGs	Ap1-L	Ap1-T	Ap2-L	Ap2-T
1.A.1.	Energy Industries	Solid Fuels	CO2	#1	#1	#1
1.A.3.	Transport	b. Road Transportation	CO2	#2		#3
1.A.1.	Energy Industries	Gaseous Fuels	CO2	#3	#3	#7
1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO2	#4	#6	#2
1.A.4.	Other Sectors	Liquid Fuels	CO2	#5	#7	#5
4.A	Forest Land	1. Forest Land remaining Forest Land	CO2	#6	#8	#4
1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO2	#7	#4	#10
2.F	Product uses as substitutes for ODS	1. Refrigeration and Air conditioning	HFCs	#8	#5	#9
1.A.1.	Energy Industries	Liquid Fuels	CO2	#9	#2	#11
1.A.4.	Other Sectors	Gaseous Fuels	CO2	#10	#9	#24
1.A.2.	Manufacturing Industries and Construction	Gaseous Fuels	CO2	#11	#10	#26
2.A	Mineral Industry	1. Cement Production	CO2	#12	#12	#23
3.C	Rice Cultivation		CH4	#13		#29
5.C	Incineration and Open Burning of Waste		CO2	#14		#14
1.A.2.	Manufacturing Industries and Construction	Other Fossil Fuels	CO2	#15	#13	#13
1.A.3.	Transport	d. Domestic Navigation	CO2	#16		
1.A.4.	Other Sectors	Other Fossil Fuels	CO2	#17		#15
3.A	Enteric Fermentation		CH4	#18		#12
1.A.4.	Other Sectors	Solid Fuels	CO2	#19	#17	
2.A	Mineral Industry	2. Lime Production	CO2	#20		
4.B	Cropland	1. Cropland remaining Cropland	CO2			#22
3.B	Manure Management		N2O			#8
3.D	Agricultural Soils	1. Direct Emissions	N2O			#27
2.F	Product uses as substitutes for ODS	2. Foam Blowing Agents	HFCs		#21	#17
5.A	Solid Waste Disposal		CH4		#18	
2.D	Non-energy Products from Fuels and Solvent Use		CO2			#18
3.D	Agricultural Soils	2. Indirect Emissions	N2O			#6
2.B	Chemical Industry	Other products except Ammonia	CO2			#19
5.D	Wastewater Treatment and Discharge		N2O			#28
2.E	Electronics Industry		PFCs			#16
	Indirect CO2	from IPPU sector	Ind CO2			#30
4.E	Settlements	2. Land converted to Settlements	CO2			#22
5.C	Incineration and Open Burning of Waste		N2O			#21
2.G	Other Product Manufacture and Use		SF6		#14	#20
1.A.3.	Transport	b. Road Transportation	N2O			#26
4.A	Forest Land	2. Land converted to Forest Land	CO2		#15	#17
1.B	Fugitive Emission from Fuel	1. Fugitive emissions from Solid Fuels	CH4		#19	#7
2.B	Chemical Industry	3. Adipic Acid Production	N2O		#16	#20
2.E	Electronics Industry		SF6			#25
2.B	Chemical Industry	9. Fluorochemical Production (Fugitive Emissions)	HFCs		#11	
2.B	Chemical Industry	4. Caprolactam, Glyoxal and Glyoxylic Acid Production	N2O			#12
2.B	Chemical Industry	9. Fluorochemical Production (Fugitive Emissions)	SF6		#20	

Note: Ap1-L: Approach1-Level Assessment, Ap1-T: Approach1-Trend Assessment,  
Ap2-L: Approach2-Level Assessment, Ap2-T: Approach2-Trend Assessment  
Figures recorded in the Level and Trend columns indicate the ranking of individual level and trend assessments.

Table A1-2 Japan's key categories (FY1990)

	A IPCC Code	B IPCC Category		C GHGs	Ap1-L	Ap2-L
#1	1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO2	#1	#1
#2	1.A.3.	Transport	b. Road Transportation	CO2	#2	#3
#3	1.A.1.	Energy Industries	Liquid Fuels	CO2	#3	#4
#4	1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO2	#4	#6
#5	1.A.4.	Other Sectors	Liquid Fuels	CO2	#5	#8
#6	1.A.1.	Energy Industries	Solid Fuels	CO2	#6	#7
#7	1.A.1.	Energy Industries	Gaseous Fuels	CO2	#7	#18
#8	4.A	Forest Land	1. Forest Land remaining Forest Land	CO2	#8	#2
#9	2.A	Mineral Industry	1. Cement Production	CO2	#9	#21
#10	1.A.4.	Other Sectors	Gaseous Fuels	CO2	#10	
#11	2.B	Chemical Industry	9. Fluorochemical Production (Fugitive Emissions)	HFCs	#11	
#12	1.A.3.	Transport	d. Domestic Navigation	CO2	#12	
#13	5.C	Incineration and Open Burning of Waste		CO2	#13	#17
#14	3.C	Rice Cultivation		CH4	#14	
#15	1.A.2.	Manufacturing Industries and Construction	Gaseous Fuels	CO2	#15	
#16	5.A	Solid Waste Disposal		CH4	#16	#14
#17	3.A	Enteric Fermentation		CH4	#17	#12
#18	2.G	Other Product Manufacture and Use		SF6	#18	#5
#19	4.B	Cropland	1. Cropland remaining Cropland	CO2	#19	#19
#20	2.C	Metal Production	1. Iron and Steel Production	CO2	#20	
#21	2.B	Chemical Industry	3. Adipic Acid Production	N2O	#21	
#22	1.A.3.	Transport	a. Domestic Aviation	CO2	#22	
#23	2.A	Mineral Industry	2. Lime Production	CO2	#23	
#24	4.A	Forest Land	2. Land converted to Forest Land	CO2	#24	#30
#25	1.A.4.	Other Sectors	Other Fossil Fuels	CO2	#25	#23
#26	1.B	Fugitive Emission from Fuel	1. Fugitive emissions from Solid Fuels	CH4	#26	#11
#27	3.D	Agricultural Soils	1. Direct Emissions	N2O	#27	#24
#28		Indirect CO2	from IPPU sector	Ind CO2		#15
#29	4.E	Settlements	2. Land converted to Settlements	CO2		#29
#30	3.B	Manure Management		N2O		#10
#31	1.A.2.	Manufacturing Industries and Construction	Other Fossil Fuels	CO2		#31
#32	2.B	Chemical Industry	Other products except Ammonia	CO2		#16
#33	1.A.3.	Transport	b. Road Transportation	N2O		#13
#34	3.D	Agricultural Soils	2. Indirect Emissions	N2O		#9
#35	5.D	Wastewater Treatment and Discharge		N2O		#28
#36	2.D	Non-energy Products from Fuels and Solvent Use		CO2		#27
#37	2.B	Chemical Industry	4. Caprolactam, Glyoxal and Glyoxylic Acid Production	N2O		#20
#38	2.E	Electronics Industry		PFCs		#25
#39	5.C	Incineration and Open Burning of Waste		N2O		#26
#40	2.E	Electronics Industry		SF6		#22

Note: Ap1-L: Approach1-Level Assessment, Ap2-L: Approach2-Level Assessment

Figures recorded in the Level and Trend columns indicate the ranking of individual level and trend assessments.

### A1.2.2 Level Assessment

Level assessment involves an identification of categories as a key by calculating the proportion of emissions and removals in each category to the total emissions and removals. The calculated values of proportion are added from the category that accounts for the largest proportion, until the sum reaches 95% for Approach 1 and 90% for Approach 2. Approach 1 level assessment uses emissions and removals from each category directly and Approach 2 level assessment analyzes the emissions and removals of each category, multiplied by the uncertainty of each category.

The key category analysis was first conducted for the inventory excluding LULUCF and the key categories for source sectors were identified (1). Then the key category analysis was repeated again for

the full inventory including the LULUCF categories and key categories for LULUCF sector were identified (2). A source category, which was identified as key in (1) but not in (2), was still regarded as key; while a source category, which was not identified as key in (1) but was done in (2), was not regarded as key (gray rows in tables below).

Approach 1 level assessment of the latest emissions and removals (FY2020) gives the following 20 sub-categories as the key categories (Table A1-3). Approach 2 level assessment of the latest emissions and removals (FY2020) gives the following 30 sub-categories as the key categories (Table A1-4).

Table A1-3 Results of Approach 1 level assessment (FY2020)

	A IPCC Code	B IPCC Category		C GHGs	F Current Year Estimate [Gg-CO2 eq.]	H Ap1-L	I Ap1-L Contrib. [%]	Cumulative contrib. [%]
#1	1.A.1.	Energy Industries	Solid Fuels	CO2	242,501.88	0.199	19.9%	19.9%
#2	1.A.3.	Transport	b. Road Transportation	CO2	161,847.20	0.133	13.3%	33.2%
#3	1.A.1.	Energy Industries	Gaseous Fuels	CO2	148,765.38	0.122	12.2%	45.5%
#4	1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO2	144,169.52	0.119	11.9%	57.3%
#5	1.A.4.	Other Sectors	Liquid Fuels	CO2	82,239.11	0.068	6.8%	64.1%
#6	4.A	Forest Land	1. Forest Land remaining Forest Land	CO2	-56,372.66	0.046	4.6%	68.7%
#7	1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO2	49,388.61	0.041	4.1%	72.8%
#8	2.F	Product uses as substitutes for ODS	1. Refrigeration and Air conditioning	HFCs	47,678.19	0.039	3.9%	76.7%
#9	1.A.1.	Energy Industries	Liquid Fuels	CO2	45,037.31	0.037	3.7%	80.4%
#10	1.A.4.	Other Sectors	Gaseous Fuels	CO2	41,831.17	0.034	3.4%	83.8%
#11	1.A.2.	Manufacturing Industries and Construction	Gaseous Fuels	CO2	29,562.69	0.024	2.4%	86.3%
#12	2.A	Mineral Industry	1. Cement Production	CO2	24,490.27	0.020	2.0%	88.3%
#13	3.C	Rice Cultivation		CH4	12,004.45	0.010	1.0%	89.3%
#14	5.C	Incineration and Open Burning of Waste		CO2	11,490.55	0.009	0.9%	90.2%
#15	1.A.2.	Manufacturing Industries and Construction	Other Fossil Fuels	CO2	10,713.05	0.009	0.9%	91.1%
#16	1.A.3.	Transport	d. Domestic Navigation	CO2	10,069.57	0.008	0.8%	91.9%
#17	1.A.4.	Other Sectors	Other Fossil Fuels	CO2	8,252.02	0.007	0.7%	92.6%
#18	3.A	Enteric Fermentation		CH4	7,632.94	0.006	0.6%	93.2%
#19	1.A.4.	Other Sectors	Solid Fuels	CO2	6,481.63	0.005	0.5%	93.7%
#20	2.A	Mineral Industry	2. Lime Production	CO2	5,470.05	0.004	0.4%	94.2%
#21	2.C	Metal Production	1 Iron and Steel Production	CO2	5,429.70	0.004	0.4%	94.6%

Note: A source category #21, which was not identified as key in (1) but was done in (2), was not regarded as key.



Table A1-4 Results of Approach 2 level assessment (FY2020)

	A IPCC Code	B IPCC Category		C GHGs	F Current Year Estimate [Gg-CO <sub>2</sub> eq.]	L Source/Sink Uncertainty [%]	N Ap2-L Contrib. [%]	Cumulative contrib. [%]
#1	1.A.1.	Energy Industries	Solid Fuels	CO <sub>2</sub>	242,501.88	6%	14.9%	14.9%
#2	1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO <sub>2</sub>	144,169.52	6%	8.9%	23.8%
#3	1.A.3.	Transport	b. Road Transportation	CO <sub>2</sub>	161,847.20	5%	8.3%	32.0%
#4	4.A	Forest Land	1. Forest Land remaining Forest Land	CO <sub>2</sub>	-56,372.66	13%	7.7%	39.8%
#5	1.A.4.	Other Sectors	Liquid Fuels	CO <sub>2</sub>	82,239.11	5%	4.2%	44.0%
#6	3.D	Agricultural Soils	2. Indirect Emissions	N <sub>2</sub> O	2,333.13	164%	4.2%	48.1%
#7	1.A.1.	Energy Industries	Gaseous Fuels	CO <sub>2</sub>	148,765.38	2%	3.9%	52.0%
#8	3.B	Manure Management		N <sub>2</sub> O	3,843.42	89%	3.7%	55.7%
#9	2.F	Product uses as substitutes for ODS	1. Refrigeration and Air conditioning	HFCs	47,678.19	6%	3.3%	59.0%
#10	1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO <sub>2</sub>	49,388.61	5%	2.5%	61.5%
#11	1.A.1.	Energy Industries	Liquid Fuels	CO <sub>2</sub>	45,037.31	5%	2.3%	63.9%
#12	3.A	Enteric Fermentation		CH <sub>4</sub>	7,632.94	27%	2.2%	66.1%
#13	1.A.2.	Manufacturing Industries and Construction	Other Fossil Fuels	CO <sub>2</sub>	10,713.05	19%	2.2%	68.3%
#14	5.C	Incineration and Open Burning of Waste		CO <sub>2</sub>	11,490.55	16%	2.0%	70.3%
#15	1.A.4.	Other Sectors	Other Fossil Fuels	CO <sub>2</sub>	8,252.02	19%	1.7%	72.0%
#16	2.E	Electronics Industry		PFCs	1,887.75	81%	1.7%	73.6%
#17	2.F	Product uses as substitutes for ODS	2. Foam Blowing Agents	HFCs	2,924.97	50%	1.6%	75.2%
#18	2.D	Non-energy Products from Fuels and Solvent Use		CO <sub>2</sub>	2,343.67	55%	1.4%	76.6%
#19	2.B	Chemical Industry	Other products except Ammonia	CO <sub>2</sub>	2,261.56	55%	1.4%	78.0%
#20	2.G	Other Product Manufacture and Use		SF <sub>6</sub>	1,355.68	83%	1.2%	79.2%
#21	5.C	Incineration and Open Burning of Waste		N <sub>2</sub> O	1,408.00	78%	1.2%	80.4%
#22	4.B	Cropland	1. Cropland remaining Cropland	CO <sub>2</sub>	4,538.93	24%	1.2%	81.6%
#23	2.A	Mineral Industry	1. Cement Production	CO <sub>2</sub>	24,490.27	4%	1.1%	82.7%
#24	1.A.4.	Other Sectors	Gaseous Fuels	CO <sub>2</sub>	41,831.17	2%	1.1%	83.8%
#25	2.E	Electronics Industry		SF <sub>6</sub>	324.20	300%	1.1%	84.8%
#26	1.A.3.	Transport	b. Road Transportation	N <sub>2</sub> O	1,274.71	72%	1.0%	85.8%
#27	3.D	Agricultural Soils	1. Direct Emissions	N <sub>2</sub> O	3,475.73	26%	1.0%	86.8%
#28	5.D	Wastewater Treatment and Discharge		N <sub>2</sub> O	2,090.54	40%	0.9%	87.7%
#29	3.C	Rice Cultivation		CH <sub>4</sub>	12,004.45	6%	0.8%	88.5%
#30		Indirect CO <sub>2</sub>	from IPPU sector	Ind CO <sub>2</sub>	1,560.69	46%	0.8%	89.3%

Approach1 level assessment of the base year emissions and removals (FY1990) gives the following 27 sub-categories as the key categories (Table A1-5). Approach 2 level assessment of the base year emissions and removals (FY1990) gives the following 31 sub-categories as the key categories (Table A1-6).

Table A1-5 Results of Approach 1 level assessment (FY1990)

A IPCC Code	B IPCC Category	C GHGs	D FY1990 Estimate [Gg-CO <sub>2</sub> eq.]	H Ap1-L	I Ap1-L Contrib. [%]	Cumulative contrib. [%]	
#1	1.A.2. Manufacturing Industries and Construction	Solid Fuels	CO <sub>2</sub>	199,587.36	0.145	14.5%	14.5%
#2	1.A.3. Transport	b. Road Transportation	CO <sub>2</sub>	180,367.42	0.131	13.1%	27.7%
#3	1.A.1. Energy Industries	Liquid Fuels	CO <sub>2</sub>	178,960.86	0.130	13.0%	40.7%
#4	1.A.2. Manufacturing Industries and Construction	Liquid Fuels	CO <sub>2</sub>	134,126.79	0.098	9.8%	50.5%
#5	1.A.4. Other Sectors	Liquid Fuels	CO <sub>2</sub>	129,077.78	0.094	9.4%	59.9%
#6	1.A.1. Energy Industries	Solid Fuels	CO <sub>2</sub>	109,537.93	0.080	8.0%	67.9%
#7	1.A.1. Energy Industries	Gaseous Fuels	CO <sub>2</sub>	80,030.95	0.058	5.8%	73.7%
#8	4.A. Forest Land	1. Forest Land remaining Forest Land	CO <sub>2</sub>	-72,390.33	0.053	5.3%	79.0%
#9	2.A. Mineral Industry	1. Cement Production	CO <sub>2</sub>	38,701.10	0.028	2.8%	81.8%
#10	1.A.4. Other Sectors	Gaseous Fuels	CO <sub>2</sub>	22,241.56	0.016	1.6%	83.5%
#11	2.B. Chemical Industry	9. Fluorochemical Production (Fugitive Emissions)	HFCs	15,930.24	0.012	1.2%	84.6%
#12	1.A.3. Transport	d. Domestic Navigation	CO <sub>2</sub>	13,674.88	0.010	1.0%	85.6%
#13	5.C. Incineration and Open Burning of Waste		CO <sub>2</sub>	12,317.55	0.009	0.9%	86.5%
#14	3.C. Rice Cultivation		CH <sub>4</sub>	12,129.25	0.009	0.9%	87.4%
#15	1.A.2. Manufacturing Industries and Construction	Gaseous Fuels	CO <sub>2</sub>	11,894.05	0.009	0.9%	88.3%
#16	5.A. Solid Waste Disposal		CH <sub>4</sub>	9,509.73	0.007	0.7%	89.0%
#17	3.A. Enteric Fermentation		CH <sub>4</sub>	9,422.90	0.007	0.7%	89.7%
#18	2.G. Other Product Manufacture and Use		SF <sub>6</sub>	8,814.04	0.006	0.6%	90.3%
#19	4.B. Cropland	1. Cropland remaining Cropland	CO <sub>2</sub>	7,406.84	0.005	0.5%	90.8%
#20	2.C. Metal Production	1. Iron and Steel Production	CO <sub>2</sub>	7,211.36	0.005	0.5%	91.4%
#21	2.B. Chemical Industry	3. Adipic Acid Production	N <sub>2</sub> O	7,210.88	0.005	0.5%	91.9%
#22	1.A.3. Transport	a. Domestic Aviation	CO <sub>2</sub>	7,162.41	0.005	0.5%	92.4%
#23	2.A. Mineral Industry	2. Lime Production	CO <sub>2</sub>	6,674.45	0.005	0.5%	92.9%
#24	4.A. Forest Land	2. Land converted to Forest Land	CO <sub>2</sub>	-6,670.96	0.005	0.5%	93.4%
#25	1.A.4. Other Sectors	Other Fossil Fuels	CO <sub>2</sub>	6,504.76	0.005	0.5%	93.9%
#26	1.B. Fugitive Emission from Fuel	1. Fugitive emissions from Solid Fuels	CH <sub>4</sub>	4,894.72	0.004	0.4%	94.2%
#27	3.D. Agricultural Soils	1. Direct Emissions	N <sub>2</sub> O	4,619.16	0.003	0.3%	94.5%
#28	2.F. Product uses as substitutes for ODS	5. Solvents	PFCs	4,549.94	0.003	0.3%	94.9%

Note: A source category #28, which was not identified as key in (1) but was done in (2), was not regarded as key.

Table A1-6 Results of Approach 2 level assessment (FY1990)

A IPCC Code	B IPCC Category	C GHGs	D FY1990 Estimate [Gg-CO <sub>2</sub> eq.]	L Source/Sink Uncertainty [%]	N Ap2-L Contrib. [%]	Cumulative contrib. [%]	
#1	1.A.2. Manufacturing Industries and Construction	Solid Fuels	CO <sub>2</sub>	199,587.36	6%	9.6%	9.6%
#2	4.A. Forest Land	1. Forest Land remaining Forest Land	CO <sub>2</sub>	-72,390.33	13%	7.7%	17.3%
#3	1.A.3. Transport	b. Road Transportation	CO <sub>2</sub>	180,367.42	5%	7.2%	24.5%
#4	1.A.1. Energy Industries	Liquid Fuels	CO <sub>2</sub>	178,960.86	5%	7.1%	31.7%
#5	2.G. Other Product Manufacture and Use		SF <sub>6</sub>	8,814.04	83%	6.2%	37.9%
#6	1.A.2. Manufacturing Industries and Construction	Liquid Fuels	CO <sub>2</sub>	134,126.79	5%	5.4%	43.2%
#7	1.A.1. Energy Industries	Solid Fuels	CO <sub>2</sub>	109,537.93	6%	5.3%	48.5%
#8	1.A.4. Other Sectors	Liquid Fuels	CO <sub>2</sub>	129,077.78	5%	5.2%	53.6%
#9	3.D. Agricultural Soils	2. Indirect Emissions	N <sub>2</sub> O	2,989.27	164%	4.2%	57.8%
#10	3.B. Manure Management		N <sub>2</sub> O	4,214.23	89%	3.2%	61.0%
#11	1.B. Fugitive Emission from Fuel	1. Fugitive emissions from Solid Fuels	CH <sub>4</sub>	4,894.72	65%	2.7%	63.7%
#12	3.A. Enteric Fermentation		CH <sub>4</sub>	9,422.90	27%	2.1%	65.8%
#13	1.A.3. Transport	b. Road Transportation	N <sub>2</sub> O	3,457.24	72%	2.1%	67.9%
#14	5.A. Solid Waste Disposal		CH <sub>4</sub>	9,509.73	22%	1.8%	69.7%
#15	Indirect CO <sub>2</sub>	from IPPU sector	Ind CO <sub>2</sub>	4,506.13	46%	1.8%	71.4%
#16	2.B. Chemical Industry	Other products except Ammonia	CO <sub>2</sub>	3,623.06	55%	1.7%	73.1%
#17	5.C. Incineration and Open Burning of Waste		CO <sub>2</sub>	12,317.55	16%	1.7%	74.8%
#18	1.A.1. Energy Industries	Gaseous Fuels	CO <sub>2</sub>	80,030.95	2%	1.6%	76.4%
#19	4.B. Cropland	1. Cropland remaining Cropland	CO <sub>2</sub>	7,406.84	24%	1.5%	77.9%
#20	2.B. Chemical Industry	4. Caprolactam, Glyoxal and Glyoxylic Acid Production	N <sub>2</sub> O	1,672.86	99%	1.4%	79.3%
#21	2.A. Mineral Industry	1. Cement Production	CO <sub>2</sub>	38,701.10	4%	1.4%	80.7%
#22	2.E. Electronics Industry		SF <sub>6</sub>	418.70	300%	1.1%	81.8%
#23	1.A.4. Other Sectors	Other Fossil Fuels	CO <sub>2</sub>	6,504.76	19%	1.0%	82.8%
#24	3.D. Agricultural Soils	1. Direct Emissions	N <sub>2</sub> O	4,619.16	26%	1.0%	83.8%
#25	2.E. Electronics Industry		PFCs	1,454.78	81%	1.0%	84.8%
#26	5.C. Incineration and Open Burning of Waste		N <sub>2</sub> O	1,438.04	78%	1.0%	85.8%
#27	2.D. Non-energy Products from Fuels and Solvent Use		CO <sub>2</sub>	2,039.82	55%	0.9%	86.7%
#28	5.D. Wastewater Treatment and Discharge		N <sub>2</sub> O	2,387.11	40%	0.8%	87.5%
#29	4.E. Settlements	2. Land converted to Settlements	CO <sub>2</sub>	4,237.43	22%	0.8%	88.3%
#30	4.A. Forest Land	2. Land converted to Forest Land	CO <sub>2</sub>	-6,670.96	13%	0.7%	89.0%
#31	1.A.2. Manufacturing Industries and Construction	Other Fossil Fuels	CO <sub>2</sub>	4,207.45	19%	0.7%	89.7%

### A1.2.3 Trend Assessment

The difference between the rate of change in emissions and removals in a category and the rate of change in total emissions and removals is calculated. The trend assessment is calculated by multiplying this value by the ratio of contribution of the relevant category to total emissions and removals. The calculated results, regarded as trend assessment values, are added from the category whose proportion to the total of trend assessment values is the largest, until the total reaches 95% for Approach 1 and 90% for Approach 2. At this point, these categories are defined as the key categories. Approach 1 trend assessment uses emissions and removals from each category directly and Approach 2 trend assessment analyzes the emissions and removals of each category, multiplied by the uncertainty of each category.

The key category analysis was first conducted for the inventory excluding LULUCF and the key categories for source sectors were identified (1). Then the key category analysis was repeated for the full inventory including the LULUCF categories and key categories for the whole inventory were identified (2). A source category, which was identified as key in (1) but not in (2), was still regarded as key; while a source category, which was not identified as key in (1) but was done in (2), was not regarded as key (gray rows in tables below).

Approach 1 trend assessment of the latest emissions and removals (FY2020) gives the following 21 sub-categories as the key categories (Table A1-7). Approach 2 trend assessment of the latest emissions and removals (FY2020) gives the following 27 sub-categories as the key categories (Table A1-8).

Table A1-7 Results of Approach 1 trend assessment (FY2020)

A IPCC Code	B IPCC Category	C GHGs	D FY1990 Estimate [Gg-CO <sub>2</sub> eq.]	F Current Year Estimate [Gg-CO <sub>2</sub> eq.]	J Ap1-T	K Ap1-T Contrib. [%]	Cumulative contrib. [%]
#1	1.A.1. Energy Industries	Solid Fuels	109,537.93	242,501.88	0.103	19.8%	19.8%
#2	1.A.1. Energy Industries	Liquid Fuels	178,960.86	45,037.31	0.087	16.7%	36.5%
#3	1.A.1. Energy Industries	Gaseous Fuels	80,030.95	148,765.38	0.055	10.5%	47.0%
#4	1.A.2. Manufacturing Industries and Construction	Liquid Fuels	134,126.79	49,388.61	0.054	10.3%	57.4%
#5	2.F Product uses as substitutes for ODS	1. Refrigeration and Air conditioning	0.00	47,678.19	0.035	6.7%	64.0%
#6	1.A.2. Manufacturing Industries and Construction	Solid Fuels	199,587.36	144,169.52	0.029	5.5%	69.5%
#7	1.A.4. Other Sectors	Liquid Fuels	129,077.78	82,239.11	0.026	5.1%	74.6%
#8	4.A Forest Land	1. Forest Land remaining Forest Land	-72,390.33	-56,372.66	0.016	3.1%	77.6%
#9	1.A.4. Other Sectors	Gaseous Fuels	22,241.56	41,831.17	0.016	3.0%	80.6%
#10	1.A.2. Manufacturing Industries and Construction	Gaseous Fuels	11,894.05	29,562.69	0.014	2.6%	83.2%
#11	2.B Chemical Industry	9. Fluorochemical Production (Fugitive Emissions)	15,930.24	216.44	0.011	2.0%	85.3%
#12	2.A Mineral Industry	1. Cement Production	38,701.10	24,490.27	0.008	1.5%	86.8%
#13	1.A.2. Manufacturing Industries and Construction	Other Fossil Fuels	4,207.45	10,713.05	0.005	1.0%	87.8%
#14	2.G Other Product Manufacture and Use	SF <sub>6</sub>	8,814.04	1,355.68	0.005	0.9%	88.7%
#15	4.A Forest Land	2. Land converted to Forest Land	-6,670.96	-766.83	0.005	0.9%	89.6%
#16	2.B Chemical Industry	3. Adipic Acid Production	7,210.88	340.65	0.005	0.9%	90.5%
#17	1.A.4. Other Sectors	Solid Fuels	353.86	6,481.63	0.004	0.9%	91.3%
#18	5.A Solid Waste Disposal	CH <sub>4</sub>	9,509.73	2,654.13	0.004	0.8%	92.2%
#19	1.B Fugitive Emission from Fuel	1. Fugitive emissions from Solid Fuels	4,894.72	468.95	0.003	0.6%	92.8%
#20	1.A.3. Transport	b. Road Transportation	180,367.42	161,847.20	0.003	0.5%	93.3%
#21	2.B Chemical Industry	9. Fluorochemical Production (Fugitive Emissions)	3,470.78	52.03	0.002	0.4%	93.7%
#22	2.F Product uses as substitutes for ODS	2. Foam Blowing Agents	1.34	2,924.97	0.002	0.4%	94.1%
#23	2.F Product uses as substitutes for ODS	5. Solvents	4,549.94	1,456.57	0.002	0.4%	94.5%
#24	Indirect CO <sub>2</sub>	from IPPU sector	4,506.13	1,560.69	0.002	0.4%	94.9%

Note: Source categories #20, #23 and #24, which were not identified as key in (1) but were done in (2), were not regarded as keys.

Table A1-8 Results of Approach 2 trend assessment (FY2020)

A IPCC Code	B IPCC Category	C GHGs	D FY1990 Estimate [Gg-CO2e q.]	F Current Year Estimate [Gg-CO2 e q.]	L Source/Sink Uncertainty [%]	O Ap2-T	P Ap2-T Contrib. [%]	Cumulative contrib. [%]	
#1	1.A.1. Energy Industries	Solid Fuels	CO2	109,537.93	242,501.88	6%	5.83	14.0%	14.0%
#2	1.A.1. Energy Industries	Liquid Fuels	CO2	178,960.86	45,037.31	5%	4.08	9.8%	23.9%
#3	2.G Other Product Manufacture and Use		SF6	8,814.04	1,355.68	83%	4.08	9.8%	33.7%
#4	1.A.2. Manufacturing Industries and Construction	Liquid Fuels	CO2	134,126.79	49,388.61	5%	2.53	6.1%	39.8%
#5	2.F Product uses as substitutes for ODS	1. Refrigeration and Air conditioning	HFCs	0.00	47,678.19	6%	2.22	5.3%	45.1%
#6	4.A Forest Land	1. Forest Land remaining Forest Land	CO2	-72,390.33	-56,372.66	13%	2.01	4.8%	49.9%
#7	1.B Fugitive Emission from Fuel	1.Fugitive emissions from Solid Fuels	CH4	4,894.72	468.95	65%	1.90	4.6%	54.5%
#8	1.A.2. Manufacturing Industries and Construction	Solid Fuels	CO2	199,587.36	144,169.52	6%	1.61	3.9%	58.4%
#9	1.A.1. Energy Industries	Gaseous Fuels	CO2	80,030.95	148,765.38	2%	1.30	3.1%	61.5%
#10	1.A.4. Other Sectors	Liquid Fuels	CO2	129,077.78	82,239.11	5%	1.24	3.0%	64.5%
#11	2.F Product uses as substitutes for ODS	2. Foam Blowing Agents	HFCs	1.34	2,924.97	50%	1.07	2.6%	67.1%
#12	2.B Chemical Industry	4. Caprolactam, Glyoxal and Glyoxylic Acid Production	N2O	1,672.86	119.26	99%	1.02	2.5%	69.5%
#13	1.A.3. Transport	b. Road Transportation	N2O	3,457.24	1,274.71	72%	0.99	2.4%	71.9%
#14	5.A Solid Waste Disposal		CH4	9,509.73	2,654.13	22%	0.98	2.4%	74.3%
#15	1.A.2. Manufacturing Industries and Construction	Other Fossil Fuels	CO2	4,207.45	10,713.05	19%	0.94	2.3%	76.6%
#16		Indirect CO2 from IPPU sector	Ind CO2	4,506.13	1,560.69	46%	0.86	2.1%	78.6%
#17	4.A Forest Land	2. Land converted to Forest Land	CO2	-6,670.96	-766.83	13%	0.59	1.4%	80.1%
#18	3.D Agricultural Soils	2. Indirect Emissions	N2O	2,989.27	2,333.13	164%	0.49	1.2%	81.2%
#19	2.B Chemical Industry	Other products except Ammonia	CO2	3,623.06	2,261.56	55%	0.43	1.0%	82.3%
#20	2.B Chemical Industry	3. Adipic Acid Production	N2O	7,210.88	340.65	9%	0.42	1.0%	83.3%
#21	4.B Cropland	1. Cropland remaining Cropland	CO2	7,406.84	4,538.93	24%	0.39	0.9%	84.2%
#22	4.E Settlements	2. Land converted to Settlements	CO2	4,237.43	1,475.39	22%	0.39	0.9%	85.2%
#23	1.A.4. Other Sectors	Gaseous Fuels	CO2	22,241.56	41,831.17	2%	0.37	0.9%	86.0%
#24	2.A Mineral Industry	1. Cement Production	CO2	38,701.10	24,490.27	4%	0.33	0.8%	86.8%
#25	2.E Electronics Industry		PFCS	1,454.78	1,887.75	81%	0.32	0.8%	87.6%
#26	1.A.2. Manufacturing Industries and Construction	Gaseous Fuels	CO2	11,894.05	29,562.69	2%	0.32	0.8%	88.4%
#27	1.A.4. Other Sectors	Other Fossil Fuels	CO2	6,504.76	8,252.02	19%	0.31	0.8%	89.2%
#28	2.B Chemical Industry	2. Nitric Acid Production	N2O	736.06	202.68	73%	0.25	0.6%	89.8%

Note: A source category #28, which was not identified as key in (1) but was done in (2), was not regarded as key.

Data utilized for the key category analysis are shown in Table A1-9 and A1-10 as references.

Table A1-9 Data used for the key category analysis (FY2020)

A IPCC Code	B IPCC Category	C GHGs	E Absolute Value of FY1990 Estimate [Gg-CO2e q.]	G Absolute Value of Current Year Estimate [Gg-CO2e q.]	H Ap1-L	I Ap1-L Contrib. [%]	J Ap1-T	K Ap1-T Contrib. [%]	L Source/Sink Uncertainty [%]	M Ap2-L	N Ap2-L Contrib. [%]	O Ap2-T	P Ap2-T Contrib. [%]	
1.A.1.	Energy Industries	Liquid Fuels	CO2	178,960.86	45,037.31	0.037	3.7%	0.0870	16.7%	5%	0.023	2.3%	4.08	9.8%
1.A.1.	Energy Industries	Solid Fuels	CO2	109,537.93	242,501.88	0.199	19.9%	0.1034	19.8%	6%	0.149	14.9%	5.83	14.0%
1.A.1.	Energy Industries	Gaseous Fuels	CO2	80,030.95	148,765.38	0.122	12.2%	0.0549	10.5%	2%	0.039	3.9%	1.30	3.1%
1.A.1.	Energy Industries	Other Fossil Fuels	CO2	0.00	29.46	0.000	0.0%	0.0000	0.0%	19%	0.000	0.0%	0.00	0.0%
1.A.1.	Energy Industries		CH4	459.35	401.80	0.000	0.0%	0.0000	0.0%	49%	0.002	0.2%	0.01	0.0%
1.A.1.	Energy Industries		N2O	889.48	1,862.45	0.002	0.2%	0.0008	0.1%	30%	0.006	0.6%	0.23	0.5%
1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO2	134,126.79	49,388.61	0.041	4.1%	0.0538	10.3%	5%	0.025	2.5%	2.53	6.1%
1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO2	199,587.36	144,169.52	0.119	11.9%	0.0285	5.5%	6%	0.089	8.9%	1.61	3.9%
1.A.2.	Manufacturing Industries and Construction	Gaseous Fuels	CO2	11,894.05	29,562.69	0.024	2.4%	0.0136	2.6%	2%	0.008	0.8%	0.32	0.8%
1.A.2.	Manufacturing Industries and Construction	Other Fossil Fuels	CO2	4,207.45	10,713.05	0.009	0.9%	0.0050	1.0%	19%	0.022	2.2%	0.94	2.3%
1.A.2.	Manufacturing Industries and Construction		CH4	359.76	537.38	0.000	0.0%	0.0002	0.0%	49%	0.003	0.3%	0.07	0.2%
1.A.2.	Manufacturing Industries and Construction		N2O	1,259.81	1,481.50	0.001	0.1%	0.0002	0.0%	30%	0.005	0.5%	0.07	0.2%
1.A.3.	Transport	a. Domestic Aviation	CO2	7,162.41	5,237.81	0.004	0.4%	0.0010	0.2%	5%	0.003	0.3%	0.05	0.1%
1.A.3.	Transport	a. Domestic Aviation	CH4	5.64	0.52	0.000	0.0%	0.0000	0.0%	79%	0.000	0.0%	0.00	0.0%
1.A.3.	Transport	a. Domestic Aviation	N2O	64.02	43.42	0.000	0.0%	0.0000	0.0%	110%	0.001	0.1%	0.01	0.0%
1.A.3.	Transport	b. Road Transportation	CO2	180,367.42	161,847.20	0.133	13.3%	0.0028	0.530%	5%	0.083	8.3%	0.13	0.3%
1.A.3.	Transport	b. Road Transportation	CH4	252.59	81.72	0.000	0.0%	0.0001	0.0%	70%	0.001	0.1%	0.08	0.2%
1.A.3.	Transport	b. Road Transportation	N2O	3,457.24	1,274.71	0.001	0.1%	0.0014	0.3%	72%	0.010	1.0%	0.99	2.4%
1.A.3.	Transport	c. Railways	CO2	935.40	488.16	0.000	0.0%	0.0003	0.1%	5%	0.000	0.0%	0.01	0.0%
1.A.3.	Transport	c. Railways	CH4	1.34	0.69	0.000	0.0%	0.0000	0.0%	105%	0.000	0.0%	0.00	0.0%
1.A.3.	Transport	c. Railways	N2O	109.95	56.62	0.000	0.0%	0.0000	0.0%	125%	0.001	0.1%	0.04	0.1%
1.A.3.	Transport	d. Domestic Navigation	CO2	13,674.88	10,069.57	0.008	0.8%	0.0018	0.3%	5%	0.005	0.5%	0.09	0.2%
1.A.3.	Transport	d. Domestic Navigation	CH4	31.73	22.46	0.000	0.0%	0.0000	0.0%	52%	0.000	0.0%	0.00	0.0%
1.A.3.	Transport	d. Domestic Navigation	N2O	108.07	76.49	0.000	0.0%	0.0000	0.0%	91%	0.001	0.1%	0.02	0.0%
1.A.4.	Other Sectors	Liquid Fuels	CO2	129,077.78	82,239.11	0.068	6.8%	0.0265	5.1%	5%	0.042	4.2%	1.24	3.0%
1.A.4.	Other Sectors	Solid Fuels	CO2	353.86	6,481.63	0.005	0.5%	0.0045	0.9%	6%	0.004	0.4%	0.25	0.6%
1.A.4.	Other Sectors	Gaseous Fuels	CO2	22,241.56	41,831.17	0.034	3.4%	0.0156	3.0%	2%	0.011	1.1%	0.37	0.9%
1.A.4.	Other Sectors	Other Fossil Fuels	CO2	6,504.76	8,252.02	0.007	0.7%	0.0017	0.3%	19%	0.017	1.7%	0.31	0.8%
1.A.4.	Other Sectors		CH4	238.65	207.19	0.000	0.0%	0.0000	0.0%	49%	0.001	0.1%	0.00	0.0%
1.A.4.	Other Sectors		N2O	689.41	662.06	0.001	0.1%	0.0000	0.0%	30%	0.002	0.2%	0.01	0.0%
1.B	Fugitive Emission from Fuel	1.Fugitive emissions from Solid Fuels	CO2	5.43	0.42	0.000	0.0%	0.0000	0.0%	68%	0.000	0.0%	0.00	0.0%
1.B	Fugitive Emission from Fuel	1.Fugitive emissions from Solid Fuels	CH4	4,894.72	468.95	0.000	0.0%	0.0029	0.6%	65%	0.003	0.3%	1.90	4.6%
1.B	Fugitive Emission from Fuel	1.Fugitive emissions from Solid Fuels	N2O	1.98	0.47	0.000	0.0%	0.0000	0.0%	119%	0.000	0.0%	0.00	0.0%
1.B	Fugitive Emission from Fuel	2.a. Oil	CO2	0.03	0.02	0.000	0.0%	0.0000	0.0%	89%	0.000	0.0%	0.00	0.0%
1.B	Fugitive Emission from Fuel	2.a. Oil	CH4	25.37	16.76	0.000	0.0%	0.0000	0.0%	69%	0.000	0.0%	0.00	0.0%
1.B	Fugitive Emission from Fuel	2.b. Natural Gas	CO2	0.63	0.72	0.000	0.0%	0.0000	0.0%	80%	0.000	0.0%	0.00	0.0%
1.B	Fugitive Emission from Fuel	2.b. Natural Gas	CH4	174.24	194.06	0.000	0.0%	0.0000	0.0%	73%	0.002	0.2%	0.02	0.0%
1.B	Fugitive Emission from Fuel	2.c. Venting & Flaring	CO2	81.17	197.63	0.000	0.0%	0.0001	0.0%	14%	0.000	0.0%	0.01	0.0%
1.B	Fugitive Emission from Fuel	2.c. Venting & Flaring	CH4	7.96	4.85	0.000	0.0%	0.0000	0.0%	49%	0.000	0.0%	0.00	0.0%
1.B	Fugitive Emission from Fuel	2.c. Venting & Flaring	N2O	0.11	0.08	0.000	0.0%	0.0000	0.0%	32%	0.000	0.0%	0.00	0.0%
1.B	Fugitive Emission from Fuel	2.d. Other (Geothermal)	CO2	104.42	145.73	0.000	0.0%	0.0000	0.0%	17%	0.000	0.0%	0.01	0.0%
1.B	Fugitive Emission from Fuel	2.d. Other (Geothermal)	CH4	5.21	7.16	0.000	0.0%	0.0000	0.0%	17%	0.000	0.0%	0.00	0.0%



Table A1-10 Data used for the key category analysis (FY1990)

A IPCC Code	B IPCC Category	C GHGs	E Absolute Value of FY1990 Estimate [Gg-CO2eq.]	H Ap1-L	I Ap1-L Contrib. [%]	L Source/Sink Uncertainty [%]	M Ap2-L	N Ap2-L Contrib. [%]	
1.A.1.	Energy Industries	Liquid Fuels	CO2	178,960.86	0.130	13.0%	5%	0.071	7.1%
1.A.1.	Energy Industries	Solid Fuels	CO2	109,537.93	0.080	8.0%	6%	0.053	5.3%
1.A.1.	Energy Industries	Gaseous Fuels	CO2	80,030.95	0.058	5.8%	2%	0.016	1.6%
1.A.1.	Energy Industries	Other Fossil Fuels	CO2	0.00	0.000	0.0%	19%	0.000	0.0%
1.A.1.	Energy Industries		CH4	459.35	0.000	0.0%	49%	0.002	0.2%
1.A.1.	Energy Industries		N2O	889.48	0.001	0.1%	30%	0.002	0.2%
1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO2	134,126.79	0.098	9.8%	5%	0.054	5.4%
1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO2	199,587.36	0.145	14.5%	6%	0.096	9.6%
1.A.2.	Manufacturing Industries and Construction	Gaseous Fuels	CO2	11,894.05	0.009	0.9%	2%	0.002	0.2%
1.A.2.	Manufacturing Industries and Construction	Other Fossil Fuels	CO2	4,207.45	0.003	0.3%	19%	0.007	0.7%
1.A.2.	Manufacturing Industries and Construction		CH4	359.76	0.000	0.0%	49%	0.002	0.2%
1.A.2.	Manufacturing Industries and Construction		N2O	1,259.81	0.001	0.1%	30%	0.003	0.3%
1.A.3.	Transport	a. Domestic Aviation	CO2	7,162.41	0.005	0.5%	5%	0.003	0.3%
1.A.3.	Transport	a. Domestic Aviation	CH4	5.64	0.000	0.0%	79%	0.000	0.0%
1.A.3.	Transport	a. Domestic Aviation	N2O	64.02	0.000	0.0%	110%	0.001	0.1%
1.A.3.	Transport	b. Road Transportation	CO2	180,367.42	0.131	13.1%	5%	0.072	7.2%
1.A.3.	Transport	b. Road Transportation	CH4	252.59	0.000	0.0%	70%	0.002	0.2%
1.A.3.	Transport	b. Road Transportation	N2O	3,457.24	0.003	0.3%	72%	0.021	2.1%
1.A.3.	Transport	c. Railways	CO2	935.40	0.001	0.1%	5%	0.000	0.0%
1.A.3.	Transport	c. Railways	CH4	1.34	0.000	0.0%	105%	0.000	0.0%
1.A.3.	Transport	c. Railways	N2O	109.95	0.000	0.0%	125%	0.001	0.1%
1.A.3.	Transport	d. Domestic Navigation	CO2	13,674.88	0.010	1.0%	5%	0.005	0.5%
1.A.3.	Transport	d. Domestic Navigation	CH4	31.73	0.000	0.0%	52%	0.000	0.0%
1.A.3.	Transport	d. Domestic Navigation	N2O	108.07	0.000	0.0%	91%	0.001	0.1%
1.A.4.	Other Sectors	Liquid Fuels	CO2	129,077.78	0.094	9.4%	5%	0.052	5.2%
1.A.4.	Other Sectors	Solid Fuels	CO2	353.86	0.000	0.0%	6%	0.000	0.0%
1.A.4.	Other Sectors	Gaseous Fuels	CO2	22,241.56	0.016	1.6%	2%	0.004	0.4%
1.A.4.	Other Sectors	Other Fossil Fuels	CO2	6,504.76	0.005	0.5%	19%	0.010	1.0%
1.A.4.	Other Sectors		CH4	238.65	0.000	0.0%	49%	0.001	0.1%
1.A.4.	Other Sectors		N2O	689.41	0.001	0.1%	30%	0.002	0.2%
1.B	Fugitive Emission from Fuel	1.Fugitive emissions from Solid Fuels	CO2	5.43	0.000	0.0%	68%	0.000	0.0%
1.B	Fugitive Emission from Fuel	1.Fugitive emissions from Solid Fuels	CH4	4,894.72	0.004	0.4%	65%	0.027	2.7%
1.B	Fugitive Emission from Fuel	1.Fugitive emissions from Solid Fuels	N2O	1.98	0.000	0.0%	119%	0.000	0.0%
1.B	Fugitive Emission from Fuel	2.a. Oil	CO2	0.03	0.000	0.0%	89%	0.000	0.0%
1.B	Fugitive Emission from Fuel	2.a. Oil	CH4	25.37	0.000	0.0%	69%	0.000	0.0%
1.B	Fugitive Emission from Fuel	2.b. Natural Gas	CO2	0.63	0.000	0.0%	80%	0.000	0.0%
1.B	Fugitive Emission from Fuel	2.b. Natural Gas	CH4	174.24	0.000	0.0%	73%	0.001	0.1%
1.B	Fugitive Emission from Fuel	2.c. Venting & Flaring	CO2	81.17	0.000	0.0%	14%	0.000	0.0%
1.B	Fugitive Emission from Fuel	2.c. Venting & Flaring	CH4	7.96	0.000	0.0%	49%	0.000	0.0%
1.B	Fugitive Emission from Fuel	2.c. Venting & Flaring	N2O	0.11	0.000	0.0%	32%	0.000	0.0%
1.B	Fugitive Emission from Fuel	2.d. Other (Geothermal)	CO2	104.42	0.000	0.0%	17%	0.000	0.0%
1.B	Fugitive Emission from Fuel	2.d. Other (Geothermal)	CH4	5.21	0.000	0.0%	17%	0.000	0.0%

Table A1-10 Data used for the key category analysis (FY1990) (Continued)

A IPCC Code	B IPCC Category	C GHGs	E Absolute Value of FY1990 Estimate [Gg-CO2eq.]	H Ap1-L	I Ap1-L Contrib. [%]	L Source/Sink Uncertainty [%]	M Ap2-L	N Ap2-L Contrib. [%]	
2.A	Mineral Industry	1. Cement Production	CO2	38,701.10	0.028	2.8%	4%	0.014	1.4%
2.A	Mineral Industry	2. Lime Production	CO2	6,674.45	0.005	0.5%	4%	0.002	0.2%
2.A	Mineral Industry	3. Glass Production	CO2	312.88	0.000	0.0%	6%	0.000	0.0%
2.A	Mineral Industry	4. Other Process Uses of Carbonates	CO2	3,542.02	0.003	0.3%	6%	0.002	0.2%
2.B	Chemical Industry	1. Ammonia Production	CO2	3,417.74	0.002	0.2%	1%	0.000	0.0%
2.B	Chemical Industry	Other products except Ammonia	CO2	3,623.06	0.003	0.3%	55%	0.017	1.7%
2.B	Chemical Industry	2. Nitric Acid Production	N2O	736.06	0.001	0.1%	73%	0.005	0.5%
2.B	Chemical Industry	3. Adipic Acid Production	N2O	7,210.88	0.005	0.5%	9%	0.006	0.6%
2.B	Chemical Industry	4. Caprolactam, Glyoxal and Glyoxylic Acid Production	N2O	1,672.86	0.001	0.1%	99%	0.014	1.4%
2.B	Chemical Industry	9. Fluorochemical Production (Fugitive Emissions)	HFCs	15,930.24	0.012	1.2%	2%	0.003	0.3%
2.B	Chemical Industry	9. Fluorochemical Production (Fugitive Emissions)	PFCs	330.92	0.000	0.0%	2%	0.000	0.0%
2.B	Chemical Industry	9. Fluorochemical Production (Fugitive Emissions)	SF6	3,470.78	0.003	0.3%	2%	0.001	0.1%
2.B	Chemical Industry	9. Fluorochemical Production (Fugitive Emissions)	NF3	2.79	0.000	0.0%	2%	0.000	0.0%
2.B	Chemical Industry	Whole of Chemical Industries	CH4	37.49	0.000	0.0%	55%	0.000	0.0%
2.C	Metal Production	1. Iron and Steel Production	CO2	7,211.36	0.005	0.5%	4%	0.002	0.2%
2.C	Metal Production	1. Iron and Steel Production	CH4	18.42	0.000	0.0%	163%	0.000	0.0%
2.C	Metal Production	2. Ferroalloys Production	CH4	4.63	0.000	0.0%	163%	0.000	0.0%
2.C	Metal Production	3. Aluminium Production	CO2	57.97	0.000	0.0%	10%	0.000	0.0%
2.C	Metal Production	3. Aluminium Production	PFCs	203.66	0.000	0.0%	38%	0.001	0.1%
2.C	Metal Production	4. SF6 Used in Aluminium and Magnesium foundries	HFCs	0.00	0.000	0.0%	5%	0.000	0.0%
2.C	Metal Production	4. SF6 Used in Aluminium and Magnesium foundries	SF6	146.54	0.000	0.0%	5%	0.000	0.0%
2.D	Non-energy Products from Fuels and Solvent Use		CO2	2,039.82	0.001	0.1%	55%	0.009	0.9%
2.E	Electronics Industry		HFCs	0.73	0.000	0.0%	100%	0.000	0.0%
2.E	Electronics Industry		PFCs	1,454.78	0.001	0.1%	81%	0.010	1.0%
2.E	Electronics Industry		SF6	418.70	0.000	0.0%	300%	0.011	1.1%
2.E	Electronics Industry		NF3	29.82	0.000	0.0%	71%	0.000	0.0%
2.F	Product uses as substitutes for ODS	1. Refrigeration and Air conditioning	HFCs	0.00	0.000	0.0%	6%	0.000	0.0%
2.F	Product uses as substitutes for ODS	2. Foam Blowing Agents	HFCs	1.34	0.000	0.0%	50%	0.000	0.0%
2.F	Product uses as substitutes for ODS	3. Fire Extinguishers	HFCs	0.00	0.000	0.0%	16%	0.000	0.0%
2.F	Product uses as substitutes for ODS	4. Aerosols	HFCs	0.00	0.000	0.0%	10%	0.000	0.0%
2.F	Product uses as substitutes for ODS	5. Solvents	HFCs	0.00	0.000	0.0%	11%	0.000	0.0%
2.F	Product uses as substitutes for ODS	5. Solvents	PFCs	4,549.94	0.003	0.3%	10%	0.004	0.4%
2.G	Other Product Manufacture and Use		N2O	290.86	0.000	0.0%	4%	0.000	0.0%
2.G	Other Product Manufacture and Use		PFCs	0.00	0.000	0.0%	10%	0.000	0.0%
2.G	Other Product Manufacture and Use		SF6	8,814.04	0.006	0.6%	83%	0.062	6.2%
2.H	Other	Use of Dry Ice	CO2	64.61	0.000	0.0%	4%	0.000	0.0%
3.A	Enteric Fermentation		CH4	9,422.90	0.007	0.7%	27%	0.021	2.1%
3.B	Manure Management		CH4	3,329.44	0.002	0.2%	17%	0.005	0.5%
3.B	Manure Management		N2O	4,214.23	0.003	0.3%	89%	0.032	3.2%
3.C	Rice Cultivation		CH4	12,129.25	0.009	0.9%	6%	0.006	0.6%
3.D	Agricultural Soils	1. Direct Emissions	N2O	4,619.16	0.003	0.3%	26%	0.010	1.0%
3.D	Agricultural Soils	2. Indirect Emissions	N2O	2,989.27	0.002	0.2%	164%	0.042	4.2%
3.F	Field Burning of Agricultural Residues		CH4	127.03	0.000	0.0%	296%	0.003	0.3%
3.F	Field Burning of Agricultural Residues		N2O	39.26	0.000	0.0%	300%	0.001	0.1%
3.G	Liming		CO2	550.24	0.000	0.0%	50%	0.002	0.2%
3.H	Urea Application		CO2	58.64	0.000	0.0%	50%	0.000	0.0%
4.A	Forest Land	1. Forest Land remaining Forest Land	CO2	72,390.33	0.053	5.3%	13%	0.077	7.7%
4.A	Forest Land	2. Land converted to Forest Land	CO2	6,670.96	0.005	0.5%	13%	0.007	0.7%
4.B	Cropland	1. Cropland remaining Cropland	CO2	7,406.84	0.005	0.5%	24%	0.015	1.5%
4.B	Cropland	2. Land converted to Cropland	CO2	1,551.00	0.001	0.1%	20%	0.003	0.3%
4.C	Grassland	1. Grassland remaining Grassland	CO2	485.52	0.000	0.0%	10%	0.000	0.0%
4.C	Grassland	2. Land converted to Grassland	CO2	173.24	0.000	0.0%	19%	0.000	0.0%
4.D	Wetlands	1.1 Peat Extraction Remaining Peat Extraction	CO2	0.00	0.000	0.0%	22%	0.000	0.0%
4.D	Wetlands	1.2 Flooded Land Remaining Flooded Land	CO2	0.00	0.000	0.0%	22%	0.000	0.0%
4.D	Wetlands	1.3 Other Wetlands Remaining Other Wetlands	CO2	0.00	0.000	0.0%	22%	0.000	0.0%
4.D	Wetlands	2. Land converted to Wetlands	CO2	90.51	0.000	0.0%	22%	0.000	0.0%
4.E	Settlements	1. Settlements remaining Settlements	CO2	1,364.90	0.001	0.1%	33%	0.004	0.4%
4.E	Settlements	2. Land converted to Settlements	CO2	4,237.43	0.003	0.3%	22%	0.008	0.8%
4.F	Other Land	1. Other Land remaining Other Land	CO2	0.00	0.000	0.0%	18%	0.000	0.0%
4.F	Other Land	2. Land converted to Other Land	CO2	1,264.65	0.001	0.1%	18%	0.002	0.2%
4.G	Harvested Wood Products		CO2	450.02	0.000	0.0%	30%	0.001	0.1%
4.H	Other (Organic soil in settlements converted from other land-use categories)		CH4	31.62	0.000	0.0%	71%	0.000	0.0%
4.H	Other (Organic soil in settlements converted from other land-use categories)		N2O	3.02	0.000	0.0%	138%	0.000	0.0%
4.(I)	Direct N2O emissions from N inputs to managed soils		N2O	0.84	0.000	0.0%	31%	0.000	0.0%
4.(II)	Drainage and rewetting		CO2	0.00	0.000	0.0%	0%	0.000	0.0%
4.(II)	CH4 Emissions from drainage of organic soils		CH4	26.43	0.000	0.0%	71%	0.000	0.0%
4.(II)	N2O Emissions from drainage of organic soils		N2O	0.00	0.000	0.0%	0%	0.000	0.0%
4.(III)	Direct N2O emissions from N mineralization/immobilization		N2O	166.41	0.000	0.0%	122%	0.002	0.2%
4.(IV)	Indirect N2O Emissions from Managed Soils		N2O	52.57	0.000	0.0%	233%	0.001	0.1%
4.(V)	Biomass Burning		CO2	0.00	0.000	0.0%	0%	0.000	0.0%
4.(V)	Biomass Burning		CH4	47.20	0.000	0.0%	79%	0.000	0.0%
4.(V)	Biomass Burning		N2O	22.15	0.000	0.0%	47%	0.000	0.0%
5.A	Solid Waste Disposal		CH4	9,509.73	0.007	0.7%	22%	0.018	1.8%
5.B	Biological Treatment of Solid Waste		CH4	53.99	0.000	0.0%	84%	0.000	0.0%
5.B	Biological Treatment of Solid Waste		N2O	180.77	0.000	0.0%	170%	0.003	0.3%
5.C	Incineration and Open Burning of Waste		CO2	12,317.55	0.009	0.9%	16%	0.017	1.7%
5.C	Incineration and Open Burning of Waste		CH4	27.78	0.000	0.0%	162%	0.000	0.0%
5.C	Incineration and Open Burning of Waste		N2O	1,438.04	0.001	0.1%	78%	0.010	1.0%
5.D	Wastewater Treatment and Discharge		CH4	2,941.55	0.002	0.2%	21%	0.005	0.5%
5.D	Wastewater Treatment and Discharge		N2O	2,387.11	0.002	0.2%	40%	0.008	0.8%
5.E	Other		CO2	702.83	0.001	0.1%	10%	0.001	0.1%
	Indirect CO2	from Energy sector	Ind CO2	1,042.29	0.001	0.1%	32%	0.003	0.3%
	Indirect CO2	from IPPU sector	Ind CO2	4,506.13	0.003	0.3%	46%	0.018	1.8%
Total (including LULUCF)				1,371,885.08	1.00	100.0%		1.00	100%

**References**

1. IPCC, *2006 IPCC Guidelines for National Greenhouse Inventories*, 2006.
2. UNFCCC, *UNFCCC reporting guidelines on annual greenhouse gas inventories* (Decision 24/CP.19 Annex I), 2013.



## Annex 2. Assessment of Uncertainty

### A2.1. Methodology of Uncertainty Assessment

“Uncertainty” is a conceptual framework which represents the differences between emissions/removals inventory estimates and true underlying values, resulting from lack of data or representativeness, sampling error, or, errors in measurement values, etc. In the paragraph 15 and 42 in the “UNFCCC reporting guidelines on annual greenhouse gas inventories” (Decision 24/CP.19 Annex I), it is noted that Annex I Parties shall quantitatively estimate and report the uncertainty of inventories. The assessment of uncertainties is intended to contribute to improve the accuracy of national inventories continuously and to guide decisions on methodological choice but not to evaluate justification of inventories nor make a comparison of accuracy of inventories among the parties.

The fundamental methodological issues of uncertainties assessment are provided in the IPCC guidelines; however, uncertainty assessment for specific emission sources and removal sinks is mainly subject to country-specific method determined by each party depending on country’s own circumstances. In Japan, the uncertainties were assessed based on the country-specific guidelines (MOE, 2013).

### A2.2. Results of Uncertainty Assessment

#### A2.2.1 Uncertainty of Japan’s Total Emissions

In FY2020, total net emissions in Japan were approximately 1,098 million tons (carbon dioxide equivalents). Uncertainty of total net emissions in FY2020 has been assessed at -4% to +2% and uncertainty introduced into the trend in total net emissions has been assessed at -4% to +2%. Thus, the uncertainty level was low in Japan, mainly because CO<sub>2</sub> emissions from low-uncertainty fuel combustion (1.A.) accounted for 90% of the net emissions.

Table A2-1 Uncertainty of Japan’s total net emissions

A Category	B GHGs	C	D	G-1990		G-2020		I Inventory trend in national emissions for 2020 increase with respect to 1990	J Uncertainty introduced into the trend in total national emissions	
		1990 emissions / removals	2020 emissions / removals	Combined uncertainty in 1990		Combined uncertainty in 2020			%	%
		kt-CO <sub>2</sub> eq.	kt-CO <sub>2</sub> eq.	(-) %	(+) %	(-) %	(+) %			(-) %
1A. Fuel Combustion (CO <sub>2</sub> )	CO <sub>2</sub>	1,078,663	986,615	-5%	+2%	-4%	+2%	-8.5%	-4.4%	+2.3%
1A. Fuel Combustion (Stationary:CH <sub>4</sub> ,N <sub>2</sub> O)	CH <sub>4</sub> , N <sub>2</sub> O	3,896	5,152	-23%	+29%	-24%	+28%	32.2%	0.0%	+0.0%
1A. Fuel Combustion (Transport:CH <sub>4</sub> ,N <sub>2</sub> O)	CH <sub>4</sub> , N <sub>2</sub> O	4,031	1,557	-32%	+92%	-30%	+88%	-61.4%	0.0%	+0.0%
1B. Fugitive Emissions from Fuels	CO <sub>2</sub> , CH <sub>4</sub> , N <sub>2</sub> O	5,301	1,037	-40%	+80%	-24%	+42%	-80.4%	0.0%	+0.0%
2. IPPU (CO <sub>2</sub> ,CH <sub>4</sub> ,N <sub>2</sub> O)	CO <sub>2</sub> , CH <sub>4</sub> , N <sub>2</sub> O	75,616	43,873	-4%	+4%	-5%	+5%	-42.0%	-0.1%	+0.1%
2. IPPU (HFCs,PFCs,SF <sub>6</sub> ,NF <sub>3</sub> )	HFCs, PFCs, SF <sub>6</sub> , NF <sub>3</sub>	35,354	57,517	-7%	+36%	-7%	+8%	62.7%	-0.6%	+0.6%
3. Agriculture	CO <sub>2</sub> , CH <sub>4</sub> , N <sub>2</sub> O	37,479	32,186	-11%	+29%	-10%	+25%	-14.1%	0.0%	+0.0%
4. LULUCF	CO <sub>2</sub> , CH <sub>4</sub> , N <sub>2</sub> O	-65,317	-52,010	-14%	+14%	-14%	+14%	-20.4%	-0.4%	+0.4%
5. Waste	CO <sub>2</sub> , CH <sub>4</sub> , N <sub>2</sub> O	29,559	20,186	-10%	+10%	-12%	+12%	-31.7%	-0.2%	+0.2%
Indirect CO <sub>2</sub>	Ind CO <sub>2</sub>	5,548	1,963	-27%	+48%	-27%	+47%	-64.6%	0.0%	+0.0%
Total Net Emissions		1,210,133	1,098,075	-4.5%	+2.3%	-3.6%	+2.2%	-9.3%	-4.5%	+2.4%

Data used for estimating emissions in each category are as follows:

Table A2-2 Data used for uncertainty assessment (Energy Sector)

A Category	B GHG	C 1990 emissions /removals / kt-CO <sub>2</sub> eq.	D 2020 emissions /removals / kt-CO <sub>2</sub> eq.	E Activity data uncertainty	F Emission factor/estimation parameter uncertainty	G Combined uncertainty		H-1990 Combined Uncertainty as % of Total Emissions in 1990		H-2020 Combined Uncertainty as % of Total Emissions in 2020		T Emission increase rate	I Type A sensitivity	J Type B sensitivity	K Uncertainty in trend in national emissions introduced by emission factor/estimation parameter uncertainty		L Uncertainty in trend in national emissions introduced by activity data uncertainty		M Uncertainty introduced into the trend in total national emissions		
						(-) %	(+) %	(-) %	(+) %	(-) %	(+) %				(-) %	(+) %	(-) %	(+) %	(-) %	(+) %	
Total		1,210,133	1,098,075					-4.5%	+2.3%	-3.6%	+2.2%	-9.3%	None*	D/ΣC							
L.A. Fuel Combustion	CO2	644,302	354,246					-8%	+2%	-2.5%	0.6%	-45.0%	0.2%	29.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
L.A. Fuel Combustion	CO2	309,482	393,154	-2%				-7%	+5%	-2.2%	1.7%	27.0%	0.1%	32.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
L.A. Fuel Combustion	CO2	114,167	220,220	+5%				-3%	+2%	-0.6%	0.3%	92.9%	0.1%	18.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
L.A. Fuel Combustion	CO2	10,712	18,995	+1%				-19%	+19%	-0.3%	0.3%	77.3%	0.0%	1.6%	NA	NA	NA	NA	NA	NA	NA
L.A. Stationary Combustion	CH4	1,058	1,146					-29%	+69%	0.0%	0.1%	8.4%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
L.A. Stationary Combustion	CH4	2,839	4,006					-30%	+30%	-0.1%	0.1%	41.1%	0.0%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
L.A.3. Transport	CH4	6	1	+5%				-57%	+100%	0.0%	0.0%	-90.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
L.A.3. Transport	N2O	64	43	+5%				-70%	+150%	0.0%	0.0%	-32.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
L.A.3. Transport	CH4	253	82					-36%	+104%	0.0%	0.0%	-67.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
L.A.3. Transport	N2O	3,457	1,275					-37%	+107%	0.0%	0.1%	-63.1%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
L.A.3. Transport	CH4	1	1	+5%				-60%	+151%	0.0%	0.0%	-48.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
L.A.3. Transport	N2O	110	57	+5%				-50%	+200%	0.0%	0.0%	-48.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
L.A.3. Transport	CH4	32	22	+13%				-52%	+52%	0.0%	0.0%	-29.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
L.A.3. Transport	N2O	108	76	+13%				-42%	+41%	0.0%	0.0%	-29.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
L.A.3. Transport	CH4	5	0					-46%	+89%	0.0%	0.0%	-92.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
L.B Fugitive Emission from Fuel	CO2	4,895	469					-43%	+87%	-0.2%	0.4%	-90.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
L.B Fugitive Emission from Fuel	CH4	2	0					-75%	+163%	0.0%	0.0%	-76.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
L.B Fugitive Emission from Fuel	CO2	0	0	+2%				-89%	+69%	0.0%	0.0%	-36.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
L.B Fugitive Emission from Fuel	CH4	25	17					-69%	+80%	0.0%	0.0%	-33.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
L.B Fugitive Emission from Fuel	CO2	1	1					-80%	+80%	0.0%	0.0%	13.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
L.B Fugitive Emission from Fuel	CH4	174	194					-70%	+76%	0.0%	0.0%	11.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
L.B Fugitive Emission from Fuel	CO2	81	198					-14%	+14%	0.0%	0.0%	143.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
L.B Fugitive Emission from Fuel	CH4	8	5					-49%	+49%	0.0%	0.0%	-39.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
L.B Fugitive Emission from Fuel	N2O	0	0					-32%	+32%	0.0%	0.0%	-26.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
L.B Fugitive Emission from Fuel	CO2	104	146	+15%				-17%	+17%	0.0%	0.0%	39.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
L.B Fugitive Emission from Fuel	CH4	5	7	+15%				-17%	+17%	0.0%	0.0%	37.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Table A2-3 Data used for uncertainty assessment (Industrial Processes and Product Use Sector)

A Category	B GHG	C 1990 emissions /removals		D 2020 emissions /removals		E Activity data uncertainty		F Emission factor/estimation parameter uncertainty		G Combined uncertainty		H-1990 Uncertainty as % of Total National Emissions in 1990		H-2020 Combined Uncertainty as % of Total National Emissions in 2020		T Emission increase rate		I Type A sensitivity		J Type B sensitivity		K Uncertainty in trend in national emissions introduced by emission factor/estimation parameter uncertainty		L Uncertainty in trend in national emissions introduced by activity data uncertainty		M Uncertainty introduced into the trend in total national emissions			
		Input Data	kt-CO <sub>2</sub> eq.	Input Data	kt-CO <sub>2</sub> eq.	(+) %	(-) %	Input Data	(+) %	(-) %	(E <sup>2</sup> +F <sup>2</sup> )/1/2	(+) %	(-) %	G <sup>2</sup> /ΣC	(+) %	(-) %	D/C	%	Noe *	%	D/ΣC	(+) %	(-) %	J*E <sup>2</sup> /2	(+) %	(-) %	(K <sup>2</sup> +L <sup>2</sup> )/1/2	(+) %	(-) %
2.A Mineral Industry	CO2	38,701	24,490	-2%	+2%	-4%	+4%	-4%	+4%	-4%	+4%	-0.1%	0.1%	-0.1%	0.1%	-36.7%	2.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%		
2.A Mineral Industry	CO2	6,674	5,470	-3%	+3%	-2%	+2%	-4%	+4%	-4%	+4%	0.0%	0.0%	0.0%	0.0%	-18.0%	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		
2.A Mineral Industry	CO2	313	191	-3%	+3%	-5%	+5%	-6%	+6%	-6%	+6%	0.0%	0.0%	0.0%	0.0%	-39.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		
2.A Mineral Industry	CO2	3,542	1,066	-3%	+3%	-5%	+5%	-6%	+6%	-6%	+6%	0.0%	0.0%	0.0%	0.0%	-69.9%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		
2.B Chemical Industry	CO2	3,418	1,410	-	-	-2%	+1%	-2%	+1%	-2%	+1%	0.0%	0.0%	0.0%	0.0%	-38.8%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		
2.B Chemical Industry	CO2	3,623	2,262	-	-	-55%	+55%	-73%	+73%	-73%	+73%	-0.2%	0.2%	-0.1%	0.1%	-37.6%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		
2.B Chemical Industry	N2O	736	203	-2%	+2%	-73%	+73%	-9%	+9%	-9%	+9%	0.0%	0.0%	0.0%	0.0%	-95.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		
2.B Chemical Industry	N2O	7,211	341	-2%	+2%	-99%	+99%	-9%	+9%	-9%	+9%	-0.1%	0.1%	0.0%	0.0%	-92.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		
2.B Chemical Industry	N2O	1,673	119	-2%	+2%	-99%	+99%	-9%	+9%	-9%	+9%	-0.1%	0.1%	0.0%	0.0%	-92.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		
2.B Chemical Industry	CH4	37	24	-	-	-	-	-58%	+51%	-58%	+51%	0.0%	0.0%	0.0%	0.0%	-36.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		
2.C Metal Industry	CO2	7,211	5,430	-	-	-4%	+4%	-4%	+4%	-4%	+4%	0.0%	0.0%	0.0%	0.0%	-24.7%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		
2.C Metal Industry	CH4	18	12	-5%	+5%	-163%	+163%	-163%	+163%	-163%	+163%	0.0%	0.0%	0.0%	0.0%	-33.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	
2.C Metal Industry	CH4	5	2	-5%	+5%	-163%	+163%	-163%	+163%	-163%	+163%	0.0%	0.0%	0.0%	0.0%	-35.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	
2.C Metal Industry	CO2	58	0	-2%	+2%	-10%	+10%	-10%	+10%	-10%	+10%	0.0%	0.0%	0.0%	0.0%	-100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	
2.C Metal Industry	CO2	2,040	2,344	-	-	-10%	+10%	-10%	+10%	-10%	+10%	0.0%	0.0%	0.0%	0.0%	-14.9%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	
2.G Other Product Manufacture and Use	N2O	291	424	-	-	-	-	-4%	+4%	-4%	+4%	0.0%	0.0%	0.0%	0.0%	45.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	
2.H Other	CO2	65	87	-	-	-	-	-4%	+4%	-4%	+4%	0.0%	0.0%	0.0%	0.0%	34.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	
2.B Chemical Industry	HFCs	15,929	141	-	-	-	-	-2%	+2%	-2%	+2%	0.0%	0.0%	0.0%	0.0%	-99.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	
2.B Chemical Industry	HFCs	2	76	-	-	-	-	-2%	+2%	-2%	+2%	0.0%	0.0%	0.0%	0.0%	49.98%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	
2.B Chemical Industry	PFCs	331	74	-	-	-	-	-2%	+2%	-2%	+2%	0.0%	0.0%	0.0%	0.0%	-77.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	
2.B Chemical Industry	SF6	3,471	52	-	-	-	-	-2%	+2%	-2%	+2%	0.0%	0.0%	0.0%	0.0%	-98.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	
2.B Chemical Industry	NF3	3	15	-	-	-	-	-2%	+2%	-2%	+2%	0.0%	0.0%	0.0%	0.0%	44.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	
2.B Chemical Industry	PFCs	204	0	-2%	+2%	-47%	+28%	-47%	+28%	-47%	+28%	0.0%	0.0%	0.0%	0.0%	-100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	
2.C Metal Industry	HFCs	0	1	-	-	-	-	-5%	+5%	-5%	+5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	
2.C Metal Industry	SF6	147	296	-	-	-	-	-5%	+5%	-5%	+5%	0.0%	0.0%	0.0%	0.0%	102.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	
2.E Electronics Industry	HFCs	1	109	-10%	+10%	-100%	+100%	-10%	+10%	-10%	+10%	0.0%	0.0%	0.0%	0.0%	148.49%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.E Electronics Industry	HFCs	1,455	1,888	-10%	+10%	-80%	+80%	-81%	+81%	-81%	+81%	-0.1%	0.1%	-0.1%	0.1%	29.8%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.E Electronics Industry	SF6	419	324	-10%	+10%	-300%	+300%	-300%	+300%	-300%	+300%	-0.1%	0.1%	-0.1%	0.1%	-22.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.E Electronics Industry	NF3	30	274	-10%	+10%	-70%	+70%	-71%	+71%	-71%	+71%	0.0%	0.0%	0.0%	0.0%	817.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.E Electronics Industry	HFCs	1	47,678	-	-	-	-	-6%	+6%	-6%	+6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.F Product uses as substitutes for ODS	HFCs	1	2,925	-	-	-	-	-16%	+16%	-16%	+16%	0.0%	0.0%	0.0%	0.0%	217867%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.F Product uses as substitutes for ODS	HFCs	0	10	-	-	-	-	-16%	+16%	-16%	+16%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.F Product uses as substitutes for ODS	HFCs	0	659	-	-	-	-	-10%	+10%	-10%	+10%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.F Product uses as substitutes for ODS	HFCs	0	127	-10%	+10%	-5%	+5%	-10%	+10%	-10%	+10%	0.0%	0.0%	0.0%	0.0%	-68.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.F Product uses as substitutes for ODS	PFCs	4,550	1,457	-10%	+10%	-10%	+10%	-10%	+10%	-10%	+10%	0.0%	0.0%	0.0%	0.0%	-68.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.G Other Product Manufacture and Use	PFCs	0	56	-10%	+10%	-10%	+10%	-10%	+10%	-10%	+10%	0.0%	0.0%	0.0%	0.0%	-84.6%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.G Other Product Manufacture and Use	SF6	8,814	1,356	-	-	-	-	-21%	+145%	-21%	+145%	-0.2%	1.1%	-0.2%	1.1%	-84.6%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Table A2-4 Data used for uncertainty assessment (Agriculture Sector)

A Category	B GHG	C 1990 emissions /removals	D 2020 emissions /removals	E Activity data uncertainty		F Emission factor/estimator parameter uncertainty		G Combined uncertainty		H-1990 Combined Uncertainty as % of Total National Emissions in 1990		H-2020 Combined Uncertainty as % of Total National Emissions in 2020		I Type A sensitivity	J Type B sensitivity	K Uncertainty in trend in national emissions introduced by emission factor/estimation parameter uncertainty	L Uncertainty in trend in national emissions introduced by activity data uncertainty	M Uncertainty introduced into the trend in total national emissions			
				Input Data	Input Data	Input Data	Input Data	(+) %	(-) %	(+) %	(-) %	(+) %	(-) %					(+) %	(-) %	(+) %	(-) %
				kt-CO <sub>2</sub> eq.	kt-CO <sub>2</sub> eq.	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %	(-) %	(-) %					(+) %	(-) %	(-) %	(+) %
3.A Enteric Fermentation	CH4	4,803	3,389	-1%	+1%	-26%	+32%	-26%	+32%	-0.1%	0.1%	-0.1%	0.1%	0.0%	0.3%	0.0%	0.0%	0.0%	0.0%		
3.A Enteric Fermentation	CH4	4,164	3,880	-1%	+1%	-40%	+49%	-40%	+49%	-0.1%	0.2%	-0.1%	0.2%	0.0%	0.3%	0.0%	0.0%	0.0%	0.0%		
3.A Enteric Fermentation	CH4	4	4	-9%	+9%	-50%	+50%	-51%	+51%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		
3.A Enteric Fermentation	CH4	397	325	-1%	+1%	-69%	+69%	-72%	+69%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		
3.A Enteric Fermentation	CH4	56	36	-9%	+9%	-50%	+50%	-51%	+51%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		
3.B Manure Management	CH4	2,675	2,028	-1%	+1%	-20%	+20%	-20%	+20%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%		
3.B Manure Management	N2O	623	623	-1%	+1%	-71%	+12%	-71%	+12%	0.0%	0.1%	0.0%	0.1%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%		
3.B Manure Management	CH4	0	0	-9%	+9%	-30%	+30%	-31%	+31%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		
3.B Manure Management	CH4	NO	NO	-9%	+9%	-71%	+12%	-72%	+12%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		
3.B Manure Management	CH4	513	146	-1%	+1%	-20%	+20%	-20%	+20%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		
3.B Manure Management	N2O	1,052	1,232	-9%	+9%	-20%	+20%	-22%	+22%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%		
3.B Manure Management	CH4	40	50	-9%	+9%	-20%	+20%	-22%	+22%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		
3.B Manure Management	N2O	283	220	-9%	+9%	-71%	+12%	-72%	+12%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		
3.B Manure Management	CH4	10	4	-9%	+9%	-30%	+30%	-31%	+31%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		
3.B Manure Management	N2O	8	1	-9%	+9%	-71%	+12%	-72%	+12%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		
3.B Manure Management	N2O	1,548	1,096	-9%	+9%	-106%	+47%	-106%	+47%	-0.1%	0.6%	-0.1%	0.4%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%		
3.C Rice Cultivation	CH4	12,129	12,004	-1%	+1%	-6%	+6%	-6%	+6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		
3.D Agricultural Soils	N2O	1,843	1,141	-1%	+1%	-31%	+31%	-31%	+31%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		
3.D Agricultural Soils	N2O	1,476	1,279	-	-	-23%	+23%	-23%	+23%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%		
3.D Agricultural Soils	N2O	54	35	-1%	+1%	-65%	+200%	-65%	+200%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		
3.D Agricultural Soils	N2O	707	545	-1%	+1%	-70%	+200%	-70%	+200%	0.0%	0.1%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		
3.D Agricultural Soils	N2O	455	393	-	-	-2%	+2%	-2%	+2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		
3.D Agricultural Soils	N2O	85	82	-1%	+1%	-75%	+200%	-75%	+200%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		
3.D Agricultural Soils	N2O	1,076	878	-9%	+9%	-106%	+47%	-106%	+47%	-0.1%	0.4%	-0.1%	0.4%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%		
3.D Agricultural Soils	N2O	1,913	1,455	-9%	+9%	-115%	+287%	-115%	+287%	-0.2%	0.5%	-0.2%	0.4%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%		
3.D Agricultural Soils	CH4	127	64	-1%	+1%	-296%	+296%	-296%	+296%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		
3.F Field Burning of Agricultural Residues	N2O	39	20	-1%	+1%	-300%	+300%	-300%	+300%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		
3.F Linnig	CO2	580	233	-1%	+1%	-50%	+50%	-50%	+50%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		
3.H Urea Application	CO2	193	193	-1%	+1%	-50%	+50%	-50%	+50%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		

Table A2-5 Data used for uncertainty assessment (LULUCF Sector)

A Category	B GHG	C 1990 emissions /removals		D 2020 emissions /removals		E Activity data uncertainty		F Emission factor estimation parameter uncertainty		G Combined uncertainty		H-1990 Combined Uncertainty as % of Total National Emissions in 1990		H-2020 Combined Uncertainty as % of Total National Emissions in 2020		T Emission increase rate	I Type A sensitivity	J Type B sensitivity	K Uncertainty in trend introduced by emission factor/estimation parameter uncertainty	L Uncertainty in trend introduced by activity data uncertainty	M Uncertainty introduced into trend in total national emissions			
		Input Data kt-CO <sub>2</sub> eq.	Input Data kt-CO <sub>2</sub> eq.	Input Data (+) %	Input Data (-) %	Input Data (+) %	Input Data (-) %	Input Data (+) %	Input Data (-) %	Input Data (+) %	Input Data (-) %	(E <sup>2</sup> +F <sup>2</sup> ) <sup>1/2</sup>	G*ΔΣC (-) %	G*ΔΣD (+) %	D/C	Note*	D/ΣC	I*F (-) %	I*F (+) %	J*F*Δ <sup>2</sup> (-) %	J*F*Δ <sup>2</sup> (+) %	(K <sup>2</sup> +L <sup>2</sup> ) <sup>1/2</sup> (-) %	(K <sup>2</sup> +L <sup>2</sup> ) <sup>1/2</sup> (+) %	
4.A Forest Land	CO2	-72,390	-56,373	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1. Forest Land remaining Forest Land	CO2	-72,390	-56,373	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2. Land converted to Forest Land	CO2	-6,671	-7,67	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4.B Cropland	CO2	7,407	4,539	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1. Cropland remaining Cropland	CO2	7,407	4,539	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2. Land converted to Cropland	CO2	1,551	118	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4.C Grassland	CO2	486	533	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1. Grassland remaining Grassland	CO2	486	533	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2. Land converted to Grassland	CO2	173	17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4.D Wetlands	CO2	NO,NENA	NO,NENA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1. Wetland remaining Wetland	CO2	NO,NENA	NO,NENA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2. Land converted to Wetlands	CO2	91	27	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4.E Settlements	CO2	-1,365	-1,298	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1. Settlements remaining Settlements	CO2	-1,365	-1,298	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2. Land converted to Settlements	CO2	4,237	1,475	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4.F Other Land	CO2	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1. Other Land remaining Other Land	CO2	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2. Land converted to Other Land	CO2	1,265	243	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4.G Harvested Wood Products	CO2	-450	-807	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1. Other Land (Organic soil in settlements converted from other land-use categories)	CO2	-450	-807	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4.H Other (Organic soil in settlements converted from other land-use categories)	CO2	32	13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4.I Direct N2O emissions from N inputs to managed soils	CO2	3	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4.J Direct N2O emissions from drainage of organic soils	CO2	26	26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4.K Indirect N2O emissions from management of organic soils	CO2	NO,NENA	NO,NENA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4.L Indirect N2O emissions from N mineralization/immobilization	CO2	166	149	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4.M Indirect N2O emissions from Managed Soils	CO2	53	42	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4.N Biomass Burning	CH4	47	30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4.O Biomass Burning	N2O	22	19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table A2-6 Data used for uncertainty assessment (Waste Sector, Indirect CO<sub>2</sub>)

A		B		C		D		E		F		G		H-1990		H-2020		I		J		K		L		M											
Category	GHG	1990 emissions / remove	2020 emissions / remove	Activity data uncertainty	Emission factor/ estimation parameter uncertainty	Combined uncertainty	Combined Uncertainty as % of Total National Emissions in 1990	Combined Uncertainty as % of Total National Emissions in 2020	Emission increase rate	Type A sensitivity	Type B sensitivity	Uncertainty in trend introduced by emission factor/ estimation parameter uncertainty	Uncertainty in trend introduced by data uncertainty	Uncertainty in trend introduced into the total national emissions	1990	2020	2020	Note*	D/ΣC	(-)	(+)	(-)	(+)	(-)	(+)	(-)	(+)										
		kt-CO <sub>2</sub> eq.	kt-CO <sub>2</sub> eq.	Input Data	Input Data	(E <sup>2</sup> +F <sup>2</sup> ) <sup>1/2</sup>	G*C/ΣC	G/D/ΣD	D/C	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%										
5.A Solid Waste Disposal	CH4	5,914	1,487	-	-	-33%	-0.2%	0.2%	-74.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%										
1. Managed disposal site (IW)	CH4	3,588	1,129	-	-	-29%	0.1%	0.0%	-68.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%										
5.A Solid Waste Disposal	CH4	9	38	+60%	-4%	-74%	0.0%	0.0%	332.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%										
3. Uncategorized (Inappropriate disposal)	CH4	54	82	+30%	-79%	-84%	0.0%	0.0%	51.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%										
5.B Biological Treatment of Solid Waste	N2O	181	272	+30%	+167%	+170%	0.0%	0.0%	50.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%										
5.B Biological Treatment of Solid Waste	CO2	5,554	2,485	-	-	-7%	+7%	0.0%	-55.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%										
5.C Incineration and Open Burning of Waste	CO2	3,670	3,548	-	-	-30%	+30%	0.0%	77.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%										
5.C Incineration and Open Burning of Waste	CO2	2,172	3,852	+30%	-2%	-30%	+30%	0.0%	3.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%										
5.C Incineration and Open Burning of Waste	CO2	916	1,606	+60%	-2%	-60%	+60%	0.0%	3.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%										
5.C Incineration and Open Burning of Waste	CO2	5	0	+30%	-2%	-30%	+30%	0.0%	3.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%										
5.C Incineration and Open Burning of Waste	CH4	12	1	+30%	-10%	-104%	+184%	0.0%	-15%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%										
5.C Incineration and Open Burning of Waste	CH4	0	0	+30%	-10%	-104%	+184%	0.0%	-15%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%										
5.C Incineration and Open Burning of Waste	CH4	2	8	+30%	-10%	-104%	+203%	0.0%	3.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%										
5.C Incineration and Open Burning of Waste	CH4	2	8	+30%	-10%	-104%	+203%	0.0%	3.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%										
5.C Incineration and Open Burning of Waste	CH4	0	1	+60%	-10%	-104%	+224%	0.0%	4.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%										
5.C Incineration and Open Burning of Waste	CH4	12	0	+30%	-10%	-104%	+104%	0.0%	3.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%										
5.C Incineration and Open Burning of Waste	CH4	306	97	-	-	-27%	+27%	0.0%	-86.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%										
5.C Incineration and Open Burning of Waste	N2O	5	24	+30%	-76%	-81%	+81%	0.0%	434.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%										
5.C Incineration and Open Burning of Waste	N2O	1,056	1,237	+30%	+60%	+117%	+224%	0.0%	49.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%										
5.C Incineration and Open Burning of Waste	N2O	64	38	-	-	-80%	50%	0.0%	-40.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%										
5.C Incineration and Open Burning of Waste	N2O	6	12	+60%	+44%	-74%	+74%	0.0%	114.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%										
5.C Incineration and Open Burning of Waste	N2O	3	0	+30%	-10%	-104%	+104%	0.0%	-98.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%										
5.C Incineration and Open Burning of Waste	N2O	216	335	+5%	-31%	-31%	+31%	0.0%	54.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%										
5.D Wastewater Treatment and Discharge	CH4	739	771	-	-	-31%	+31%	0.0%	1.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%										
1. DW (Domestic wastewater treatment plant)	CH4	131	7	+10%	-84%	-84%	+84%	0.0%	-95.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%										
5.D Wastewater Treatment and Discharge	CH4	1,543	326	+10%	-58%	-59%	+59%	0.0%	-78.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%										
1. DW (Human waste treatment plant)	CH4	56	42	+30%	-60%	-67%	+67%	0.0%	-24.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%										
5.D Wastewater Treatment and Discharge	CH4	206	93	+30%	-58%	-66%	+66%	0.0%	-54.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%										
2. IW (Industrial wastewater treatment)	CH4	31	4	+100%	-39%	-107%	+107%	0.0%	-85.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%										
5.D Wastewater Treatment and Discharge	N2O	416	520	+5%	+100%	+146%	+146%	0.0%	25.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%										
1. DW (Sewage treatment plant)	N2O	453	466	-	-	-42%	42%	0.0%	2.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%										
5.D Wastewater Treatment and Discharge	N2O	67	3	+10%	-87%	-88%	+88%	0.0%	-27.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%										
1. DW (Human waste treatment plant)	N2O	830	600	+10%	+58%	+59%	-59%	0.0%	-95.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%										
5.D Wastewater Treatment and Discharge	N2O	298	336	+30%	+95%	+100%	-100%	0.0%	12.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%										
5.D Wastewater Treatment and Discharge	N2O	316	165	+30%	-58%	-66%	+66%	0.0%	-47.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%										
5.D Wastewater Treatment and Discharge	N2O	8	1	+100%	-39%	-107%	+107%	0.0%	-85.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%										
2. IW (Landfill leachate treatment)	CO2	703	601	+10%	-1%	-10%	+10%	0.0%	-14.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%										
5.E Other																																					
A		C	D	E	F	G	H-1990	H-2020	T	J	K	L	M	C	D	E	F	G	H-1990	H-2020	T	J	K	L	M	C	D	E	F	G	H-1990	H-2020	T	J	K	L	M
Indirect CO2	Ind CO2	1,042	403	-	-	-23%	+40%	0.0%	-61.4%	0.0%	0.0%	0.0%	0.0%	1,042	403	-	-	-23%	+40%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1,042	403	-	-	-23%	+40%	0.0%	0.0%	0.0%	0.0%		
Indirect CO2	Ind CO2	4,506	1,561	-	-	-33%	+58%	0.0%	-65.4%	0.0%	0.0%	0.0%	0.0%	4,506	1,561	-	-	-33%	+58%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	4,506	1,561	-	-	-33%	+58%	0.0%	0.0%	0.0%	0.0%		

$$\text{Note*}: \text{Type A sensitivity} = \frac{0.01 \times D_x + \sum D_i - (0.01 \times C_x + \sum C_i)}{(0.01 \times C_x + \sum C_i)} \times 100 - \frac{\sum D_i - \sum C_i}{\sum C_i} \times 100$$

Where:  $C_x, D_x$  = entry of row  $x$  of column C and D respectively in the table A2

$\sum C_i, \sum D_i$  = sum of column C and D respectively

### References

1. IPCC, *2006 IPCC Guidelines for National Greenhouse Inventories*, 2006.
2. UNFCCC, *UNFCCC reporting guidelines on annual greenhouse gas inventories* (Decision 24/CP.19 Annex I), 2013.
3. Ministry of the Environment, *Guidelines for Uncertainty Assessment of GHG inventories in Japan*, 2013.





## Annex 3. Detailed Methodological Descriptions for Individual Source or Sink Categories

### A3.1. Methodology for Estimating Emissions of Precursors

In addition to the mandatory greenhouse gases (CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O, HFCs, PFCs, SF<sub>6</sub>, NF<sub>3</sub>), Japan reports on the emissions of precursors (NO<sub>x</sub>, CO, Non-Methane Volatile Organic Compounds [NMVOCs], and SO<sub>x</sub><sup>1</sup>) calculated by established methods. This section explains the categories for which estimation methodologies were established, and emissions are reported.

#### A3.1.1 Energy Sector

##### A3.1.1.1. Stationary Combustion (1.A.1., 1.A.2., 1.A.4.: NO<sub>x</sub>, CO, NMVOCs, and SO<sub>x</sub>)

##### A3.1.1.1.a. Energy Industries (1.A.1), Manufacturing Industries and Construction (1.A.2), Commercial/institutional (1.A.4.a) and Agriculture/forestry/fishing (1.A.4.c)

###### a) Category Description

This section provides the estimation methods for emissions of precursors and other substances (NO<sub>x</sub>, CO, NMVOCs, and SO<sub>x</sub>) from Energy industries (1.A.1), Manufacturing industries and construction (1.A.2), Commercial/institutional (1.A.4.a) and Agriculture/forestry/fishing (1.A.4.c).

###### b) Methodological Issues

###### 1) NO<sub>x</sub> and SO<sub>x</sub>

###### ● Methodology for Estimating Emissions

###### ➤ Facilities emitting soot and smokes

*General Survey of the Emissions of Air Pollutants* by the Ministry of the Environment (MOE) was used as data source for NO<sub>x</sub> and SO<sub>x</sub> emissions from fuel combustion of the “facilities emitting soot and smokes” specified in laws such as the Air Pollution Control Act. To ensure consistency with the categorization of the common reporting format (CRF), the emissions from the energy sector were isolated from the emissions listed in the *General Survey of the Emissions of Air Pollutants* by the following operation:

1. All emissions from the following facilities and industry sectors are reported under Energy:

Facility: [0101–0103: Boilers]; [0601–0618: Metal rolling furnaces, metal furnaces, and metal forge furnaces]; [1101–1106: Drying ovens]; [2901–3202: Gas turbines, diesel engines, gas engines, and gasoline engines]

Industry sector: [A–D: Accommodation/eating establishments, health care/educational and academic institutions, public bathhouses, laundry services]; [F–L: Agriculture/fisheries, mining, construction, electricity, gas, heat distribution, building heating/other operations]

<sup>1</sup> Most SO<sub>x</sub> consists of SO<sub>2</sub>. For major sources, SO<sub>2</sub> emissions are estimated.

2. For emissions from the facilities and industry sectors other than the above and [1301–1304: Waste incinerators], after emissions from the Industrial Processes and Product Use (IPPU) sector were identified, the emissions from the Energy sector are estimated by subtracting the emissions of the IPPU sector from the emissions listed in the *General Survey of the Emissions of Air Pollutants*. For estimation method in the IPPU sector, see A3.1.2.1. Mineral Industry, Chemical Industry, Metal Production, and Other Production (2.A., 2.B., 2.C., 2.D.: NO<sub>x</sub>, SO<sub>x</sub>).

➤ **Small facilities**

NO<sub>x</sub> and SO<sub>x</sub> emitted by the “small facilities” (i.e. the facilities in commercial/institutional and manufacturing categories that do not correspond to the facilities emitting soot and smokes) were calculated by multiplying the energy consumption in each facility type by Japan’s country-specific emission factor.

● **Emission factors**

➤ **Facilities emitting soot and smokes**

Not applicable.

➤ **Small facilities**

Emission factors were established for each fuel type for [0102: Heating system boilers] for facilities listed in [L: Heating systems for buildings/other places of business] in the *General Survey of the Emissions of Air Pollutants* by aggregating emissions and energy consumption by fuel type.

● **Activity data**

➤ **Facilities emitting soot and smokes**

Not applicable.

➤ **Small facilities**

Energy consumption by small facilities by fuel type was calculated by subtracting energy consumption by fuel type, identified by the *General Survey of the Emissions of Air Pollutants*, from energy consumption by fuel type provided in the *General Energy Statistics* (Agency for Natural Resources and Energy). If the activity data shown in the *General Survey of the Emissions of Air Pollutants* exceeded the activity data provided in the *General Energy Statistics*, the activity data for the specified sources was deemed to be zero. The fuels covered were city gas, LPG, kerosene, and fuel oil A.

2) **CO and NMVOCs**

● **Estimation Method**

Emissions of CO and NMVOCs from the specified sources were calculated by multiplying the energy consumption in each facility type by Japan’s country-specific emission factor.

● **Emission factors**

CO emission factors were established based on the summary data of the Japan Society for Atmospheric Environment (1996).

NMVOC emission factors for each facility by fuel type were established by multiplying the CH<sub>4</sub> emission factor by the ratio of the NMVOC emission factor to the CH<sub>4</sub> emission factor (NMVOC/CH<sub>4</sub> ratio). The CH<sub>4</sub> emission factors are elaborated in Chapter 3. The NMVOC/CH<sub>4</sub> ratios were determined from Japan Environmental Sanitation Center (1989), Institute of Behavioral Science (1984), and United States Environmental Protection Agency (1985).

- **Activity data**

Energy consumption calculated for estimation of CH<sub>4</sub> and N<sub>2</sub>O was used for activity data. (see Chapter 3.)

### **A3.1.1.1.b. Residential Sector (1.A.4.b)**

#### **a) Category Description**

This section provides the estimation methods for emissions of precursors and other substances (NO<sub>x</sub>, CO, NMVOCs, and SO<sub>x</sub>) from fuel combustion of households.

#### **b) Methodological Issues**

- **Estimation Method**

NO<sub>x</sub>, CO, NMVOCs, and SO<sub>x</sub> emissions from the target source were calculated by multiplying energy consumed of each fuel type by Japan's country-specific emission factors or the default emission factors from *EMEP/EEA Air Pollutant Emission Inventory Guidebook 2016*.

- **Emission factors**

##### **1) NO<sub>x</sub>**

For solid fuels (steam coal and coal briquettes) and biomass, emission factors were established by converting the default values provided in the *EMEP/EEA Air Pollutant Emission Inventory Guidebook 2016* to gross calorific values.

For liquid (kerosene) and gaseous (LPG and city gas) fuels, the emission factors by usage by fuel type provided in a report by Air Quality Management Bureau, Environmental Agency (1996) were used. This report calculated the emission factors by taking the average of the concentration of NO<sub>x</sub> emissions by product, obtained through questionnaires and interviews in the household gas appliances industry, weighted by the number of products sold.

##### **2) CO**

For solid fuels (steam coal, and coal briquettes), and biomass, emission factors were established by converting the default values provided in the *EMEP/EEA Air Pollutant Emission Inventory Guidebook 2016* to gross calorific values.

For liquid (kerosene) and gaseous (LPG and city gas) fuels, the emission factors by usage by fuel type provided in the report by Institute of Behavioral Science (1997) were used. This report tabulated the emission factors by usage by fuel type from the actual values measured in Tokyo, Yokohama City and Chiba Prefecture.

### 3) NMVOCs

For solid fuels (steam coal and coal briquettes), liquid fuels (kerosene), gaseous fuels (LPG and city gas), and biomass, emission factors were established by converting the default values provided in the *EMEP/EEA Air Pollutant Emission Inventory Guidebook 2016* to gross calorific values.

### 4) SO<sub>x</sub>

For solid fuels (steam coal and coal briquettes), and biomass, emission factors were established by converting the default values provided in the *EMEP/EEA Air Pollutant Emission Inventory Guidebook 2016* to gross calorific values.

For liquid fuel (kerosene), emission factors were calculated from energy consumption, specific gravity and sulfur content based on the fuel characteristics of kerosene described in information material compiled by the Petroleum Association of Japan.

#### ● *Activity data*

Fuel consumption by fuel type for residential use in the *General Energy Statistics* has been taken for the activity data. The fuels covered were steam coal, coal briquettes, kerosene, LPG, and city gas. For the ratio of consumption by fuel type by type of use in households, the *Handbook of Energy & Economic Statistics in Japan* (Energy Data and Modeling Center) is used.

#### **A3.1.1.1.c. Incineration of Waste for Energy Purposes and With Energy Recovery**

Emissions of NO<sub>x</sub>, CO, NMVOCs and SO<sub>x</sub> from the incineration of waste for energy purposes and from the incineration of waste with energy recovery are reported under the relevant subcategories of 1.A.1, 1.A.2 and 1.A.4. Explanations for estimation method, emission factors, and activity data are all given in the section “A3.1.5Waste”.

#### **A3.1.1.2. Mobile Combustion (NO<sub>x</sub>, CO, NMVOCs, and SO<sub>x</sub>)**

##### **A3.1.1.2.a. Domestic Aviation (1.A.3.a) and International Aviation (NO<sub>x</sub>, CO, and NMVOCs)**

###### ***a) Category Description***

This section provides the estimation methods for emissions of precursors (NO<sub>x</sub>, CO, and NMVOCs) from combustion of aviation fuel.

###### ***b) Methodological Issues***

###### ● ***Estimation Method***

NO<sub>x</sub>, CO, and NMVOC emissions from the specified sources are calculated by multiplying the fuel consumption converted to net calorific value by the default emission factors provided in the *2006 IPCC Guidelines* and the *Revised 1996 IPCC Guidelines*.

###### ● ***Emission factors***

Data in the following table are used.

Table A 3-1 IPCC default emission factors for domestic aviation

Gas	EF [g/MJ(NCV)]
NO <sub>x</sub>	0.25 <sup>1)</sup>
CO	0.12 <sup>2)</sup>
NMVOCs	0.018 <sup>2)</sup>

Reference: 1) 2006 IPCC Guidelines, Vol. 2; Page 3.64, Table 3.6.5

2) Revised 1996 IPCC Guidelines, Vol. 3; Page 1.90, Table 1-47, Jet and Turboprop Aircraft

### ● *Activity data*

For domestic aviation, figures for jet fuel consumption (for domestic scheduled flights and others [commuter, sightseeing and charter flights]) converted to net calorific value from data described in the *Statistical Yearbook of Air Transport* (Ministry of Land, Infrastructure, Transport and Tourism) are used. For international aviation, the totals for bonded imports and bonded exports given in *Yearbook of Mineral Resources and Petroleum Products Statistics* (former *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*) (METI) are used. It is assumed that jet fuel is used by aircrafts.

### c) *Completeness*

For aviation gasoline, emissions of NO<sub>x</sub>, CO, and NMVOCs are reported as “NE”.

## A3.1.1.2.b. Road Transportation (1.A.3.b.): Fuel Combustion (NO<sub>x</sub>, CO, NMVOCs, and SO<sub>x</sub>)

### a) *Description of emission source categories*

This section provides the estimation methods for emissions of precursors and other substances (NO<sub>x</sub>, CO, NMVOCs, and SO<sub>x</sub>) from fuel combustion of vehicles.

### b) *Methodological Issues*

#### 1) *NO<sub>x</sub>, CO, and NMVOCs*

#### ● *Estimation Method*

NO<sub>x</sub>, CO, and NMVOC emissions from the specified mobile sources are calculated by multiplying the distance traveled per year for each vehicle type per fuel by Japan’s country-specific emission factor.

#### ● *Emission factors*

Emission factors are established for each vehicle class per fuel type based on the *Survey for Estimation of Emission Factors and Total Emissions of Exhaust Gas from Automobiles* (Ministry of the Environment, 2002) and the *Survey for Consideration of Estimation of Emission Factors and Total Emissions of Exhaust Gas from Automobiles* (Ministry of the Environment, 2004, 2007, 2008, and every year after 2011). The NMVOC emission factors, however, are calculated by multiplying the emission factor of total hydrocarbon (THC) of the Survey by the percentage of NMVOCs in the THC emissions (60% for gasoline and LPG vehicles and 99% for diesel vehicles; surveyed by the Ministry of the Environment).

The trend of these emission factors over the years includes not only the impact of replacement to vehicles compatible with the latest exhaust gas regulation, but also the impact of the methodological change in the calculation of the emission factors among the survey years.

For reference, Table A 3-5 shows the outline of motor vehicle exhaust emission standards of air pollutants.

● **Activity data**

For the activity data, the travel distance per year for each vehicle class by fuel type, estimated for CH<sub>4</sub> and N<sub>2</sub>O emissions, are used. (See Chapter 3)

Table A 3-2 NO<sub>x</sub> emission factors for automobiles [g-NO<sub>x</sub>/km]

Fuel	Vehicle type	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Gasoline	Light vehicle	0.23	0.16	0.16	0.08	0.15	0.12	0.12	0.10	0.08	0.06	0.09	0.07	0.07	0.05	0.04
	Passenger vehicle (including LPG)	0.24	0.20	0.20	0.08	0.14	0.12	0.09	0.07	0.06	0.05	0.09	0.08	0.06	0.06	0.04
	Light cargo truck	0.87	0.66	0.38	0.20	0.27	0.23	0.27	0.23	0.19	0.18	0.32	0.32	0.25	0.26	0.19
	Small cargo truck	1.12	0.90	0.48	0.09	0.15	0.11	0.09	0.08	0.07	0.06	0.14	0.10	0.07	0.07	0.05
	Regular cargo truck	1.83	1.09	0.56	0.16	0.33	0.26	0.25	0.23	0.23	0.20	0.24	0.20	0.16	0.12	0.09
	Bus	4.45	3.65	2.44	0.09	0.15	0.09	0.07	0.06	0.06	0.05	0.08	0.08	0.10	0.07	0.08
	Special-purpose vehicle	1.47	0.87	0.43	0.12	0.32	0.26	0.19	0.17	0.15	0.12	0.31	0.22	0.17	0.16	0.12
Diesel	Passenger vehicle	0.64	0.53	0.44	0.45	0.47	0.46	0.44	0.38	0.34	0.26	0.40	0.39	0.35	0.28	0.26
	Small cargo truck	1.33	1.10	1.01	1.00	1.06	1.00	0.93	0.89	0.79	0.73	1.87	1.02	0.96	0.94	0.90
	Regular cargo truck	5.35	4.59	4.33	4.50	3.26	3.09	2.86	2.73	2.64	2.40	3.05	2.50	2.28	1.96	1.84
	Bus	4.23	3.83	3.60	4.07	3.38	3.48	3.39	3.23	3.13	2.96	3.74	3.46	3.25	3.04	2.88
	Special-purpose vehicle	3.38	2.76	2.15	3.63	2.97	2.75	2.50	2.41	2.24	2.05	3.21	2.97	2.75	2.42	2.30

Table A 3-3 CO emission factors for automobiles [g-CO/km]

Fuel	Vehicle Type	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Gasoline	Light vehicle	1.75	1.55	1.54	0.97	1.51	1.33	1.47	1.22	1.08	0.94	1.39	1.32	1.29	1.26	1.23
	Passenger vehicle (including LPG)	2.32	2.06	2.03	0.94	1.37	1.19	1.07	0.92	0.81	0.75	1.33	1.27	1.16	1.14	1.03
	Light cargo truck	10.42	8.54	5.51	2.77	2.87	2.41	3.17	2.76	2.38	2.27	2.46	2.48	2.06	2.21	1.85
	Small cargo truck	9.66	10.08	8.31	2.05	2.73	2.13	1.85	1.61	1.40	1.25	1.67	1.19	1.05	1.00	0.90
	Regular cargo truck	12.62	10.60	8.95	3.62	7.53	5.73	5.67	5.04	4.77	4.36	4.18	3.06	2.89	2.25	2.02
	Bus	26.21	25.08	21.94	2.07	2.62	1.88	1.77	1.78	1.65	1.57	1.79	1.72	1.60	1.61	1.40
	Special-purpose vehicle	12.47	10.67	8.92	2.30	5.34	4.24	3.69	3.44	3.09	2.76	3.51	2.23	1.79	1.95	1.61
Diesel	Passenger vehicle	0.48	0.43	0.43	0.37	0.39	0.37	0.36	0.29	0.22	0.17	0.24	0.23	0.20	0.11	0.09
	Small cargo truck	0.98	0.90	0.81	0.59	0.45	0.42	0.36	0.34	0.30	0.25	0.54	0.34	0.28	0.21	0.15
	Regular cargo truck	3.22	2.99	2.44	2.04	1.10	0.97	0.80	0.72	0.65	0.55	0.50	0.36	0.31	0.21	0.17
	Bus	2.58	2.53	2.20	2.03	1.24	1.18	1.14	1.05	0.98	0.89	0.86	0.76	0.66	0.55	0.46
	Special-purpose vehicle	2.11	1.89	1.30	1.60	0.93	0.79	0.63	0.58	0.50	0.43	0.53	0.48	0.41	0.29	0.24

Table A 3-4 NMVOC emission factors for automobiles [g-NMVOC/km]

Fuel	Vehicle Type	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Gasoline	Light vehicle	0.08	0.03	0.03	0.03	0.08	0.07	0.06	0.05	0.04	0.04	0.05	0.05	0.04	0.03	0.03
	Passenger vehicle (including LPG)	0.11	0.07	0.06	0.02	0.06	0.05	0.04	0.04	0.03	0.03	0.06	0.06	0.06	0.05	0.05
	Light cargo truck	0.64	0.37	0.16	0.09	0.14	0.13	0.13	0.12	0.10	0.10	0.12	0.11	0.08	0.09	0.06
	Small cargo truck	0.71	0.53	0.21	0.04	0.07	0.06	0.05	0.04	0.04	0.03	0.10	0.05	0.04	0.04	0.04
	Regular cargo truck	0.99	0.58	0.28	0.06	0.17	0.14	0.14	0.13	0.14	0.11	0.14	0.07	0.06	0.05	0.05
	Bus	2.16	1.90	1.32	0.04	0.07	0.05	0.04	0.04	0.03	0.03	0.06	0.05	0.06	0.05	0.05
	Special-purpose vehicle	0.97	0.47	0.19	0.05	0.16	0.13	0.10	0.10	0.09	0.08	0.24	0.09	0.08	0.08	0.08
Diesel	Passenger vehicle	0.11	0.10	0.10	0.09	0.10	0.10	0.10	0.08	0.07	0.05	0.06	0.05	0.04	0.03	0.02
	Small cargo truck	0.39	0.34	0.26	0.20	0.14	0.13	0.10	0.09	0.08	0.07	0.14	0.09	0.07	0.06	0.04
	Regular cargo truck	1.62	1.47	1.03	0.75	0.35	0.30	0.23	0.21	0.19	0.15	0.14	0.08	0.06	0.05	0.03
	Bus	1.26	1.24	0.98	0.80	0.43	0.39	0.38	0.34	0.32	0.28	0.32	0.26	0.21	0.18	0.14
	Special-purpose vehicle	1.09	0.96	0.52	0.57	0.27	0.23	0.17	0.16	0.13	0.12	0.14	0.11	0.08	0.06	0.05



## 2) SO<sub>x</sub>

### ● *Estimation Method*

The emissions of SO<sub>x</sub> from these sources are calculated by multiplying the fuel consumption of each fuel type by Japan's country-specific emission factors.

### ● *Emission factors*

Sulfur content (by weight) by fuel type was used.

Table A 3-6 Sulfur content (by weight) by fuel type

Fuel	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Gasoline	0.008%	0.008%	0.008%	0.005%	0.001%	0.001%	0.001%	0.001%	0.001%	0.001%	0.001%	0.001%	0.001%	0.001%	0.001%
Diesel	0.350%	0.136%	0.050%	0.005%	0.001%	0.001%	0.001%	0.001%	0.001%	0.001%	0.001%	0.001%	0.001%	0.001%	0.001%
LPG	0.002%	0.002%	0.002%	0.002%	0.002%	0.002%	0.002%	0.002%	0.002%	0.002%	0.002%	0.002%	0.002%	0.002%	0.002%

Reference: Gasoline – The Institute of Behavioral Science (until 2004); Upper limits of regulations (2005 onward),  
 Diesel oil – Petroleum Association of Japan (until 1997); Upper limits of regulations (1998 onward)  
 LPG – The Institute of Behavioral Science

### ● *Activity data*

Activity data, fuel consumption data of weight value, are calculated by multiplying the fuel consumption of each fuel type, reported in in the *General Energy Statistics* (Agency for Natural Resources and Energy), by the specific gravity of each fuel type.

### c) *Completeness*

Emissions of NO<sub>x</sub>, CO, NMVOCs, and SO<sub>x</sub> from natural gas vehicles and motorcycles are reported as “NE”.

## A3.1.1.2.c. Road Transportation (1.A.3.b.): Fuel Volatilization (Excluding Motorcycle) (NMVOCs)

### a) *Description of emission source categories*

This section provides the estimation methods for emissions of NMVOCs caused by fuel volatilization of vehicles. NMVOCs are emitted from vehicles which run on gasoline, by volatilization of the gasoline component in the tank. Fuel evaporative emission is classified into the following three types. Evaporating gas in filling gasoline is included in the calculation of fugitive emissions from fuels at gas stations (1.b.2.a.v.).

Table A 3-7 Classification of fuel evaporative gases

Types	Description
Diurnal Breathing Loss (DBL)	Evaporated gas which is generated when gasoline vapor, generated mainly due to the change in temperature during parking, is vented to the atmosphere after breakthrough <sup>1)</sup> from the canister <sup>2)</sup> .
Hot Soak Loss (HSL)	Evaporated gas which is generated from gasoline attached to the induction pipe within one hour after shutdown of an engine.
Running Loss (RL)	Evaporated gas which is generated when the temperature of gasoline rises during driving and it goes beyond the limitation of canister purging <sup>3)</sup> .

Note:

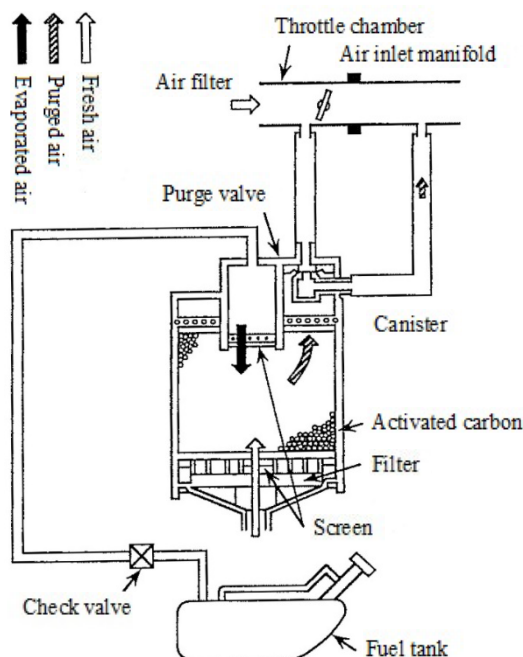
- 1) “Breakthrough” means going through the absorption process without being absorbed when the amount of gas/gasoline goes beyond the absorption capacity of canister.



- 2) Canister is absorption equipment in which activated carbon and other substances are included to prevent generating evaporated gas in the fuel system of gasoline car. Evaporated gas during parking is absorbed by the canister; absorbed evaporated gas is delivered to the intake manifold during driving, then, absorption capacity of the canister recovers.

- 3) Purge means delivering evaporated gas, together with air, to intake manifold.

Reference: *Estimation Methods for Releases from Sources not Required to Report under PRTR (Pollutant Release and Transfer Register)* (Ministry of Economy, Trade and Industry, and Ministry of the Environment, 2012)



Reference: Society of Automotive Engineers of Japan, Inc. (2008)

Figure A 3-1 Structure of fuel tank and canister

### b) Methodological issues

Fuel evaporated emissions are estimated by adjusting THC emission data of DBL, HSL, and RL in 2002 by the annual number of cars owned and annual travel distance. The emissions in 2002 are provided in *Development Research of New Testing Methodology for Emission Gas from Vehicle (Off-road vehicle)* (Ministry of the Environment, FY2003). This methodology is similar to that described in the *Estimation Methods for Releases from Sources not Required to Report under PRTR* (Ministry of Economy, Trade and Industry, and Ministry of the Environment).

In estimating emissions in RL, PRTR emission data is used after 2003.

It was assumed that THC emissions = NMVOC emissions, since methane is not included in fuel evaporated gas<sup>2</sup>. The outline of estimation method for each emission source and used data is shown in Table A 3-8.

<sup>2</sup> Regarding concrete volatile element composition, please refer to Yokota *et al.* (2011) for example.

Table A 3-8 Descriptions for estimating emissions from evaporated gas by mobile fuel combustion

Category	Equation	Data for calculation
DBL	$E_n = \sum_p \sum_q \sum_r \left( E_{2002} \times \frac{N_{n,p,q,r}}{N_{2002,p,q,r}} \right)$ <p><math>E_n</math>: DBL emissions in fiscal year (FY) <math>n</math> [t-NMVOC]  <math>N_{n,p,q,r}</math>: Number of gasoline vehicles owned in FY <math>n</math> in a prefecture <math>p</math>, by vehicle type <math>q</math>, by status if regulated or not <math>r</math></p>	<p><math>E_{2002}</math>: THC emission amount in FY2002 provided in <i>Development Research on New Testing Methodology for Emission Gas from Vehicle (Off-road vehicle)</i> (Ministry of the Environment, FY2003).</p> <p><math>N</math>: Based on <i>Monthly Report Statistics of Vehicles</i> (Japan Automobile Manufacturers Association, Inc. (JAMA)) and <i>Statistics of AIRIA/ Number of Motor Vehicles</i> (Automobile Inspection &amp; Registration Information Association (AIRIA)).</p>
HSL	$E_n = \sum_p \sum_q \left( E_{2002} \times \frac{N_{n,p,q}}{N_{2002,p,q}} \right)$ <p><math>E_n</math>: DBL emissions in FY <math>n</math> [t-NMVOC]  <math>N_{n,p,q}</math>: Number of gasoline vehicles owned in FY <math>n</math> in a prefecture <math>p</math>, by usage <math>q</math></p>	<p><math>E_{2002}</math>: THC emission amount in FY2002 provided in <i>Development Research on New Testing Methodology for Emission Gas from Vehicle (Off-road vehicle)</i></p> <p><math>N</math>: Based on <i>Monthly Report Statistics of Vehicles</i> and <i>Statistics of AIRIA/ Number of Motor Vehicles</i>.</p>
RL	<p>[1990-2002]</p> $E_n = \sum_p \sum_q \left( E_{2002} \times \frac{N_{n,p,q}}{N_{2002,p,q}} \times \frac{M_{n,p}}{M_{2002,p}} \right)$ <p><math>E_n</math>: RL emissions in FY <math>n</math> [t-NMVOC]  <math>N_{n,p,q}</math>: Number of gasoline vehicles owned in FY <math>n</math> in a prefecture <math>p</math>, by status if regulated or not <math>q</math>  <math>M_{n,p}</math>: Travel distance of motorcycle [km] in FY <math>n</math> in a prefecture <math>p</math></p> <p>[2003-]  PRTR emissions were used.</p>	<p><math>E_{2002}</math>: THC emission amount in FY2002 provided in <i>Development Research on New Testing Methodology for Emission Gas from Vehicle (Off-road Vehicle)</i></p> <p><math>N</math>: Based on <i>Monthly Report Statistics of Vehicles</i> and <i>Statistics of AIRIA/ Number of Motor Vehicles</i>.</p> <p><math>M</math>: Based on <i>Monthly Report of Motor Vehicle Transport Statistics</i> and <i>Monthly Report Statistics of Vehicles</i>.</p>

#### A3.1.1.2.d. Road Transportation (1.A.3.b.): Fuel Volatilization (Motorcycle) (NMVOCs)

##### a) Description of emission source categories

This section provides the estimation methods for emissions of NMVOCs by motorcycle caused by fuel volatilization. NMVOCs are emitted from motorcycles which run on gasoline, by volatilization of the gasoline component in the tank due to changes in temperature as described in the above section. This section provides the estimation method for DBL and HSL as described in the *PRTR*.

##### b) Methodological issues

Fuel evaporated emissions from motorcycle are estimated by using THC emissions in 2001, provided in *Development Research on New Testing Methodology for Emission Gas from Vehicle (Motorcycle)* (Ministry of the Environment, FY2002), which are yearly-adjusted by the activity data, number of motorcycles owned and travel distance, using the same methodology as that in the *Estimation Methods for Releases from Sources not Required to Report under PRTR* (Ministry of Economy, Trade and Industry, and Ministry of the Environment).

Table A 3-9 Description of estimating emissions from evaporated gas by motorcycle fuel combustion

Category	Equation	Data for calculation
DBL	$E_n = \sum_p \sum_q \left( E_{2001} \times \frac{M_{n,p,q}}{M_{2001,p,q}} \right)$ <p><math>E_n</math>: DBL emissions in FY <math>n</math> [t-NMVOC]  <math>M_{n,p,q}</math>: travel distance of motorcycle [km] in FY <math>n</math> in a prefecture <math>p</math>, by vehicle type <math>q</math></p>	<p><math>E_{2001}</math>: THC emission amount in FY2001 estimated based on <i>Development Research on New Testing Methodology for Emission Gas from Vehicle (Motorcycle)</i> (Ministry of the Environment, FY2002).</p> <p><math>M</math>: Based on <i>Monthly Report Statistics of Vehicles</i> (Japan Automobile Manufacturers Association, Inc. (JAMA)), and <i>Survey of Motorcycle Market Trends</i> (JAMA).</p>
HSL	$E_n = \sum_p \sum_q \left( E_{2001} \times \frac{M_{n,p}}{M_{2001,p}} \times R_{n,p} \right)$ <p><math>E_n</math>: DBL emissions in FY <math>n</math> [t-NMVOC]  <math>M_{n,p}</math>: travel distance of motorcycle [km] in FY <math>n</math> by vehicle type <math>p</math>  <math>R</math>: Use factor adjustment ratio in FY <math>n</math> by vehicle type <math>p</math></p>	<p><math>E_{2001}</math>: THC emission amount in FY2001 estimated based on <i>Development Research on New Testing Methodology for Emission Gas from Vehicle (Motorcycle)</i>.</p> <p><math>M</math>: Based on <i>Monthly Report Statistics of Vehicles</i>, and <i>Survey of Motorcycle Market Trends</i>.</p> <p><math>R</math>: Estimated by multiplying the sales unit for domestic sales of each vehicle type (Website of JAMA) by survival rate of each elapsed year (Ministry of the Environment), by the usage factor of each elapsed year (<i>Estimation Methods for Releases from Sources not Required to Report under PRTR</i>).</p>

#### A3.1.1.2.e. Railways (1.A.3.c.: NO<sub>x</sub>, CO, and NMVOCs)

##### a) Category Description

This section provides the estimation methods for emissions of precursors (NO<sub>x</sub>, CO, and NMVOCs) caused by combustion of diesel railway fuel.

##### b) Methodological Issues

NO<sub>x</sub>, CO, and NMVOC emissions from the specified sources are calculated by multiplying the fuel consumption converted to net calorific value by the default emission factors provided in the *Revised 1996 IPCC Guidelines*.

##### ● Emission factors

The default emission factors provided for the “Locomotives” category in the *Revised 1996 IPCC Guidelines* are used.

Table A 3-10 IPCC default emission factors for locomotives

Gas	Emission factor [g/MJ(NCV)]
NO <sub>x</sub>	1.8
CO	0.61
NMVOCs	0.13

Reference: *Revised 1996 IPCC Guidelines*, Vol. 3; Page 1.89, Table 1-47

##### ● Activity data

The diesel oil consumption by railways in the *General Energy Statistics* (Agency for Natural Resources and Energy) is used.

### A3.1.1.2.f. Domestic Navigation (1.A.3.d) and International Navigation (NO<sub>x</sub>, CO, NMVOCs, and SO<sub>x</sub>)

#### a) Category Description

This section provides the estimation methods for emissions of precursors (NO<sub>x</sub>, CO, and NMVOCs) and SO<sub>x</sub> from combustion of marine fuel.

#### b) Methodological Issues

##### 1) NO<sub>x</sub>, CO, and NMVOCs

###### ● Estimation Method

NO<sub>x</sub>, CO, and NMVOC emissions from the specified sources are calculated by multiplying the fuel consumption converted to net calorific value by the default emission factors provided in the *Revised 1996 IPCC Guidelines*.

###### ● Emission factors

The default emission factors provided in the “Ocean-Going Ships” category in the *Revised 1996 IPCC Guidelines* are used.

Table A 3-11 IPCC default emission factors for ocean-going ships

Gas	Emission factor [g/MJ(NCV)]
NO <sub>x</sub>	1.8
CO	0.18
NMVOCs	0.052

Reference: *Revised 1996 IPCC Guidelines*, Vol. 3; Page 1.90, Table 1-48

###### ● Activity data

For domestic navigation, the marine fuel consumption data converted to net calorific value by fuel type (diesel oil, fuel oil A, fuel oil B, and fuel oil C) from the *General Energy Statistics* (Agency for Natural Resources and Energy) are used. For international navigation, the totals for bonded imports and bonded exports given in *Yearbook of Mineral Resources and Petroleum Products Statistics* (former *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*) (METI) are used. It is assumed that fuel oil A, B, C, diesel oil, kerosene and lubricants are used by vessels.

##### 2) SO<sub>x</sub>

###### ● Estimation Method

Emissions from the specified sources are calculated by multiplying the fuel consumption by the emission factors.

###### ● Emission factors

Emission factors are calculated by multiplying the specific gravity of each marine fuel by the sulfur ratio of each fuel by the molecular weight ratio of sulfur dioxide<sup>3</sup> versus sulfur. The sulfur ratio of each fuel is restricted by domestic law and *Japanese Industrial Standard*. Therefore, the regulation values are used for the sulfur ratio in the estimation.

<sup>3</sup> Most SO<sub>x</sub> consists of SO<sub>2</sub>. For major sources, SO<sub>2</sub> emissions are estimated.

Table A 3-12 Specific gravity and sulfur ratio of fuel for ocean-going ships

Fuel	Specific Gravity [kg/L]	Sulfur Ratio [% in weight]
Diesel Oil	0.83	0.5 (1990-1991)
		0.2 (1992-1997)
		0.05 (1998-2004)
		0.005 (2005-2006)
		0.001 (2007 onward)
Fuel Oil A	0.84	2.0
Fuel Oil B	0.91	3.0
Fuel Oil C	0.93	3.5

Reference: Sulfur ratio of diesel oil based on Petroleum Association of Japan (2015)

Sulfur ratio of each fuel oil based on *Japanese Industrial Standard K2205*

Specific gravity based on Environmental Research and Control Center (2000)

### ● *Activity data*

The marine fuel consumption data of each fuel type (diesel oil, fuel oil A, fuel oil B, and fuel oil C) provided in the *General Energy Statistics* (Agency for Natural Resources and Energy) are used for the activity data.

## A3.1.1.3. Fugitive Emissions from Fuel (Oil and Natural Gas) (1.B.2: NMVOCs)

### A3.1.1.3.a. Oil production (1.B.2.a.ii)

#### a) *Category Description*

This section provides the estimation methods for NMVOC emissions occurring during production of crude oil in oil fields. As for the NMVOC emissions when lowering measuring instruments into operating wells at servicing, the estimation methods are provided in the section “Fugitive emissions during servicing of operating gas fields” (1.B.2.b.ii).

#### b) *Methodological Issues*

In order to keep consistency with the methods to estimate CH<sub>4</sub> and CO<sub>2</sub>, the emissions from offshore and onshore oil fields are estimated separately.

### ● *Estimation Method*

Using the equation below, the emission amount of NMVOCs in this category is estimated by multiplying the amounts of crude oil production from offshore oil fields and onshore oil fields by the default emission factors for offshore and onshore given in the *2006 IPCC Guidelines*.

$$E = \sum_i (AD_i \times EF_i)$$

$E$  : NMVOC fugitive emissions caused by crude oil production [kt-NMVOC]

$AD_i$  : Amount of crude oil production (excluding condensate) from offshore oil fields or onshore oil fields [1000 kL]

$EF_i$  : Emission factor for crude oil production from offshore oil fields or onshore oil fields [kt-NMVOC/1000 kL]

### ● *Emission factors*

For NMVOC emission factors of fugitive emissions from oil production, the default values for fugitive emissions of conventional oil from onshore and offshore oil fields (onshore:  $2.25 \times 10^{-3}$ , offshore:  $7.4 \times 10^{-7}$  kt-NMVOC/10<sup>3</sup> kL), which are indicated in the *2006 IPCC Guidelines*, are

used. As for the emission factor for onshore fields, the median of the default values ( $1.80 \times 10^{-6}$  -  $4.50 \times 10^{-3}$ ) is used.

- **Activity Data**

The amount of crude oil production (excluding condensate) by offshore and onshore oil field is used for activity data.

As for the amount of crude oil production (excluding condensate) in offshore oil fields, the condensate production in offshore gas fields is estimated by multiplying the production amount of condensate by the ratio of natural gas production amount in offshore fields to the total production amount of natural gas, and then subtracted from the crude oil production amount in offshore fields.

The amount of crude oil production (excluding condensate) in offshore fields estimated above is deducted from the total amount of domestic crude oil production (excluding condensate) to obtain the production amount of crude oil (excluding condensate) in onshore oil fields.

Total production volumes of natural gas, crude oil, and condensate are obtained from the data given in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* (FY1990-2000), the *Yearbook of Mineral Resources and Petroleum Products* (FY2001-2010), and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics* (FY2011 onward), all by the Ministry of Economy, Trade and Industry (METI). The production amounts of natural gas and crude oil from offshore are obtained from *Natural Gas Data Yearbook* compiled by the Japan Natural Gas Association.

### A3.1.1.3.b. Oil Transport (1.B.2.a.iii): Distribution of Crude Oil

- a) **Category Description**

This section provides the estimation methods for NMVOC emissions which are, like evaporating gas, emitted in losses from breathing and acceptance for storage tank, and loading to lorry tank during distributing domestic crude oil.

- b) **Methodological Issues**

- **Estimation Method**

Emission amount of NMVOCs in this category is estimated by multiplying the amount of domestic production of crude oil by the emission factor for NMVOCs per production volume.

$$E = AD \times EF$$

$E$  : NMVOC emissions caused by oil transport [t-NMVOC]

$AD$  : Amount of domestic crude oil production [1000 kL]

$EF$  : Emission factor per crude oil production [t-NMVOC/1000 kL]

- **Emission factors**

Emission factors for oil transport are established by dividing the emission amount from crude oil (evaporating gas) estimated in *Study to Develop the National Emission Inventory for Volatile Organic Compounds* (hereafter, “*Study on the VOC Emission Inventory*”), Ministry of the

Environment, by the activity data (amount of crude oil production). Since emission data indicated in the *Study on the VOC Emission Inventory* is limited only to FY2000 and FY2005 onward, emission factors in and before FY2004 are established by dividing the emissions estimated by Japan Natural Gas Association<sup>4</sup> by the activity data.

- **Activity Data**

The activity data for this category are the amount of crude oil production (including condensate) which is provided in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products Statistics*, and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics*.

### A3.1.1.3.c. Oil Transport (1.B.2.a.iii): Navigation

#### a) Category Description

NMVOCs are emitted in the process of ocean transportation of liquid cargo including gasoline, gas-free operation, and ship loading. This section provides the estimation methods for NMVOCs which are emitted from cargo operations by two types of tanker, crude oil tanker and product tanker.

Naphtha is also highly volatile and NMVOCs are likely to be emitted. However, naphtha is delivered by chemical tankers, which have high airtightness and pressure resistance, and is prohibited from being delivered by product tankers, which are not enough treated for electrostatic generation which involves the risk of auto-ignition. Therefore, it is considered that naphtha is not emitted into the air during delivering, thus, the naphtha delivery is not subject to the emission estimation. (Although chemical agents are usually delivered by chemical tankers, sometimes they are delivered by product tankers, so all chemical agents are used for estimation to avoid underestimation).

VOC emissions from “crude oil” and “oil products (gasoline)” are also included in “1.b.2.a.iv. Refining and storage of oil”. Therefore, the emissions are subtracted from the total emissions in “1.B.2.a.iv. Refining and storage of oil” and included and reported in this category.

VOC emissions from “chemical agent” are also estimated in “A3.1.2.2.n Chemicals Manufacture” in “2.Industrial Process and Product Use”. Therefore, the emissions are subtracted from the total emissions in “Chemicals Manufacture” and included and reported in this category.

#### b) Methodological Issues

- **Estimation Method**

The NMVOC emissions are estimated by multiplying the amount of exported or domestically transported “crude oil”, “oil products (gasoline)”, and “chemical agents” which are reported in the tables entitled “Export cargo volume by type of goods, by destination” and “Delivery cargo

<sup>4</sup> Japan Natural Gas Association provided the emissions from the following five sources: “breathing and acceptance”, “shipping (lorry)”, “reboiler vent (GDH)”, “gas release” and “CO<sub>2</sub> venting”. The first two sources were chosen as the emissions from this subcategory and the rest of the sources were chosen as the emissions from processing of natural gas (1.B.2.b.iii) in accordance with the *Studies on VOC Emission Inventories*.

volume by type of goods, by destination” in the *Statistical Yearbook of Port* (Ministry of Land, Infrastructure, Transport and Tourism), by the emission factors.

The following equation is used:

$$E = \sum_i (AD_i \times EF_i)$$

- $E$  : Emission amount of NMVOCs from evaporation in vessels [t -NMVOC]  
 $AD_i$  : Traffic volume of cargo  $i$  (export volume + transport volume) [t]  
 $EF_i$  : Emission factor for cargo  $i$  [kg-NMVOC/t]  
 $i$  : Type of cargo (crude oil, gasoline, chemical agent)

### ● Emission factors

Emission factors for this category are established as can be seen in Table A 3-13.

Table A 3-13 Emission factors for evaporation from vessels

Activity data		Emission factors [kg-NMVOC/t]
Crude oil	With vapor recovery (only in port of Kiire for FY2007 onward)	0.03
	Without vapor recovery	0.14
Gasoline	During loading	0.12
	During gas-freeing	0.14
Chemical agent	Benzene	0.011
	Methanol	0.006
	Toluene	0.004
	Dichloroethane	0.016
	Acetone	0.023

Reference: Ocean Policy Research Foundation (2006)

### ● Activity Data

Based on the tables entitled “Export cargo volume by type of goods, by destination” and “Delivery cargo volume by type of goods, by destination” in the *Statistical Yearbook of Port*, the following methods in Table A 3-14 are used for activity data for this category.

Table A 3-14 Activity data for NMVOC emissions from vessels

Activity data	Description
Crude oil	The volume of export and transport of crude oil is used.
Gasoline	Estimated by multiplying the volume of export and transport of crude petroleum products by the percentage of gasoline in the volume of domestic sales and export of petroleum products provided in the <i>Yearbook of Mineral Resources and Petroleum Products Statistics</i> .
Chemical agent	Estimated by multiplying the volume of export and transport of chemical agents by the percentage of NMVOCs in chemical agents. The percentage of the actual export amount in 2003 of five chemical agents (benzene, methanol, toluene, dichloroethane, and acetone), probable emission sources of NMVOCs (Ocean Policy Research Foundation, 2012), is adopted for the percentage of NMVOCs in chemical agents.

Note: Each activity data is based on calendar year (CY); therefore, CY-based-activity data are converted into FY-based data by combining 75% of the data from corresponding CY and 25% of the data from the subsequent CY.

## A3.1.1.3.d. Refining and Storage of Oil (1.B.2.a.iv): Fugitive Emissions From Oil Refineries

### a) Category Description

This section provides the estimation methods for NMVOC emissions from fugitive emissions in the process of refining crude oil and producing oil products.



**b) Methodological Issues****● Estimation Method**

The NMVOC emissions are estimated by multiplying BPSD (Barrel per Stream Day), production amount per Steam day of crude oil distillation unit at normal pressure, by Steam day per year by the emission factor. Steam day per year are estimated by multiplying the number of days per year (365 days, but 366 days in leap years) by the annual operating rate.

$$E = AD \times D \times R \times EF$$

*E* : NMVOC emissions from fugitive emissions in refinery [g-NMVOC/year]

*AD* : Fugitive Barrel per Stream Day [BPSD]

*D* : Number of working days in a year (365 days, but 366 days in leap years)

*R* : Annual operating rate [%]

*EF* : Emission factor [g-NMVOC/BPSD]

**● Emission factors**

Emission factor for this category is established at 5.675 [kg/day/10<sup>5</sup>BPSD] which is provided in Institute of Behavioral Sciences (2000), in accordance with the *Study on the VOC Emission Inventory*.

**● Activity Data**

In accordance with the *Study on the VOC Emission Inventory*, the capacity of oil refineries (BPSD: Barrels per Stream Day) by *Sekiyu Shiryō* (Sekiyu Tsushin) is used for activity data. Stream days in a year are calculated by multiplying 365 days (366 days for leap years: FY1991, 1995, 1999, 2003, 2007, 2011, 2015, 2019) by the annual operating ratio of the crude oil distillation units at normal pressure, which is provided by *Sekiyu Shiryō* (=annual processing amount [bbl/year] / annual capacity[bbl/year]).

**A3.1.1.3.e. Refining and Storage of Oil (1.B.2.a.iv): Production of Lubricant Oil****a) Category Description**

This section provides the estimation methods for NMVOC emissions from fugitive emissions in the process of dewaxing and deasphalting during production of lubricants.

**b) Methodological Issues****● Estimation Method**

NMVOC emissions from the specified sources are calculated by multiplying the amount of domestic gross sales of lubricants to consumers by Japan's country-specific emission factors for toluene and methyl ethyl ketone.

**● Emission factors**

Based on measurements in Japan shown in Institute of Behavioral Science (1987), emission factors for lubricant oil production are established as 333.2 [g/kL] for toluene and 415.5 [g/kL] for methyl ethyl ketone.

**● Activity data**

The activity data for this category are the domestic gross sales amount of lubricants to consumers,

provided in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* and the *Yearbook of Mineral Resources and Petroleum Products Statistics*.

### **A3.1.1.3.f. Refining and Storage of Oil (1.B.2.a.iv): Fugitive Emissions From Storage/Shipping Facilities**

#### ***a) Category Description***

NMVOCs are emitted, with accompanying fuel-evaporated fugitive gases, by storage and shipping of fuel (e.g., gasoline, crude oil, and naphtha) in crude oil transshipment stations, refineries, and oil tank facilities.

NMVOC emissions from storage facilities include losses from breathing and acceptance for fixed-roof type tanks and shipping losses from floating-roof type storage tanks at refineries, and the NMVOC emissions from shipping facilities include shipping losses in loading crude oil or oil products to tanker, tank car, or tank lorry.

#### ***b) Methodological Issues***

##### **● *Estimation Method***

NMVOC emissions from storage and shipping of fuel in crude oil transshipment stations, refineries and oil tank facilities are estimated by multiplying the activity data of received amount of crude oil, gasoline and naphtha, by the emission factor per received amount.

$$E = (AD_1 + AD_2 + AD_3) \times EF$$

<i>E</i>	: Fugitive NMVOC emissions at fuel storage and shipping facilities [kg-NMVOC]
<i>AD<sub>1</sub></i>	: Received amount of crude oil [kL]
<i>AD<sub>2</sub></i>	: Received amount of gasoline [kL]
<i>AD<sub>3</sub></i>	: Received amount of naphtha [kL]
<i>EF</i>	: Emission factor per received amount of petroleum products [kg-NMVOC/kL]

The above-estimated NMVOC emissions include emissions during loading “crude oil” and “oil products (gasoline)” to tankers, which are included and reported in “Oil transport (1.B.2.a.iii)”; therefore, these emissions are subtracted from this category.

##### **● *Emission factors***

The emission factors are established by dividing the emission amount in fuel storage and shipping in crude oil transshipment stations, refineries, and oil tank facilities, which has been estimated in the *Study on the VOC Emission Inventory*, by the following activity data (the received amounts of crude oil, gasoline and naphtha). The emission amount provided in the *Study on the VOC Emission Inventory* are limited to FY2000 and from FY2005 onward, therefore, the emission factors for the other years are established as follows.

For FY1990-1999, no relevant information is available since no measures based on voluntary action plan on environment had been implemented during the period. Therefore, the emission factor for FY2000 is adopted for this period.

For FY2001-2003, emission factors are established by interpolating the figures in FY2000 and FY2004 under the assumption of linearly decreasing emissions factors, since member companies

of Petroleum Association of Japan had been continuously implementing voluntary measures for reducing emissions.

For FY2004, emission factors are established by dividing the emissions reported in Petroleum Association of Japan's voluntary action plan by the activity data.

- **Activity Data**

The activity data are the processed amount of crude oil, and the received amounts of gasoline and naphtha provided in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* and the *Yearbook of Mineral Resources and Petroleum Products Statistics*. As for the crude oil, the received amount has not yet been identified, therefore the processed amount is used instead.

### A3.1.1.3.g. Distribution of Oil Products (1.B.2.a.v): Fugitive Emissions From Gas Stations

#### a) Category Description

NMVOCs are emitted by evaporation from underground gasoline storage tanks (loss from acceptance) or by filling gasoline in cars (loss from filling gasoline).

#### b) Methodological Issues

- **Estimation Method**

The NMVOC emissions by prefecture and by month in this category are estimated by multiplying the sales volume of each prefecture and month of gasoline by the emission factors per sales volume of each prefecture and month of gasoline. By such estimation by prefecture and by month, the influences of monthly temperature difference and of vapor pressure drop of gasoline for summer season to the emissions are taken into consideration.

$$E = \sum_{i,j} (AD_{i,j} \times EF_{i,j})$$

$E$  : NMVOC emissions at gas filling stations [kg-NMVOC]

$AD_{i,j}$  : Sales amount of gasoline in prefecture  $i$  in month  $j$  [kL]

$EF_{i,j}$  : Emission factor per sales amount of gasoline in prefecture  $i$  in month  $j$  (loss from acceptance, loss from filling gas) [kg-NMVOC/kL]

- **Emission factors**

#### 1) Loss from acceptance

Emission factors are established, taking into consideration the temperature difference among prefectures and months, according to the following equation which is based on Agency for Natural Resources and Energy (1975).

The average monthly temperature in each prefectural capital provided in *Weather Statistics Information* (Japan Meteorological Agency) is used for calculation.

$$EF_{i,j} = (0.46 \times T_{i,j} + 13.92)/21$$

$EF_{i,j}$  : Emission factor for loss from acceptance in prefecture  $i$  in month  $j$  [kg-NMVOC/kL]

$T_{i,j}$  : Average of temperature in prefecture  $i$  in month  $j$  [°C]

As for seven prefectures (Saitama, Tokyo, Kanagawa, Fukui, Aichi, Kyoto and Osaka) where the installation of vapor recovery instrument for acceptance is required by ordinance, the emission factors for losses from acceptance are established by multiplying the emission factors calculated from the equation above by 0.15, under the assumption of the 85% emission reduction by vapor recovery instrument, since the fiscal year when the ordinances are effective, according to the *Study on the VOC Emission Inventory*.

Also, in summer season, the gasoline vapor control action is performed, therefore the emission factors from June to September are consistently multiplied by the value of 0.9, according to the *Study on the VOC Emission Inventory*.

## 2) Loss from filling gasoline

The NMVOC emission factors for loss from filling gasoline are established by using the formula below which is developed in the *Study on the VOC Emission Inventory* based on the domestic test results. The average temperature by prefecture and by month used for parameter setting are the same as those used for emission factors for loss from acceptance.

$$EF_{i,j} = 0.0359 \times A_{i,j} - 0.0486 \times B_{i,j} - 0.0092 \times C + 0.0149 \times D - 0.1804$$

$EF_{i,j}$  : Emission factor for loss from filling gasoline in prefecture  $i$  in month  $j$   
[kg-NMVOC/kL]

$A_{i,j}$  : Fuel temperature in car tank in prefecture  $i$  in month  $j$  (Established as  $T_{i,j} + 5$  [°C])

$B_{i,j}$  :  $A_{i,j} - E_{i,j}$  [°C]

$C$  : Gasoline filling speed (Established as 35 [L/minute])

$D$  : Reid vapor pressure

(Established as 63.2 [kPa] for June to September and 86.0 [kPa] for October to May)

$T_{i,j}$  : Average temperature in prefecture  $i$  in month  $j$  [°C]

$E_{i,j}$  : Fuel filling temperature (fuel temperature in underground tank) in prefecture  $i$  in month  $j$  [°C]

$E_{i,j}$  is established depending on  $T_{i,j}$  as follows:

$T_{i,j} < 15$  :  $E_{i,j} = T_{i,j} + 5$

$15 \leq T_{i,j} < 20$  :  $E_{i,j} = T_{i,j} + 2.5$

$20 \leq T_{i,j} < 25$  :  $E_{i,j} = T_{i,j}$

$25 \leq T_{i,j} < 30$  :  $E_{i,j} = T_{i,j} - 2.5$

$30 \leq T_{i,j}$  :  $E_{i,j} = T_{i,j} - 5$

### ● Activity Data

The activity data are domestic sales volume of gasoline by prefecture and by month, which are calculated by proportionally dividing the domestic monthly gasoline sales volume, provided in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* and the *Yearbook of Mineral Resources and Petroleum Products Statistics*, by annual gasoline sales volume by prefecture, provided in the *Oil Product Sales Summary by Prefecture* (Petroleum Association of Japan).

#### A3.1.1.3.h. Production of Natural Gas (1.B.2.b.ii)

##### a) Category Description

This section provides the estimation methods for NMVOC emissions occurring during production of natural gas in gas fields. As for the NMVOC emissions when lowering measuring instruments into wells at servicing, the estimation methods are provided in the section “Fugitive

emissions during servicing of operating gas fields” (1.B.2.b.ii).

### **b) Methodological Issues**

In order to keep consistency with the methods to estimate CH<sub>4</sub> and CO<sub>2</sub>, the emissions from offshore and onshore are estimated separately.

#### ● **Estimation Method**

The NMVOC emissions are estimated by multiplying the amounts of natural gas production from offshore gas fields and onshore gas fields by the default emission factors for offshore and onshore gas fields given in the *2006 IPCC Guidelines*.

$$E = \sum_i (AD_i \times EF_i)$$

$E$  : NMVOC fugitive emissions caused by natural gas production [kt-NMVOC]

$AD_i$  : Amount of natural gas production from offshore gas fields or onshore gas fields [million m<sup>3</sup>]

$EF_i$  : Emission factor for natural gas production from offshore gas fields or onshore gas fields [kt-NMVOC/million m<sup>3</sup>]

#### ● **Emission factors**

For NMVOC emission factors of fugitive emissions from gas production, the default values for fugitive emissions of gas production from onshore and offshore gas fields (onshore:  $5.5 \times 10^{-4}$ , offshore:  $9.1 \times 10^{-5}$  kt-NMVOC/million m<sup>3</sup>), which are indicated in the *2006 IPCC Guidelines*, are used.

#### ● **Activity Data**

The production volume of natural gas from offshore gas fields is taken from the *Natural Gas Data Yearbook*. The production volume of natural gas from onshore gas fields is estimated by subtracting the production volume of natural gas from offshore gas fields above from the total production volume of natural gas in Japan given in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products Statistics* and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics*.

### **A3.1.1.3.i. Fugitive Emissions During Servicing of Operating Gas Fields (1.B.2.b.ii)**

#### **a) Category Description**

This section provides the estimation methods for the NMVOC emissions which occur when lowering measuring instruments into operating wells at servicing.

#### **b) Methodological Issues**

For the fugitive emissions relating to well servicing, the estimation method of using the crude oil production amount as activity data is indicated in the *2006 IPCC Guidelines*, however, the correlation between the crude oil production amount and the emissions relating to natural gas well servicing is not clear. Therefore, the number of operation wells is used for the activity data for CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emission estimation based on IPCC, *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*, 2000 (hereafter, *GPG (2000)*).

However as for NMVOCs, the emission factor based on the number of operating wells is not indicated in the *GPG (2000)*, thus the estimation method of using the crude oil production amount is adopted based on the *2006 IPCC Guidelines*.

- **Estimation Method**

Emission amount of NMVOCs in this category is estimated by multiplying the amount of domestic production of crude oil by the default emission factor for NMVOC.

$$E = AD \times EF$$

*E* : NMVOC emissions during well servicing [kt-NMVOC]  
*AD* : Amount of domestic crude oil production [1000 kL]  
*EF* : Emission factor per crude oil production [kt-NMVOC/1000 kL]

- **Emission factors**

For NMVOC emission factor for flaring and venting during well servicing, the default value per crude oil production amount ( $1.7 \times 10^{-5}$  kt-NMVOC/1000 kL), which is indicated in the *2006 IPCC Guidelines*, is used. In CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emission estimation, the emissions from other than flaring and venting are also estimated for well servicing, however the emission factor, which is available for NMVOC emission estimation for well servicing, is only the default value for flaring and venting during well servicing shown in the *2006 IPCC Guidelines*, thus such emission factor is used.

- **Activity Data**

The activity data for this category are the production amount of crude oil in Japan given in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products Statistics*, and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics*.

### A3.1.1.3.j. Processing of Natural Gas (1.B.2.b.iii)

- a) **Category Description**

In the distribution process to the sellers of mined natural gas, NMVOCs originated from natural gas treatment are emitted by vapor from removal device of fluid or impurities (e.g., carbon dioxide gas) contained in natural gas, or, by being released into the air in construction of pipeline relocation.

- b) **Methodological Issues**

- **Estimation Method**

NMVOC emissions by processing of natural gas are estimated by multiplying the domestic production volume of natural gas by the NMVOC emission factors per production volume.

$$E = AD \times EF$$

*E* : NMVOC emission amount by processing of natural gas [t-NMVOC]  
*AD* : Production volume of natural gas [million m<sup>3</sup>]  
*EF* : Emission factor per production volume of natural gas [t-NMVOC/million m<sup>3</sup>]

- **Emission factors**

Emission factors are established by dividing the emissions related to natural gas, which has been estimated in the *Study on the VOC Emission Inventory* by the Ministry of the Environment (based on the reported figures of voluntary action plan by Japan Natural Gas Association), by the later-indicated activity data (domestic production volume of natural gas). Emission factors in and before FY2004 are established by dividing the emissions provided by Japan Natural Gas Association by the activity data, since the emission amounts in the *Study on the VOC Emission Inventory* are limited only to FY2000 and from FY2005 onward (same as shown in “Oil transport (1B.2.a.iii)”).

- **Activity data**

The activity data for this category are domestic production volume of natural gas provided by the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products Statistics*, and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics*.

- **Completeness**

The emissions from this source include the emissions from “transmission and storage of natural gas (1.B.2.b.iv)” and “venting (gas) (1.B.2.c.Venting.ii)”.

### A3.1.1.3.k. Natural Gas Distribution (1.B.2.b.v): City Gas Production

#### a) Category Description

NMVOCs are emitted by fugitive emissions from naphtha tanks in the process of city gas production. In Japan, no emission activity in this category has been made since FY2006, because naphtha has not been used for city gas production due to the completion of shifting raw materials of city gas from low calorific gas made of naphtha to high calorific gas made of LNG in FY2005.

#### b) Methodological Issues

- **Estimation Method**

NMVOC emissions from naphtha tank in city gas production are estimated by multiplying the consumption amount of gasoline used as raw material for city gas production by the NMVOC emission factor per consumption amount. The emissions in this category from FY2006 onward are reported as “NO” since no emission activity has been made during this period.

$$E = AD \times EF$$

$E$  : NMVOC emission amount in city gas production [t-NMVOC]

$AD$  : Consumption amount of gasoline used as raw material for city gas production [kL]

$EF$  : NMVOC emission factor per consumption amount [t-NMVOC/kL]

- **Emission factors**

Emission factors for city gas production are established by dividing the emission amount from “gas production facilities” (estimated based on *Report on Voluntary Action Plan* by the Japan Gas Association) provided in the *Study on the VOC Emission Inventory*, by the activity data (the consumption amount of crude gasoline for city gas production).

Since the emitted amount provided by the *Study on the VOC Emission Inventory* is limited to FY2000 and FY2005 onward, the emission factors for the other years are established as follows. For FY1990-1999, the emission factor for FY2000 is used. For FY2001-2003, emission factors are established by interpolation, using the emission factors for FY2000 and FY2004. For FY2004, the emission factor is established by dividing the emission amount in FY2004 provided in the *Voluntary Action Plan* by the activity data.

- **Activity data**

The activity data for this category are the consumption amount of gasoline used as raw material for city gas production provided in the *Current Survey of Production Concerning Gas Industry* (Agency for Natural Resources and Energy).

#### **A3.1.1.3.l. Venting (Oil) (1.B.2.c.Venting.i)**

- a) Category Description**

This category provides the estimation method for NMVOC emissions from venting in the petroleum industry.

- b) Methodological Issues**

- **Estimation Method**

The emissions are estimated by multiplying the amount of domestic production of crude oil by the NMVOC default emission factor given in the *2006 IPCC Guidelines*.

$$E = AD \times EF$$

$E$  : NMVOC emissions from venting in oil production [kt-NMVOC]

$AD$  : Amount of domestic crude oil production [1000 kL]

$EF$  : Emission factor per crude oil production [kt-NMVOC/1000 kL]

- **Emission factors**

For the emission factor, the NMVOC default emission factor for venting in oil production ( $4.3 \times 10^{-4}$  kt-NMVOC/1000 kL) given in the *2006 IPCC Guidelines* is used.

- **Activity Data**

The activity data for this category are the production amount of crude oil in Japan given in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products Statistics*, and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics*.

#### **A3.1.1.3.m. Flaring (Oil) (1.B.2.c.Flaring.i)**

- a) Category Description**

This category provides the estimation method for NMVOC emissions from flaring in the petroleum industry.



**b) Methodological Issues**● **Estimation Method**

The emissions are estimated by multiplying the amount of domestic production of crude oil by the NMVOC default emission factor given in the *2006 IPCC Guidelines*.

$$E = AD \times EF$$

$E$  : NMVOC emissions from flaring in oil production [kt-NMVOC]

$AD$  : Amount of domestic crude oil production [1000 kL]

$EF$  : Emission factor per crude oil production [kt-NMVOC/1000 kL]

● **Emission factors**

For the emission factor, the NMVOC default emission factor for flaring in oil production ( $2.1 \times 10^{-5}$  kt-NMVOC/1000 kL) given in the *2006 IPCC Guidelines* is used.

● **Activity Data**

The activity data for this category are the production amount of crude oil in Japan given in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products Statistics*, and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics*.

**A3.1.1.3.n. Flaring (Gas) (1.B.2.c.Flaring.ii)****a) Category Description**

This category provides the estimation method for NMVOC emissions from flaring in the natural gas industry.

**b) Methodological Issues**● **Estimation Method**

The emissions are estimated by multiplying the amount of domestic production of natural gas by the NMVOC default emission factor given in the *2006 IPCC Guidelines*.

$$E = AD \times EF$$

$E$  : NMVOC emissions from flaring in gas production [kt-NMVOC]

$AD$  : Amount of domestic natural gas [1000 m<sup>3</sup>]

$EF$  : Emission factor per natural gas production [kt-NMVOC/1000 m<sup>3</sup>]

● **Emission factors**

For the emission factor, the NMVOC default emission factor for flaring in gas production ( $6.2 \times 10^{-7}$  kt-NMVOC/1000 kL) given in the *2006 IPCC Guidelines* is used.

● **Activity Data**

The activity data for this category are the production amount of natural gas in Japan given in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products Statistics*, and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics*.

Statistics.

### A3.1.1.3.o. Flaring (Combined) (1.B.2.c.Flaring.iii)

#### a) Category Description

In Japan, the statistical data are reported for two categories of oil and natural gas. Therefore, the fugitive emissions whose categories can be distinguished are reported in Flaring (Oil) (1.B.2.c.Flaring.i) or in Flaring (Gas) (1.B.2.c.Flaring.ii) respectively. In this category, CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emissions arising from exploration and test before production of oil and natural gas, which are unable to be distinguished by their categories of oil industry or natural gas industry, are reported.

#### b) Methodological Issues

For the fugitive emissions arising from exploration and test before production of oil and natural gas, the default emission factors, which are established using the crude oil production as activity data, are indicated in the *2006 IPCC Guidelines*. However, in case of CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O emission estimation, the correlation between the emissions which accompany exploration and testing of natural gas fields, and the crude oil production amount, and the correlation between the emissions from exploration and testing and the production amount from commercial plants are not clear, thus the number of drilled and tested wells is used for the activity data based on *GPG (2000)* similar to the emissions from well servicing. Especially, as for the emissions from the exploration of wells, the number of wells is extremely small compared to the number of operating wells in Japan, thus there is a possibility of overestimation if the crude oil production amount is adopted as activity data. However, as for NMVOCs, the emission factor based on the number of operating wells is not indicated in the *GPG (2000)*, thus the estimation method of using the crude oil production amount is adopted based on the *2006 IPCC Guidelines*. Also, as for NMVOC emissions from flaring in well drilling and well testing, the default values are not prepared for oil industry and gas industry separately but the total of both values is indicated in the *2006 IPCC Guidelines*, thus the emissions are estimated together and reported in this category.

#### ● Estimation Method

The emissions are estimated by multiplying the amount of domestic production of crude oil by the NMVOC default emission factor given in the *2006 IPCC Guidelines*.

$$E = AD \times EF$$

$E$  : NMVOC emissions from flaring and venting in well drilling and well testing [kt-NMVOC]  
 $AD$  : Amount of domestic crude oil [1000 kL]  
 $EF$  : Emission factor per crude oil production [kt-NMVOC/1000 kL]

#### ● Emission factors

For the emission factor, the sum of NMVOC default emission factors for flaring and venting in well drilling and well testing (well drilling:  $8.7 \times 10^{-7}$ , well testing:  $1.2 \times 10^{-5}$  kt-NMVOC/1000 kL) given in the *2006 IPCC Guidelines* is used.

#### ● Activity Data

The activity data for this category are the production amount of natural gas in Japan given in the

*Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke, the Yearbook of Mineral Resources and Petroleum Products Statistics, and the Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics.*

### A3.1.2 Industrial Processes and Product Use (IPPU)

#### A3.1.2.1. Mineral Industry, Chemical Industry, Metal Production, and Other Production (2.A., 2.B., 2.C., 2.D.: NO<sub>x</sub>, SO<sub>x</sub>)

##### a) Category Description

This section provides the estimation methods for emissions of precursors and other substances (NO<sub>x</sub> and SO<sub>x</sub>) from the process of producing mineral products, chemical products, metal production and other production.

##### b) Methodological Issues

###### ● Estimation Method

NO<sub>x</sub> and SO<sub>x</sub> emissions from the specified sources, not included in the following facilities or industry sectors, were estimated by isolating the emissions of the IPPU sector from the data in the *General Survey of the Emissions of Air Pollutants* (MOE).

Facility: [0101–0103: Boilers]; [0601–0618: Metal rolling furnaces, metal furnaces, and metal forge furnaces]; [1101–1106: Drying ovens]; [1301–1304: Waste incinerators]; [2901–3202: Gas turbines, diesel engines, gas engines, and gasoline engines]

Industry sector: [A–D: Accommodation/eating establishments, health care/educational and academic institutions, public bathhouses, laundry services]; [F–L: Agriculture/fisheries, mining, construction, electricity, gas, heat distribution, building heating/other operations]

###### ➤ NO<sub>x</sub>

For raw material falling under either [44: Metallurgical coal] or [45: Metallurgical coke], the following equation is used:

$$E = \sum \{EF_{NO_x} \times A \times (1-R)\}$$

*E* : NO<sub>x</sub> emissions from metallurgical coal or metallurgical coke [t-NO<sub>x</sub>]  
*EF<sub>NO<sub>x</sub></sub>* : NO<sub>x</sub> emission factor by material [t- NO<sub>x</sub> /kcal]  
*A* : Energy consumed by material [kcal]  
*R* : Nitrogen removal rate [%]

For raw material falling under either [41: Iron/ironstone] or [46: Other], the following equation is used:

$$E = \sum \{N \times (1-R)\}$$

*E* : NO<sub>x</sub> emissions from iron/iron ore or other material [t-NO<sub>x</sub>]  
*N* : Nitrogen content in each material [t-NO<sub>x</sub>]

$R$  : Nitrogen removal rate [%]

However, when the emissions from the IPPU sector calculated by the above equations exceed the emission amount listed in the *General Survey of the Emissions of Air Pollutants*, the total emissions listed in the Survey are considered to be the emissions from the IPPU sector. Materials listed in the categories [42: Sulfide minerals] and [43: Non-ferrous metal ores] are excluded from the calculation due to the lack of data.

#### ➤ **SO<sub>x</sub>**

Emissions from the IPPU sector is calculated from the consumption and sulfur content of the materials in categories [41: Iron/ironstone] to [46: Other materials]. Energy sector emissions are estimated by subtracting IPPU sector emissions from the emissions listed in the *General Survey of the Emissions of Air Pollutants* to determine SO<sub>x</sub> emissions.

$$E = \sum \{S \times (1 - R)\}$$

$E$  : SO<sub>x</sub> emissions [t-SO<sub>x</sub>]

$S$  : Sulfur content in each material [t-SO<sub>x</sub>]

$R$  : Desulfurization rate [%]

#### ● **Emission factors**

##### ➤ **NO<sub>x</sub> emission factors for metallurgical coal and coke**

NO<sub>x</sub> emission factors for the materials used in calculation of NO<sub>x</sub> emissions from metallurgical coal and coke (in the IPPU sector) were established for each facility and material type based on the *General Survey of the Emissions of Air Pollutants*.

##### ➤ **Nitrogen removal rate**

The nitrogen removal rate was calculated by the following equation:

$$R = RE \times (O_{removal} / O_{furnace}) \times (P / E)$$

$R$  : Nitrogen removal rate [%]

$RE$  : Nitrogen removal efficiency

$O_{removal}$  : Hours of operation of nitrogen removal unit [h/yr]

$O_{furnace}$  : Hours of operation of furnace [h/yr]

$P$  : Processing capacity of nitrogen removal unit [m<sup>3</sup>/yr]

$E$  : Maximum exhaust gas emissions [m<sup>3</sup>/yr]

$$RE = (V_{before} - V_{after}) / V_{SS}$$

$RE$  : Nitrogen removal efficiency

$V_{before}$  : NO<sub>x</sub> volume before treatment

$V_{after}$  : NO<sub>x</sub> volume after treatment

$V_{SS}$  : Volume of smoke and soot

The *General Survey of the Emissions of Air Pollutants* data was used for all items.

##### ➤ **Desulfurization rate**

The desulfurization rate was calculated by the following equation:

$$R = DE \times (O_{removal} / O_{furnace}) \times (P / E)$$

$R$  : Desulfurization rate [%]

$DE$  : Desulfurization efficiency

$O_{removal}$  : Hours of operation of desulfurization unit [h/yr]

$O_{furnace}$  : Hours of operation of furnace [h/yr]

$P$  : Processing capacity of desulfurization unit [m<sup>3</sup>/yr]

$E$  : Maximum exhaust gas emissions [m<sup>3</sup>/yr]

$$DE = (V_{before} - V_{after}) / V_{SS}$$

$DE$	: Desulfurization efficiency
$V_{before}$	: SO <sub>x</sub> volume before treatment
$V_{after}$	: SO <sub>x</sub> volume after treatment
$V_{SS}$	: Volume of smoke and soot

The *General Survey of the Emissions of Air Pollutants* data were used for all items.

- **Activity data**

- **Energy consumption of metallurgical coal or coke**

The activity data was calculated by multiplying the consumption of materials (under [44: Metallurgical coal] and [45: Metallurgical coke]) provided in the *General Survey of the Emissions of Air Pollutants* by the gross calorific value.

- **Nitrogen content of iron/ironstone and other materials**

The activity data was calculated by multiplying the weighted average of nitrogen content, calculated from the nitrogen content and consumption of the materials (under [41: Iron/ironstone] and [46: Other raw materials]) provided in the *General Survey of the Emissions of Air Pollutants*, by the consumption amount of the materials.

- **Sulfur content of various materials**

The activity data was calculated by multiplying the weighted average of sulfur content, calculated on the basis of sulfur content and consumption of the materials (under [41: Iron/ironstone] through [46: Other materials]) provided in the *General Survey of the Emissions of Air Pollutants*, by the consumption amount of the materials.

### A3.1.2.2. Non-energy Products From Fuels and Solvent Use (2.D.3.) (NMVOCs)

#### A3.1.2.2.a. Use of Paint

##### a) Category Description

NMVOCs are emitted from paint containing solvent and diluent, in the process of using paint including painting industrial products or buildings<sup>5</sup>.

##### b) Methodological Issues

- **Estimation Method**

Emissions were estimated by multiplying the sales amount of paint by the emission factors per sales amount of paint.

$$E = AD \times EF$$

$E$	: NMVOC emissions from use of paint [1000t -NMVOC]
$AD$	: Sales amount of paint [1000t]
$EF$	: Emission factors per sales amount of paint [t-NMVOC/t]

- **Emission factors**

The annual survey on VOC emissions from use of paint by Japan Paint Manufacturers Association has been conducted since FY2000 (excluding FY2002). The NMVOC emissions per

<sup>5</sup> The emissions in the process of manufacturing were estimated in “A3.1.2.2.n Chemicals Manufacture”

sales amount of paint which was calculated by dividing the emissions provided in the survey by the sales amount of paints are used for emission factor for use of paint. For FY2002, the emission factor was established by interpolating between the FY2001 and FY2003 emission factors that were each established by dividing emissions by activity data.

Due to the lack of quantified data for establishing emission factors for FY1999 and before, emission factors for these periods were established by extrapolation based on the trend during FY2000-FY2010. A decreasing trend was obvious during FY2000-FY2010, and FY2010 was the target year of voluntary action plan based on the Air Pollution Control Act; it was assumed, similarly, that during FY1990-1999 emissions might have decreased because of a possible shift to aqueous paint and installation of VOC processing instruments.

- **Activity Data**

The sales amount of paint provided in the *Yearbook of Current Production Statistics - chemical industry* (METI) (hereafter, *Yearbook of chemical industry*) was used for activity data.

### A3.1.2.2.b. Dry-Cleaning

#### a) Category Description

NMVOCs are emitted from dry-cleaning laundry equipment by using solvent for dry cleaning of clothes.

#### b) Methodological Issues

NMVOC emissions from dry-cleaning were estimated by deducting “weight as waste” (including residual weights in cartridge and distilling sludge) from “used weight of dry cleaning solvent”

$$E = AD - A - B$$

*E* : NMVOC emissions from use of dry-cleaning solvent [t -NMVOC]

*AD* : Used weight of dry-cleaning solvent (Tetrachloroethylene, Industrial gasoline No.5) [t]

*A* : Absorbed residual solvent in cartridge filter to be disposed as waste (Transferred weight of absorption solution during the changing of cartridge filters) [t]

*B* : Residual solvent containing distilling sludge to be disposed as waste (Transferred weight of residual solvents during the distilling of sludge) [t]

- **Emission factors**

No emission factor was established, as all the solvents used in dry cleaning were assumed to be discharged into the atmosphere.

- **Activity data**

#### 1) Used weight of dry-cleaning solvent

Estimated according to the below tables, based on data in the *Study on the VOC Emission Inventory*.

Table A 3-15 Method of estimating activity data for dry-cleaning solvent (Tetrachloroethylene)

Fiscal year (FY)	Method of estimating activity data
1990, 1991	Estimated by multiplying the total consumption weight of the solvent in FY1990 and FY1991 by the percentage for dry-cleaning in FY1992 which was calculated based on <i>Demand by end-use</i> by Japan Association for Hygiene of Chlorinated Solvents (hereafter, JAHCS), since the data for FY1990 and 1991 was not available.
1992, 1995-	Used weight of tetrachloroethylene provided in <i>Demand by end-use</i> by JAHCS was used for activity data.
1993, 1994	Estimated by interpolating the value provided in <i>Demand by end-use</i> by JAHCS for FY1992 and FY1995.

Table A 3-16 Method of estimating activity data for dry-cleaning solvent (Industrial gasoline No.5)

Fiscal year (FY)	Method of estimating activity data
1990, 1991	Estimated by multiplying the used weight of industrial gasoline No.5 in FY1992 by the installation ratio of laundry machines which use petroleum dissolution in FY1992, provided in <i>The survey on usage of dry-cleaning solvent</i> (Ministry of Health, Labour and Welfare (hereafter, MHLW))
1992-1999	Estimated by multiplying the shipping weight of petroleum dry-cleaning solvent in FY2000, provided in <i>Shipping weight of solvents</i> by Japan Cleaning Chemicals Association, by the used weight of industrial gasoline no.5 in FY2000
2000, 2005-	Used the result of the survey on the shipping weight of dry-cleaning solvent by petroleum solvent manufacturer, indicated in the <i>Study on the VOC Emission Inventory</i> .
2001-2004	Estimated by interpolating the values in FY2000 and FY2005.

## 2) Weight transferred as waste

The weight of waste transfer (including residual weights in cartridge and distilling sludge) was estimated using the equations in Table A 3-17, in accordance with the method of the *Study on the VOC Emission Inventory*; the weight was deducted from the used weight of dry-cleaning solvent. Values used for the *Study on the VOC Emission Inventory* based on hearings and other surveys were used as parameters for estimation.

As for installed units of dry-cleaning laundry, values provided in the *Survey on usage and management of solvent for dry-cleaning* (MHLW) were used. However, the survey has been conducted biennially after FY2001; therefore, the same values as those in the previous fiscal year were used for years in which the survey was not conducted.

Table A 3-17 Method of estimation for weight of waste transfer in dry-cleaning solvent

Type of waste	Method of estimation for weight of waste transfer in dry-cleaning solvent
Transfer weight of absorbed solvent in changing cartridge filter	<p>Since 2L solvent per 1kg of laundry is absorbed in changing cartridge on average, the estimated annual weight is calculated according to the following formula.</p> $A = A_{unit} \times L \times D \times W_{ave.} / T \times N$ <p> <i>A</i> : Absorbed weight in cartridge [kg/year]  <i>A<sub>unit</sub></i> : Absorbed VOC weight [L/time/kg] in each changing of cartridge per 1kg of loading weight by washer  <i>L</i> : Standard load of washer per washing [kg]  <i>D</i> : Density [kg/L]  <i>W<sub>ave.</sub></i> : Annual average of operating washer [time/year]  <i>T</i> : Average washer times per changing cartridge filter [time/time]  <i>N</i> : Number of laundry units installed [unit] </p>
Transfer weight of residual solvent in distilling sludge	<p>Transferred weight of solvent in distilling was estimated according to the following formula.</p> $R = L \times T \times F \times N \times I$ <p> <i>R</i> : Contained residual solvent in distilling sludge [kg/year]  <i>L</i> : Standard load of washer [kg/unit]  <i>T</i> : Annual average of operating times of washer [time/year]  <i>F</i> : Factors by type of filter [kg/kg]  <i>N</i> : Unit of installation of laundry [unit]  <i>I</i> : Installation rate of distilling [%] </p>

Reference: *Study on the VOC Emission Inventory*

### A3.1.2.2.c. Metallic Cleaning

#### a) Category Description

NMVOCs are emitted from cleaning of metallic components by industrial cleaners in the process of manufacturing electrical/electronic products or metallic components.

#### b) Methodological Issues

##### ● Estimation Method

#### 1) Chlorine Cleaners

NMVOC emissions from the use of chlorine cleaners were estimated by multiplying the used amount of chlorine cleaners by the emission rate. Since some chlorine cleaners are recycled, the emissions were adjusted for the recycling.

$$E = AD \times R \times EF$$

- E* : NMVOC emissions from the use of chlorine cleaners [1000t -NMVOC]  
*AD* : Sales amount of chlorine cleaners [1000t]  
*R* : Adjustment rate for recycling (x 1.1)<sup>6</sup>  
*EF* : Atmospheric emission rate by use of chlorine cleaners [%]

#### 2) Non-chlorine cleaners

NMVOC emissions from the use of non-chlorine cleaners (semi-aquatic, hydrocarbon system, alcohol system, fluorinated, and other types of cleaners) were estimated by multiplying the used

<sup>6</sup> The research by the Japan Industrial Conference on Cleaning at Japan Solvent Recycling Industry Association found that approximately 10 % of the sales amount of chlorine cleaners were recycled and resupplied by recycling companies. (*Studies to develop the national emissions inventory for volatile organic compounds (VOC), FY 2011*, Ministry of the Environment)



weight of cleaners by the atmospheric emission rate.

$$E = AD \times EF$$

*E* : NMVOC emissions from the use of each non-chlorine cleaner [1000t -NMVOC]

*AD* : Used weight of each non-chlorine cleaner [1000t]

*EF* : Atmospheric emission rate from the use of each non-chlorine cleaner [%]

### ● Emission factors

Emission factors provided in the *Study on the VOC Emission Inventory*, as shown in Table A 3-18, were used for chlorine cleaners and non-chlorine cleaners.

Table A 3-18 NMVOC emission factors for use of each type of cleaner

Type of cleaner	Atmospheric emission rate	Reference
Chlorine cleaner	75%	<i>Commission report on manual for promoting voluntary approach for emission control of VOCs in FY2005</i> (Japan Industrial Conference on Cleaning (hereafter, JICC))
Semi-aquatic cleaner	0.4%	The result of the survey by JICC
Hydrocarbon system cleaner	31.3%	
Alcohol system cleaner	60% (45% for FY2010 and thereafter)	
Fluorinated cleaner	84%	
Other types of cleaners	75%	

### ● Activity Data

#### 1) Chlorine cleaners

Activity data for chlorine cleaner was established as shown in the following Table A3-19 which was based on the *Study on the VOC Emission Inventory* by the Ministry of the Environment and data provided by JAHCS. According to the *Study on the VOC Emission Inventory*, about 10% of the sales amount of chlorine cleaners are recycled and resupplied; therefore, this was taking into consideration, by multiplying the estimates of the amount of cleaners used by 110%, to adjust for recycling and to use as activity data.

Table A 3-19 Activity data for the use of chlorine cleaners (dichloromethane, trichloroethylene, tetrachloroethylene)

Fiscal Year (FY)	Activity data
1990-1994	Estimated by multiplying the total consumption amount in each fiscal year by the proportion of metallic cleaners in FY1995 (calculated based on the <i>Demand by use</i> (JAHCS), (hereafter <i>Demand by use</i> )) since data was not available for FY1990-1994.
1995-	The sales amount of dichloromethane, trichloroethylene, and tetrachloroethylene for metallic cleaning provided in the <i>Demand by use</i> was adopted for activity data.

Table A 3-20 Activity data for the use of chlorine cleaners (other types of chlorine cleaner)

Fiscal Year (FY)	Activity data
1990-1999	Estimated by multiplying the total consumption amount for three major chlorine cleaners ( <i>Demand by use</i> ) for 2000 by the ratio in FY1990-1999 to the activity data in FY2000.
2000, 2005-	The sales amount provided in the <i>Study on the VOC Emission Inventory</i> was used for activity data. (the results of research by JICC).
2001-2004	Estimated by interpolating the activity data for FY2000 and FY2005.

## 2) Non-chlorine cleaner

Activity data for non-chlorine cleaners was established as shown in Table A 3-21 based on the information provided in the *Study on the VOC Emission Inventory*.

Table A 3-21 Activity data for non-chlorine cleaner

Fiscal year (FY)	Activity data
FY1990-1999	Total amount of raw materials by type of cleaner was estimated by multiplying the proportion for each type of manufacturer provided in the <i>Study on the VOC Emission Inventory</i> (Table A 3-22) by the corresponding used weight of raw material; then, the activity data (the used weight) for each year was estimated by multiplying the estimated total weight by the ratio from FY2000.
FY2000	Used weight of each type of cleaner in the <i>Study on the VOC Emission Inventory</i> was adopted for activity data.
FY2001-2004	Estimated by interpolating the activity data for FY2000 and FY2005.
FY2005-	Used weight of each type of cleaner in the <i>Study on the VOC Emission Inventory</i> was adopted for activity data. As for values in the <i>Study on the VOC Emission Inventory</i> , the results of a sampling survey were used after an adjustment. The survey has not been conducting every year. Therefore, for years when the survey was not conducted, data has been supplemented by using the interpolation method.

Table A 3-22 Proportion by type of manufacturer in VOC emissions from non-chlorine cleaner

Manufacture	n-Methyl-pyrrolidone admixture	Glycol ether admixture	n-Paraffin cleaner	Isoparaffin cleaner	Naphthene cleaner	Other carbon hydride cleaner	Isopropyl alcohol cleaner	Other alcohol cleaner	HFC cleaner	Other fluorine cleaner	Bromine cleaner	Other cleaner
Plastic Products			3%	6%	4%			12%				
Iron and Steel			3%	0.1%	5%				1%	2%		
Non-Ferrous Metals and Products			16%	0.05%	7%				1%	2%		
Fabricated Metal Products		2%	17%	30%	26%	8%					4%	
Machinery			11%	8%	15%	11%			1%	2%		
Communications		19%					1%					
Electric device	70%	49%	17%	15%	7%	13%	25%	28%	28%	38%	30%	33%
Transport		2%	16%	26%	36%	10%		12%	7%	19%	18%	67%
Precision apparatus	30%	18%	17%	15%		18%	74%	46%	61%	37%	48%	
Other		10%	0.1%		1%	41%		3%				
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Reference: The *Study on the VOC Emission Inventory*

### A3.1.2.2.d. Use of Thinner for Cleaning Manufacturing Equipment

#### a) Category Description

NMVOCs are emitted from the use of thinner for cleaning manufacturing equipment.

#### b) Methodological Issues

##### ● Estimation Method

NMVOC emissions from the use of thinner for cleaning manufacturing equipment were estimated by multiplying the sales volume of thinner excluding that for painting by the emission factor for NMVOC per sales volume.

$$E = AD \times EF$$

$E$  : NMVOC emissions from the use of cleaning thinner [t-NMVOC]

$AD$  : The sales volume of thinner excluding that for painting [kL]

$EF$  : Emission factor per sales volume of cleaning thinner [t-NMVOC/kL]

#### ● **Emission factors**

Emission factor was established by using the emissions from “thinner for cleaning manufacturing equipment” provided in the *Study on the VOC Emission Inventory* and later-described activity data.

Although the emission factor has a slightly decreasing trend after FY2000, the emission factor for FY2000 is applied for fiscal years FY1990 to FY1999, since there are no quantitative data for estimating emission factors in the related organization and that difficulties have been faced for implementation of technical measures for reduction of emissions from thinner cleaning ( Table A 3-23).

Table A 3-23 The Method of establishing emission factors of cleaning thinner for manufacturing equipment

Fiscal Year (FY)	Method of establishing emission factor
1990-1999	Emission factor for FY2000 was applied for all fiscal years.
2000, 2005-	Estimated by dividing the emissions for each fiscal year provided in the <i>Study on the VOC Emission Inventory</i> by the activity data for each fiscal year.
2001-2004	Estimated by interpolating the activity data for FY2000 and FY2005.

#### ● **Activity data**

Established based on the sales amount of thinner, etc. in the *Yearbook of chemical industry* as shown in the below table.

Table A 3-24 Method of estimating activity data for the use of cleaning thinner for manufacturing equipment

Fiscal Year (FY)	Activity data
1990-2004	Since data on the consumption amount of diluent thinner in and before FY2004 was unidentified, the consumption amount of diluent thinner for this period, which was estimated by multiplying the proportion of the amount of diluent thinner to the sales volume of thinner in FY2005 by the sales volume of thinner in and before FY2004, and, deducting the amount from the total sales volume of thinner, was adopted for activity data.
2005-	Estimated by deducting the consumption amount of diluent thinner for painting provided in <i>Summary of estimation for the current status of VOC emissions from painting</i> (Japan Paint Manufacturers Association) from the sales amount of thinner given in the <i>Yearbook of chemical industry</i> , where the whole time series data from FY1990 were available.

### A3.1.2.2.e. Use of Printing Ink Solvents

#### a) **Category Description**

VOCs are emitted from printing ink solvent or other types of diluent in the process of printing. Ink included in stationaries, solvent for cleaning of printing machine (estimated as “A3.1.2.2.d thinner for cleaning manufacturing equipment”), and emissions at the stage of production of printing ink (estimated as “A3.1.2.2.n Chemicals Manufacture”) were excluded from emissions in this category.

## b) Methodological Issues

### ● Estimation Method

VOC emissions were estimated by multiplying the used weight of VOCs in the process of printing, which was provided in the *Study on the VOC Emission Inventory*, by the atmospheric emission rate.

$$E = AD \times EF$$

$E$  : NMVOC emissions from the use of printing ink solvents [t-NMVOC]

$AD$  : Used weight of VOCs in the process of printing [t]

$EF$  : Atmospheric emission rate per used weight of VOCs [%]

### ● Emission factors

Atmospheric emission rate by type of ink, provided in the *Study on the VOC Emission Inventory* was adopted for emission factor. As for printing ink other than planographic and photogravure ink, the same atmospheric emission rate was adopted for the emission factor for FY2000 and thereafter; in a similar way, the atmospheric emission rate in FY2000 was adopted for and before FY1999.

As for emissions from planographic ink and photogravure ink, the atmospheric emission rate for FY1990-1999 was estimated by extrapolation, using the trend in FY2000-2010: the decreasing trend after FY2000 suggested that some measures aimed at reducing emissions might have been implemented during this period. (Table A 3-25) However, as for photogravure ink, the emission factor was established by interpolating between of the FY1983 value from the *Study of Establishment of Methodology for Estimation of Hydrocarbon Emissions* (Institute of Behavioral Science, 1984) and the FY2000 value, since the atmospheric emission rate in FY1990 would surpass 100% by a simple extrapolating calculation.

Table A 3-25 The method of establishing emission factor for the use of printing ink solvent  
(Planographic ink, photogravure ink)

Fiscal Year (FY)	The method of establishing of emission factor	
	Planographic ink	Photogravure ink
1990-1999	Estimated by extrapolation, using the trend in FY2000-2010.	Interpolated between the 1983 value from the <i>Study of Establishment of Methodology for Estimation of Hydrocarbon Emissions</i> (Institute of Behavioral Science, 1984) and the 2000 value.
2000	Established based on the <i>Study on the VOC Emission Inventory</i> in FY2000.	
2001-2004	Established by interpolating the figures in FY2000 and FY2005.	
2005-	Emission factors in each fiscal year provided in the <i>Study on the VOC Emission Inventory</i> .	

Note: The same emission factor was applied for resin anastatic ink, metallic printing ink, news ink, and other inks for all time-series.

### ● Activity data

The used amount of VOCs, provided in the *Study on the VOC Emission Inventory* (estimated based on the results of the survey by Japan Printing Ink Makers Association and voluntary action plan of Japan Federation of Printing Industries) was used for activity data and was estimated as shown in Table A 3-26.

Table A 3-26 Method of estimating activity data

Fiscal Year (FY)	Activity data
1990-1999	Estimated by multiplying the ratio of sales amount of print ink for each product type in each year to that in FY2000, provided in the <i>Yearbook of Chemical Industry</i> , by the activity data of FY2000.
2000, 2005-	Used amount of VOCs in the process of printing, provided in the <i>Study on the VOC Emission Inventory</i> , was used.
2001-2004	Estimated by interpolating the activity data of FY2000 and 2005.

#### A3.1.2.2.f. Use of Adhesive Agent for Laminate

##### a) Category Description

VOC are emitted from lamination, caused by solvent contained in adhesive agents for bonding base material and laminate. VOC emissions from producing adhesive agents for laminate are estimated in “A3.1.2.2.n Chemicals Manufacture”.

##### b) Methodological Issues

###### ● Estimation Method

NMVOC emissions from polyethylene laminate were estimated by multiplying the sales amount of film for laminate, which was adopted for activity data, by the NMVOC emission factor per sales amount of film for laminate.

$$E = AD \times EF$$

$E$  : NMVOC emissions from lamination [t-NMVOC]

$AD$  : Sales amount of film for laminate [t]

$EF$  : Emission factor per sales amount of film for laminate [t-NMVOC/t]

###### ● Emission factors

Emission factor was established by dividing VOC emissions, which was estimated based on reported values in voluntary action plan in the *Study on the VOC emission inventory*, by the sales amount of film for laminating for FY2000, and FY2005 and thereafter. For fiscal years which were not subject to the voluntary action plan, emission factor in FY2000 was adopted for FY1990-1999. The emission factor for FY2001-2004 was established by interpolating between the emission factors for FY2000 and FY2005.

###### ● Activity data

The sales amount of film for laminate provided in the *Yearbook of Current Production Statistics - paper, printing, plastics products and rubber products* (METI), (hereafter, *Yearbook of Paper, Printing, Plastics Products and Rubber Products Statistics*) was used for activity data.

#### A3.1.2.2.g. Use of Solvent-Type Adhesives

##### a) Category Description

VOCs are emitted from the use of solvent-type adhesive.

**b) Methodological issues****● Estimation Method**

As for VOC emissions from the use of solvent-type adhesive, the atmospheric emission rate was regarded as 100%; the total amount was used for estimating emissions.

$$E = AD$$

*E* : NMVOC emissions from the use of adhesive [t-NMVOC]

*AD* : The used amount of VOCs from the use of adhesive [t]

**● Emission factors**

No emission factors were established since it was assumed that the total amount of the solvent used for adhesive were emitted into the air.

**● Activity Data**

Activity data was estimated as shown in the following table, and based on the *Study on the VOC Emission Inventory* and the *Current Survey Report on Adhesives* (Japan Adhesive Industry Association).

Table A 3-27 Method of establishing activity data for the use of adhesive

Fiscal year (FY)	Activity data
1990-1999	Estimated by multiplying the used amount of VOCs in FY2000 by the ratio of the total of shipping weight of each type of adhesive in each year to the 2000 level.
2000, 2005-	Used amount of VOC emissions provided in the <i>Study on the VOC Emission Inventory</i> (estimated by the Committee for the VOC Emission Inventory).
2001-2004	Estimated by interpolation, using activity data for FY2000 and FY2005.

**A3.1.2.2.h. Use of Gum Solvents****a) Category Description**

VOCs are emitted from gum solvent in the manufacturing of gum products.

**b) Methodological Issues****● Estimation Method**

NMVOC emissions from gum solvents for gum production were estimated by multiplying the consumption of volatile oil for solvent use for gum production by the NMVOC emission factor per consumption of volatile oil for solvent use, which was estimated based on the *Study on the VOC Emission Inventory*.

$$E = AD \times EF$$

*E* : NMVOC emissions from gum production [t-NMVOC]

*AD* : Consumption of volatile oil for solvent use for gum production [t]

*EF* : Emission factor per consumption of volatile oil for solvent use [t-NMVOC/t]

**● Emission Factors**

VOC emissions per consumption of volatile oil for solvent use, which was calculated by dividing emissions based on reported values in the voluntary action plan by the Japan Rubber Manufacturers Association in the *Study on the VOC Emission inventory*, by the consumption of volatile oil for solvent use, were adopted as emission factors for gum production for FY2000, and

FY2005 and thereafter. For fiscal years which were not subject to the voluntary action plan, emission factor in FY2000 was applied for FY1990-1999 and the median value of FY2000 and FY2005 was applied for FY2001-2004.

- **Activity data**

Consumption of volatile oil for solvent use, which was obtained from the *Yearbook of Rubber Products Statistics* by the Ministry of Economy, Trade and Industry and the survey results by the Japan Rubber Manufacturers Association, was applied for activity data. The consumption was converted from volume to mass using the solvent density. As for FY2006-2010, the activity data was adjusted using interpolation since the business entities surveyed for this period was possibly different from before/after this period.

### A3.1.2.2.i. Use of Adhesive Solvents and Detachment Solvents

- a) **Category Description**

NMVOCs are emitted from the use of adhesive solvent and detachment solvent in manufacturing adhesive tape or adhesive label. This source category does not deal with the NMVOC emissions in manufacturing adhesive solvent and detachment solvent since the emissions are included in “A3.1.2.2.n Chemicals Manufacture”.

- b) **Methodological Issues**

- **Estimation Method**

The shipping amount of adhesive tape was used for activity data. NMVOC emissions from the use of adhesive solvent and detachment solvent were estimated by multiplying the activity data by the emission factor per shipping amount.

$$E = AD \times EF$$

$E$  : NMVOC emissions from the use of adhesive and detachment solvent [t-NMVOC]

$AD$  : Shipping amount of adhesive tape [million m<sup>2</sup>]

$EF$  : Emission factor per shipping amount of adhesive tape [t-NMVOC/million m<sup>2</sup>]

- **Emission factors**

Emission factors for FY2000, and FY2005 and thereafter per adhesive for use of solvent and detachment solvent were established by dividing emissions, which were based on the reported values in voluntary action plan by four business associations including Japan Paper Association, by the shipping amount of adhesive tape. For fiscal years which were not subject to the voluntary action plan, emission factor in FY2000 was applied for FY1990-1999 and emission factors in FY2001-2004 were established by interpolating between the FY2000 and FY2005 EFs.

- **Activity data**

The shipping amount provided by Japan Adhesive Tape Manufacturers Association was adopted for activity data.

**A3.1.2.2.j. Use of Repellents and Air Fresheners****a) Category Description**

NMVOCs are emitted from the sublimation of chemical agents during the use of repellents or air fresheners such as at home. The major substance in the emissions is p-dichlorobenzene.

**b) Methodological Issues**● **Estimation Method**

Repellents and air fresheners are mainly used in general households; it is considered that the total amount of them are released into the atmosphere. Therefore, the atmospheric emission rate was regarded as 100% and the amount of p-dichlorobenzene contained in repellents or air fresheners was applied for VOC emissions.

● **Emission factors**

It was assumed that the total amount of p-dichlorobenzene contained in repellent and air fresheners was released into the atmosphere. Therefore, no emission factor has been established.

● **Activity data**

Total amount of p-dichlorobenzene shipped as repellent and air fresheners, which was provided by Japan Moth Repellent Association and indicated in *Estimation Methods for Releases from Sources not Required to Report under PRTR* (METI and MOE) was applied for activity data.

The shipping amount provided by Japan Moth Repellent Association was not available for and before FY2000; therefore, for this period, the shipping amount was estimated by multiplying the amount in FY 2001 by the growth rate of market size from FY2001. For FY1990 and 1991, it was estimated by extrapolation from the shipping amount.

**A3.1.2.2.k. Use of Aerosols Inhalers****a) Category Description**

NMVOCs are emitted from inhalers by the use of aerosols products including pesticide, lacquer, and hair spray. NMVOC emissions from content fluid including paint solvent are estimated in other categories such as the use of paint or cosmetic products. Therefore, to avoid double counting, only NMVOC emissions from liquefied gas in inhalers are included in this category. As for inhalers for aerosols products, propane (LPG) and dimethyl ether (DME) are mainly used.

**b) Methodological Issues**● **Estimation Method**

The emissions were estimated based on the estimation method provided in the *Research Report on VOC emissions from private sector* by the Institute of Behavioral Science (hereafter, Survey by Tokyo Metropolitan Government), in March in 2010. The emissions were estimated as shown in the following equation, by multiplying the production amount for each type of product, by the emission factors for LPG and DME.

$$E = \sum (AD_i \times EF_{LPG,DME})$$



$E$	: NMVOC emissions from the use of aerosols products [g]
$AD_i$	: Production capacity of aerosols product $i$ [cc]
$EF_{LPG, DME}$	: LPG and DME emission factor [g/cc]

### ● Emission factors

Based on each parameter which was used by the Survey by Tokyo Metropolitan Government, the LPG and DME emission amount per aerosols production capacity was applied using the following equation.

$$EF_{LPG, DME} = R_{LPG, DME} \times R_P \times C_{LPG, DME} \times d_{LPG, DME}$$

$EF_{LPG, DME}$	: LPG and DME emission factor per aerosols production capacity [g/cc]
$R_{LPG, DME}$	: Percentage of LPG and DME aerosols products [%]
$R_P$	: Percentage of aerosols propellant in can [%]
$C_{LPG, DME}$	: Percentage of LPG and DME in propellant [%]
$d_{LPG, DME}$	: Specific gravity of LPG and DME [g/cc]

Emission factors for LPG and DME by aerosols products were shown in Table A 3-28.

Table A 3-28 Emission factors for aerosols products (g/cc)

Type of products		LPG	DME
Pesticide	For fly and mosquito	0.223	0.0296
	Other pesticides	0.223	0.0296
Paint	Paint	0.227	0.0151
Household product	Room air freshener	0.236	-
	Cleaner	0.236	-
	Wax and polish	0.236	-
	Laundry articles	0.236	-
	Other household products	0.236	-
Body care products	Hair spray	0.202	0.0269
	Other hair care products	-	0.269
	Shaving cream	0.202	0.0269
	Perfume and cologne	0.112	0.134
	Pharmaceutical products	0.176	0.0905
	Deodorizing and antiperspirant agents	0.225	-
Other body care products		0.112	0.134
Car-related items	Anti-fog	0.213	-
	Other car-related products	0.213	-
Others	Handy extinguisher	-	-
	Others	0.221	-

Reference: Survey by Tokyo Metropolitan Government

### 1) Percentage of aerosol products which used LPG and DME as propellant

As for the percentage of aerosols products which used LPG and DME as propellant, it was calculated by deducting the percentages indicated in Table A 3-29 (established by Tokyo Metropolitan Government research) from 100% for each product and was adapted to each use. As for paint and pharmaceutical products, 100% was applied since no data was available. (Table A 3-30)

Table A 3-29 Percentage of aerosols products which used compressed gas as propellant aerosols

Product	Percentage
Pesticide	1.8%
Household product	6.2%
Cosmetic items	10.8%
Industrial goods	2.3%
Car-related items	15.3%
Others	12.5%

Reference: Survey by Tokyo Metropolitan Government

Table A 3-30 Percentage of aerosol products which used LPG and DME as propellant

Type of product		Percentage
Pesticide	For fly and mosquito	98.2%
	Other pesticides	98.2%
Paint	Paint	100.0%
Household product	Room air freshener	93.8%
	Cleaner	93.8%
	Wax and polish	93.8%
	Laundry articles	93.8%
	Other household products	93.8%
Body care products	Hair spray	89.2%
	Other hair care products	89.2%
	Shaving cream	89.2%
	Perfume and cologne	89.2%
	Pharmaceutical products	100.0%
	Deodorizing and antiperspirant agents	89.2%
	Other body care products	89.2%
Car-related items	Anti-fog	84.7%
	Other car-related products	84.7%
Others	Handy extinguisher	87.5%
	Others	87.5%

Note: Based on the Survey by Tokyo Metropolitan Government

**2) Percentage of propellant gas contained in aerosols cans**

According to the Survey by Tokyo Metropolitan Government, the percentage of propellant gas contained in aerosols cans was estimated to be 45%.

**3) Percentage of LPG and DME in propellant gas**

According to the Survey by Tokyo Metropolitan Government, the percentage of LPG and DME in propellant gas was estimated as shown in Table A 3-31.

Table A 3-31 Percentage of LPG and DME in propellant

Type of product		LPG	DME
Pesticide	For fly and mosquito	90%	10%
	Other pesticides	90%	10%
Paint	Paint	90%	5%
Household products	Room air freshener	100%	0%
	Cleaner	100%	0%
	Wax and polish	100%	0%
	Laundry articles	100%	0%
	Other household products	100%	0%
Body care products	Hair spray	90%	10%
	Other hair care products	0%	100%
	Shaving cream	90%	10%
	Perfume and cologne	50%	50%
	Pharmaceutical products	70%	30%
	Deodorizing and antiperspirant agents	100%	0%
Car-related products	Other body care products	50%	50%
	Anti-fog	100%	0%
	Other car-related products	100%	0%
Others	Handy extinguisher	0%	0%
	Others	100%	0%

Reference: Survey by Tokyo Metropolitan Government

#### 4) Specific gravity of LPG and DME

Based on the Survey by Tokyo Metropolitan Government, specific gravity of LPG and DME was established as 0.56 and 0.67, respectively.

#### ● Activity data

Following the Survey by Tokyo Metropolitan Government, production volume of aerosols products was adopted as activity data; it was estimated by multiplying the production volume of aerosols products for each type of container and capacity, by the average capacity per a can for each type of container and capacity, which converts it to capacity base.

$$AD_i = \sum (N_{i,k} \times P_{ave,k})$$

$AD_i$  : Production capacity of aerosols product  $i$  [cc]

$N_{i,k}$  : Production amount of aerosols Product  $i$ , Container capacity  $k$  [can]

$P_{ave,k}$  : Average capacity of aerosol cans with container capacity  $k$  [cc/can]

As for “Production volume for each type of container and capacity”, the results of the *Survey of Production Amounts of Aerosols* which has been annually conducted by the Aerosols Industry Association of Japan were used. As for “average capacity”, the values were set by the type of container and capacity which was provided in the Survey by Tokyo Metropolitan Government, based on the hearing survey of the Aerosols Industry Association of Japan (shown in Table A 3-32 and TableA3-33).

Table A 3-32 Average capacity by capacity class (tinplate container, aluminum container)

Tinplate container	Capacity class [cc]	100-	150-	180-	220-	280-	420-
	Average capacity[cc]	125	165	200	250	350	420
Aluminum container	Capacity class [cc]	-49	50-	100-	150-	200-	300-
	Average capacity[cc]	25	75	125	175	250	300

Table A 3-33 Average capacity by capacity class (synthetic resin container)

Capacity class [cc]	*
Average capacity[cc]	210

Note: \* Same for all capacity classes

Reference: Survey by Tokyo Metropolitan Government (TableA3-32 and TableA3-33)

### A3.1.2.2.1. Use of Cosmetic Products

#### a) Category Description

VOCs contained in various types of cosmetic products are emitted to the atmosphere by the use of cosmetics.

#### b) Methodological Issues

##### ● Estimation Method

Following the methodology of the *Survey by Tokyo metropolitan government*, VOC emissions were estimated by multiplying the sales amount of cosmetic products for each type by the VOC content rate for each type of cosmetic product, by the atmospheric emission rate for each type of cosmetic product.

$$E = \sum_i (AD_i \times C_i \times EF_i)$$

$E$  : NMVOC emissions from the use of cosmetic product [t-NMVOC]

$AD_i$  : Sales amount of cosmetic items  $i$  [t]

$C_i$  : VOC content in cosmetic products  $i$  [%]

$EF_i$  : Atmospheric emission rate of cosmetic products  $i$  [%]

##### ● Emission factors

The VOC content rate of products was classified according to the *Yearbook of chemical industry* from the VOC content rate which was provided in the Survey by Tokyo Metropolitan Government based on some reports. (Table A3-34)

The smaller classified categories in the Survey by Tokyo Metropolitan Government than those in *Yearbook of chemical industry* were integrated by weighted average using shipping amount allocated ratio provided in *Cosmetic Products Marketing Directory* (Fuji Keizai CO., Ltd.), to make them correspond to the categories in the *Yearbook of chemical industry*.

Table A 3-34 VOC content rate and atmospheric emission rate based on classification in *Yearbook of Chemical Industry*

Cosmetic products		VOC content rate	Atmospheric emission rate
Skin care	Massage and cold cream	7.5%	100%
	Moisturizing cream	7.5%	100%
	Cleansing foam	10.0%	0%
	Cleansing cream	10.0%	0%
	Lotion	10.0%	100%
	Milk	6.0%	100%
	Beauty essence	8.5%	100%
	Facial mask <sup>1)</sup>	4.4%	100%
	Other skincare products	7.5%	100%
Makeup	Foundation <sup>1)</sup>	2.6%	100%
	Face powder	0.0%	100%
	Eye makeup	4.0%	100%
	Eyebrow and eyelash cosmetics	0.0%	100%
	Cheek rouge	0.0%	100%
	Lip rouge	0.0%	100%
Nail cosmetics (including nail-polish remover) <sup>1)</sup>	76.8%	100%	
Fragrance	Perfume and cologne	7.5%	100%
Body care	Lip balm	10.0%	100%
	Sunscreen and cosmetics for sun-burn	83.5%	100%
Hair care in bath	Shampoo	1.5%	0%
	Rinse	1.5%	0%
	Hair conditioner	1.5%	0%
Hair making	Pomade, hair oil, hair dress, perfume oil <sup>1)</sup> Hairdressing <sup>1)</sup> , Setting lotion <sup>1)</sup>	10.6%	100%
	Hair spray	27.5%	100%
	Other items for hair (including permanent wave lotion)	1.5%	100%
Hair color	Hair color (Including hair bleach) <sup>1)</sup>	22.1%	100%
For men	Products for shaving or bath	25.0%	100%
	Skin care products	7.5%	100%
	Hair tonic (including hair growing agents)	42.5%	100%

Note: 1) Integrated categories by weighted average

Reference: *Survey by Tokyo Metropolitan Government*

The atmospheric emission rate, as well as VOC content in the category were reset, so that they correspond to the categories in the *Yearbook of chemical industry*. Assuming that cosmetic products were used in a normal way, atmospheric emission rate of solid products and liquid products were set at either 0% or 100% (Table A 3-35 and Table A 3-36).

Table A 3-35 Atmospheric emission rate by the way of usage, provided in the Survey by Tokyo Metropolitan Government

State of matter	Usage and process	Atmospheric emission rate
Solid	To use in water or wash away	0%
	To leave it and volatilize component	100%
Liquid	To use in water or wash away in a short time	0%
	To leave it for a long time and dry it	100%
	To volatilize component	100%
	To spray mist (only undiluted solution is used for estimation. Propellant solvent is separately estimated.)	100%

Reference: *Survey by Tokyo Metropolitan Government*

Table A 3-36 Atmospheric emission rate based on the Survey by Tokyo Metropolitan Government

Cosmetic products		Atmospheric emission rate	
Skin care	Massage and Cold cream *1	100%	
	Remover	0%	
	Facial-wash	Facial-wash	0%
		Cleansing	0%
	Lotion	Lotion	100%
	Milk	Milk	100%
	Beauty essence	Beauty essence	100%
	Facial mask	Wash-off facial mask	0%
		Peel-off pack	100%
		Sheet pack	100%
Face cream	(Classified into *1)	-	
Others	Spot care	100%	
Makeup	Base	Makeup base	100%
	Foundation, concealer	Foundation, etc.	100%
	Face powder	Face powder	100%
	Eye color	Eye shadow	100%
	Eye liner	Eye liner	100%
	Eyelash liner	Eyelash liner	100%
	Eyebrow	Eyebrow	100%
	Cheek rouge	Cheek rouge	100%
	Lip color	Lip color	100%
	Nail color	Nail enamel	100%
Nail care (including remover)		100%	
Body care	Body cream, lotion	Body cream, lotion, etc.	100%
	Lip cream	Lip cream	100%
	Hand cream	Hand cream	100%
	UV care product	Suntan, sunscreen	100%
	Unwanted hair treatment agent	Hair removal, depilatory	100%
	Anhidrotic deodorant *2	Deodorant (for foot, for underarm)	100%
Fragrance	Perfume *3	Parfum, Eau de Parfum	0%
	Eau de toilette *3		100%
	Cologne *3		0%
Hair care in bath	Shampoo	Shampoo	0%
	Rinse, Hair conditioner	Rinse, Hair conditioner	0%
	Hair treatment, pack	Hair treatment	0%
Hair make	Blow styling agent, Hair spray, Hair gloss	Hair styling agent	100%
	Hair tonic for female	(Classified into *6)	-
	Hair growing agent for female	(Classified into *7)	-
	Permanent wave lotion	Cold wave treating agent	100%
Hair color	Hair coloring agent for black hair, Hair coloring agent for white hair*4	Hair coloring agent for white hair	100%
		Hair coloring agent for black hair	100%
		Hair manicure for white hair	100%
		Hair manicure for black hair	100%
		Other types of hair color (including spray)	100%
		Bleach (decoloring)	100%
For men	Pre-shaving agent, shaving agent	Shaving agent	100%
	Face wash, pack	Skin care products	0%
	Skin lotion		100%
	Skin cream and milk		0%
	Make-up items		0%
	Hair tonic for men *6		Hair tonic
	Hair growing agent *7	Hair growing agent, tonic	100%
	Blow styling agent	(Classified into *4)	-
	Hair spray, hair gloss		0%
	Hair coloring agent for black hair		(Classified into *5)
	Hair coloring agent for white hair	(Classified into *5)	-
	Anhidrotic deodorant	(Classified into *2)	-
	Fragrance	(Classified into *3)	-

Reference: Research report on VOC emissions from public sector (March, 2010, The Institute of Behavioral Science)

● **Activity data**

Sales amount of cosmetic products by types provided in the *Yearbook of chemical industry* is used for activity data. However, since import goods are not included in the *Yearbook of chemical industry* there might be a wide gap between reported sales amount and actual consumption amount. Therefore, as for “perfume and cologne”, since the percentage of import excess was especially high, correction measures were conducted.

Table A 3-37 Cosmetic products provided in Yearbook of chemical industry

Skin care	Massage and cold cream
	Moisturizing cream
	Cleansing foam
	Cleansing cream
	Lotion
	Milk
	Beauty essence
	Facial mask
	Other skincare products
Makeup	Foundation
	Face powder
	Eye makeup
	Eyebrow and eyelash cosmetics
	Cheek rouge
	Lip rouge
	Nail cosmetics (including nail-polish remover)
Fragrance	Perfume and cologne
Body care	Lip balm
	Sunscreen and cosmetics for sun-burn
Hair care in bath	Shampoo
	Rinse
	Hair conditioner
Hair making	Pomade, hair oil, hair dress, perfume oil
	Hairdressing
	Setting lotion
	Hair spray
	Other items for hair (including permanent wave lotion)
Hair color	Hair color (including hair bleach)
For men	Products for shaving or bath
	Skin care products
	Hair tonic (including hair growing agents)

**A3.1.2.2.m. Use of Products for Car Washing and Repair**

**a) Category Description**

VOC components contained in various products for car washing and repairing including wax and cleaner are emitted into the air.

**b) Methodological Issues**

● **Estimation Method**

Following the methodology of the Survey by Tokyo Metropolitan Government, the VOC amount used was estimated by multiplying the production amount of car repairing and washing products for each type of product, by the VOC content by type of product. The whole amount of VOCs contained in car repairing and washing products is assumed to be emitted into the atmosphere by the use of the products. The used amount of VOCs was applied for VOC emissions from this

source category.

$$E = \sum_i (AD_i \times C_i)$$

$E$  : NMVOC emissions by the use of car washing and repairing products [t-NMVOC]

$AD_i$  : The production amount of  $i$  [t]

$C_i$  : VOC content rate of car washing and repairing products  $i$  [%]

### ● Emission factors

VOC content rate was newly established based on various statistical data and existing VOC content provided in the Survey by Tokyo Metropolitan Government; as for some whose minimum value and maximum value was indicated, the median value was calculated. (Table A 3-38 )

Table A 3-38 VOC content rate for car washing and repairing products

Product		VOC	VOC content rate
Wax for cars, coating material		Hydrocarbon compounds including kerosene	50.0%
Products for car window	Window washer fluid	Methanol	25.0%
	Water repellent product	Ethanol	49.0%
		Isopropyl alcohol	42.0%
	Oil film remover	Ethanol	6.5%
		Isopropyl alcohol	12.5%
		Diethanolamine	5.0%
	Frost remover	Petroleum solvent	30.0%
		Ethylene glycol	25.0%
	Isopropyl alcohol	25.0%	
Car cleaner		Ethylene glycol	10.0%
Paint for car, repairing agent	Paint		-
	Adhesive		-
Air fresher and air freshener for cars	Air fresher	Aroma chemical (liquid)	1.5%
		Ethanol	2.3%
		Methanol	3.5%
		Aroma chemical (gel)	3.5%
	Air freshener	Ethanol	50.0%

Reference: Survey by Tokyo Metropolitan Government

### ● Activity data

Production weight by type of chemical product for car indicated in *Research report on the current status of auto chemical manufacturing* (Japan Auto Chemical Industry Association) was used for activity data for FY1991-1996 and FY1999-2005. Activity data in FY2006 and thereafter was estimated by multiplying the consumption of car washing and repairing products per vehicle by the number of registered vehicles provided in *Statistical Yearbook of Motor Vehicle Transport* (Ministry of Land, Infrastructure, Transport and Tourism). Consumption of car washing and repairing products per vehicle was estimated by dividing the production weight for each type of chemical product for car of FY2003 to FY2005 by the number of registered vehicles of each fiscal year, and multiplying the average weight of the three years<sup>7</sup> by the growth rate of travel distance per vehicle from FY2005. The average value was used to reflect the trend of travel distance per vehicle because the consumption of wax and coating material for cars has been showing a downward trend since FY1990 and according to Auto-parts & Accessories Retail Association, recently, consumption per vehicle has been decreasing due to a decline in the rate of

<sup>7</sup> Three-year average was used since the FY2005 value drastically increased from the previous year.



utilization of cars, miniaturization of cars, and the prevalence of car washing machines. The consumption of other products for cars was also estimated based on the growth rate of travel distance per vehicle. For FY1990, the value for FY1991 was used. For FY1997 and FY1998, it was estimated by interpolation, using activity data in FY1996 and FY1999.

### A3.1.2.2.n. Chemicals Manufacture

#### a) Category Description

This source category provides the methods for estimating NMVOC emissions from highly-volatile substances in manufacturing facilities to polymerize or synthesize chemical products, fugitive emissions by storage or shipping of chemical products, and emissions from solvent in chemical reaction by polymerizing or component extraction.

#### b) Methodological Issues

##### ● Estimation Method

NMVOC emissions from chemicals manufacture were estimated by multiplying source-specific activity data (production amount of paint, production amount of print ink, shipping amount of solvent-type adhesive, amount of VOC of surface finishing equipment, shipping value of chemical industry-related products and production amount of film soft chemical products for wrapping) by each NMVOC emission factor defined by dividing source-specific VOC emissions in the *Study on the VOC Emission Inventory* by activity data.

$$E = AD \times EF$$

$E$  : NMVOC emissions by chemical manufacture [t-NMVOC]

$AD$  : Activity data by source

$EF$  : Emission factor per activity data [t-NMVOC/t]

The emissions estimated by the equation above include the emissions from chemical tankers estimated in A3.1.1.3.c Oil transport (1.B.2.a.iii): Navigation. Therefore, the emissions from chemical tankers were subtracted from the total emissions in this category.

##### ● Emission factors

Emission factor was established by dividing emissions from emission activities indicated in the *Study on the VOC Emission Inventory* by each activity data shown in Table A 3-45. The emission factor for each fiscal year which was not subject to the voluntary action plan / the PRTR report was established as shown in Table A 3-39 - Table A 3-44.

Table A 3-39 Method of establishing NMVOC emission factors for chemical manufacture  
(paint manufacturing)

Fiscal Year (FY)	Method of establishing emission factor
1990-1999	Emission factor for FY2000 was used for all fiscal years.
2000, 2005-	Established by dividing VOC emissions (estimated figure based on voluntary action plan by Japan Paint Manufacturers Association) by the production amount of paint.
2001-2004	Average value of FY2000 and 2005 was used.

Table A 3-40 Method of establishing NMVOC emission factors for chemical manufacture  
(print ink manufacturing)

Fiscal Year (FY)	Method of establishing emission factor
1990-1999	Emission factor for FY2000 was used for all fiscal years.
2000, 2005-	Established by dividing VOC emissions (estimated figure based on voluntary action plan by Japan Printing Ink Makers Association) by the production amount of print ink.
2001-2004	Average value of FY2000 and 2005 was used.

Table A 3-41 Method of establishing NMVOC emission factors for chemical manufacture  
(solvent-type adhesive manufacturing)

Fiscal Year (FY)	Method of establishing emission factor
1990-1999	Emission factor for FY2000 was used for all fiscal years.
2000, 2005-	Established by dividing VOC emissions (estimated figure based on voluntary action plan by Japan Adhesive Industry Association) by the shipping amount of solvent-type adhesive.
2001-2004	Average value of FY2000 and 2005 was used.

Table A 3-42 Method of establishing NMVOC emission factors for chemical manufacture  
(manufacturing of surface finishing equipment)

Fiscal Year (FY)	Method of establishing emission factor
1990-1999	Emission factor for FY2000 was used for all fiscal years.
2000, 2005-	Established by dividing VOC emissions (estimated figure based on voluntary action plan by Japan Surface Finishing Suppliers Association) by the used amount of VOCs by manufacturing of surface finishing equipment.
2001-2004	Average value of FY2000 and 2005 was used.

Table A 3-43 Method of establishing NMVOC emission factors for chemical manufacture  
(manufacturing of various chemical products)

Fiscal Year (FY)	Method of establishing emission factor
1990-1994	Since no aggressive actions to reduce emissions have been taken, the emission factor for FY1995 was used for all fiscal years.
1995-1999	Since voluntary actions started in FY1995, it is considered that emissions have been on a downward trend since then. Therefore, emissions were estimated by extrapolation, using the trend for 2000-2010 <sup>1)</sup> .
2000, 2005-	Established by dividing VOC emissions from chemical industry (estimated figure based on voluntary action plan by Japan Chemical Industry Association) by shipping value of chemical industry-related products.
2001-2004	Estimated by interpolation, using emission factors in FY2000 and 2005.

Note: 1) In the case that emission factor for FY1990-1999 is established by extrapolation, it should be established based on the trend for and before FY2010, which is the target year of the voluntary action plans for VOC emission reduction.

Table A 3-44 Method of establishing emission factors for chemical manufacture  
(cellophane manufacturing)

Fiscal Year (FY)	Method of establishing emission factor
1990-1999	Emission factor for FY2000 was applied for all fiscal years.
2000, 2005-	Established by dividing VOC emissions from cellophane manufacturing (emissions reported to the PRTR) by the production amount of film soft chemical products for wrapping.
2001-2004	Average value of FY2000 and 2005 was used.

#### ● Activity data

The following data indicated in Table A 3-45 was used for activity data, since it is considered to be correlated to each emission activity. As for “Manufacturing of various chemical products”, the total shipping value for all various chemical products was used for activity data due to difficulty in selecting specific chemical products from many chemical products provided in voluntary

action plan by Japan Chemical Industry Association. Since the total shipping value is available only for calendar year, the value was converted from calendar year to fiscal year using the following equation.

$$S_{FYi} = S_{CYi} \times 0.75 + S_{CY(i+1)} \times 0.25$$

$S$  : Shipping value

$FY_i$  : Fiscal year  $i$

$CY_i$  : Calendar year  $i$

Table A 3-45 Activity data for chemical manufacture

Emission source	Activity data	Reference
Paint manufacturing	The production amount of paint	<i>Yearbook of chemical industry</i> (METI)
Print ink manufacturing	The production amount of print ink	<i>Yearbook of chemical industry</i> (METI)
Solvent-type adhesive manufacturing	The shipping amount of solvent-type adhesive	<i>Current Survey Report on Adhesive</i> (Japan Adhesive Industry Association)
Manufacturing of surface finishing equipment	Used amount of VOCs by manufacturing surface finishing equipment. Note: For FY1990-1999, the value for FY2000 was applied. For FY2001-2004, the average of the values for FY2000 and 2005 was used.	<i>VOC voluntary action plan and achievement report</i> (METI)
Manufacturing of various chemical products	Total shipping value of various chemical products reported in PRTR in voluntary action plan. (“Chemical industry” and “Manufacturing plastic products (not specified elsewhere)”) )	<i>Census of manufactures</i> (METI)
Cellophane manufacturing	The production amount of film-soft chemical products for wrapping.	<i>Yearbook of Paper, Printing, Plastics Products and Rubber Products Statistics</i> (METI)

### A3.1.2.2.o. Use of Removers

#### a) Category Description

Dichloroethane is used to remove paint before re-painting and is emitted during use.

#### b) Methodological issues

##### ● Estimation Method

It is difficult to take measures to reduce emissions such as through local venting during the use of removers. Therefore, the total amount of Dichloroethane used for removers was used for estimating emissions.

##### ● Emission factors

No emission factors were established since the activity data is directly the emissions.

##### ● Activity Data

The Dichloroethane used for removers was established based on the data provided by the JAHCS data as follows:

Table A 3-46 The method of establishing activity data for the use of removers

Fiscal year (FY)	Method of establishing activity data
1990-1994	Since there is no data on the consumption by end-use between 1990 and 1994, it is estimated by multiplying the total consumption amount of each year by the ratio of remover-use to the total consumption of FY1995.
1995-	The Dichloroethane used for removers in <i>Consumption by End-Use</i> by the JAHCS.

### A3.1.2.2.p. Use of Reagents

#### a) Category Description

NMVOCs are included in reagents that are used to induce chemical reactions during chemical experiments and component analyses, etc, and are emitted during use.

#### b) Methodological issues

##### ● Estimation Method

Following the estimation method in the VOC emission inventory, the amount of reagents used by substance is multiplied by the emission rate by substance, to estimate emissions.

$$E = AD \times EF$$

$E$  : NMVOC emissions from the use of reagents [t-NMVOC]

$AD$  : Amount of reagents used [t]

$EF$  : Emission rate during reagent use [t-NMVOC/t]

##### ● Emission factors

Following the VOC emission inventory, the EF for reagent use as described in the *Report on the Promotion of Chemical Substance Safety Measures (The Survey on Methods for Emission Estimation for Below-threshold Entities and Methods for Emission Estimation for Ozone-depleting Substances and Low-content Substances)* is used for FY2000 and FY2005. Emission factor for FY2000 was used for the EFs up to FY1999, and the emission factors for FY2001-FY2004 are estimated by interpolating between FY2000 and FY2005 EFs.

##### ● Activity Data

The Dichloroethane/Trichloroethylene used for reagents was established based on the *Study on the VOC Emission inventory* by the Ministry of the Environment and the data provided by the JAHCS data as follows:

Table A 3-47 The method of establishing activity data for the use of reagents

Fiscal year (FY)	Method of establishing activity data
1990-1994	Since there is no data on the consumption by end-use between 1990 and 1994, it is estimated by multiplying the total consumption amount of each year by the ratio of reagent-use to the total consumption of FY1995. (calculated from the <i>Consumption by End-Use</i> by the JAHCS).
1995-	The Dichloroethane/Trichloroethylene used for reagents in <i>Consumption by End-Use</i> by the JAHCS.

For other reagents, Dichloroethane used for reagents in *Consumption by End-Use* by the JAHCS is multiplied by the ratio of reported substances in the *Study on the VOC Emission inventory* (from the environmental ordinance of Tokyo) that are used as reagents to the amount of Dichloroethane used as reagents, to estimate emissions.

**A3.1.2.2.q. Use of Blowing Agents****a) Category Description**

Dichloroethane is used as an auxiliary blowing agent for flexible polyurethane foams of polyurethane and is emitted during use.

**b) Methodological issues**● **Estimation Method**

The total amount of Dichloroethane used for blowing agents was used for estimating emissions.

● **Emission factors**

No emission factors were established since the activity data is directly the emissions.

● **Activity Data**

The Dichloroethane used for blowing agents production was established based on the data provided by JAHCS as follows:

Table A 3-48 The method of establishing activity data for the use of blowing agents production

Fiscal year (FY)	Method of establishing activity data
1990-1994	Since there is no data on the consumption by end-use between 1990 and 1994, it is estimated by multiplying the total consumption amount of each year by the ratio of blow agent-use to the total consumption of FY1995.
1995-	The Dichloroethane used for blowing agents in <i>Consumption by End-Use</i> by JAHCS.

**A3.1.2.2.r. Use of Fishing Net Antifouling Agents****a) Category Description**

Solvents are used to dilute fishing net antifouling agents which are applied to nets used in fish farms or stationary nets. The nets are first immersed in the chemicals and then dried off before use. Solvents are emitted into the atmosphere at this stage.

**b) Methodological issues**● **Estimation Method**

Total amount of xylene used (sea aquaculture and stationary nets) from the 'Total amounts used for fishing net antifouling agents in sea aquaculture, etc' (surveyed by the Fisheries Agency), in the 'emissions from fishing net antifouling agents', from the Emissions from Sources not Required to Report under PRTR, was used for emissions.

● **Emission factors**

No emission factors were established since the activity data is directly the emissions.

● **Activity Data**

Activity data is established as shown in the below Table, based on *Emissions from Sources not Required to Report under PRTR* and data provided by the Fisheries Agency.

Table A 3-49 The method of establishing activity data for the use of Fishing Net Antifouling Agents

Fiscal year (FY)	Method of establishing activity data
1990-1997	Xylene used for fishing net antifouling agents for sea aquaculture and stationary nets in FY1998 is used, since no data exist for xylene used for fishing net antifouling agents.
1998-2001	Data provided by the Fisheries Agency is used.
2002-	Total amount of xylene used (sea aquaculture and stationary nets) from the 'Total amounts used for fishing net antifouling agents in sea aquaculture, etc' (surveyed by the Fisheries Agency), in the 'emissions from fishing net antifouling agents', from the Emissions from Sources not Required to Report under PRTR, was used.

### A3.1.2.2.s. Use of Converting Solvents

#### a) Category Description

The solvents used at the drying stage of the converting processing facilities, the drying and baking (wrinkle-resistant processing) stage during finishing, and the drying stage of printing, are emitted into the atmosphere.

#### b) Methodological issues

##### ● Estimation Method

Emissions were estimated by multiplying the product quantity in the dyeing and finishing processes, by the emission factor per product quantity.

##### ● Emission factors

Emission factors were established by dividing emissions based on the reported values in the Voluntary Action Plan of the Japan Textile Finishers' Association in the VOC emission inventory, by product quantity totals in the dyeing and finishing processes (excluding wool fabrics).

Table A 3-50 The method of establishing emission factors for the use of converting solvents

Fiscal Year (FY)	The method of establishing emission factor
1990-1999	Emission factor for FY2000 was applied.
2000, 2005-	Emission factors were established by dividing VOC emissions from the use of converting solvents (estimated values based on the reported values in the Voluntary Action Plan of the Japan Textile Finishers' Association), by product quantity in the dyeing and finishing processes (excluding wool fabrics).
2001-2004	Estimated by interpolating between FY2000 and FY2005 EFs.

##### ● Activity Data

Product quantity in the dyeing and finishing processes (excluding wool fabrics) in the *Yearbook of Current Production Statistics - Textiles and Consumer Goods Statistics* (METI) is used. As for wool fabrics, converting solvents are not used in the production process and is therefore excluded from the activity data.

### A3.1.2.2.t. Use of Coating Solvents

#### a) Category Description

Emissions occur from solvents used when coating plastic films for special functions (antistatic agents, abrasion and scratch resistant, anti-fogging agents, electromagnetic shielding, conductivity imparting agents, UV absorbers, etc).

**b) Methodological issues**● **Estimation Method**

Emissions were estimated by multiplying the film sales amount by the emission factor per sales amount.

● **Emission factors**

Emission factors were established by dividing emissions based on the reported values in the Voluntary Action Plan of the Japan Polyethylene Products Industrial Federation in the VOC emission inventory by film sales amounts.

Table A 3-51 The method of establishing emission factors for the use of coating solvents

Fiscal Year (FY)	The method of establishing emission factor
1990-2004	The EF for FY2005 is applied.
2005-	Emission factors were established by dividing VOC emissions from the use of coating solvents (estimated values based on the reported values in the Voluntary Action Plan of Japan Polyethylene Products Industrial Federation) by film sales amounts.

● **Activity Data**

The film sales amounts in the *Yearbook of Paper, Printing, Plastics Products and Rubber Products Statistics* are used.

**A3.1.2.2.u. Use of Synthetic Leather Solvents****a) Category Description**

N, N-dimethylformamide is used to dissolve polyurethane when manufacturing synthetic leather and is emitted in the process of use.

**b) Methodological issues**● **Estimation Method**

The sum of the atmospheric emissions of N, N-dimethylformamide from the plastic product manufacturing industry reported under the PRTR and the emissions similar as the above but from below-threshold entities given in the Estimation Results of Emissions from Sources That Are Not Required to Report Under the PRTR, are used as emissions.

● **Emission factors**

No emission factors were established since the activity data is directly the emissions.

● **Activity Data**

The sum of the atmospheric emissions of N, N-dimethylformamide from the plastic product manufacturing industry under the PRTR and the emissions similar as the above but from below-threshold entities given in the Estimation Results of Emissions from Sources That Are Not Required to Report Under the PRTR, are used as emissions.

Table A 3-52 The method of establishing activity data for the use of synthetic leather solvents

Fiscal Year (FY)	Method of establishing activity data	
	Emissions under the PRTR	Emissions from sources not required to report under the PRTR
1990-2000	Estimated by multiplying FY2001 atmospheric emissions by the ratio to the FY2001 data for consumption amounts of other resin for synthetic leather in the <i>Yearbook of Paper, Printing, Plastics Products and Rubber Products Statistics</i> .	
2001-2012	The atmospheric emissions of N, N-dimethylformamide from the plastic product manufacturing industry, reported under the PRTR is used as emissions.	Estimated by multiplying FY2001 to FY2012 emissions reported under the PRTR, by the ratio of FY2017 <sup>8</sup> emissions from sources not required to report under PRTR to the FY2017 emissions reported under the PRTR.
2013-		The atmospheric emissions of N, N-dimethylformamide from the plastic product manufacturing industry from below-threshold entities given in the Estimation Results of Emissions from Sources That Are Not Required to Report Under the PRTR is used.

### A3.1.2.2.v. Use of Fumigants

#### a) Category Description

Methyl bromide is emitted from the use of fumigants on croplands and in warehouses, etc.

#### b) Methodological issues

##### ● Estimation Method

Emissions were estimated by multiplying the amount of methyl bromide used for fumigants by the emission factor per use amount.

##### ● Emission factors

An emission factor (64%) based on the *Survey of Actual Use of Methyl Bromide* (National Institute for Environmental Studies, 1998) is applied to all years.

##### ● Activity Data

The activity data was established as follows, based on the amount of methyl bromide used for fumigants provided in the domestic shipment amounts by use from the Methyl Bromide Association. As for the Soil and Quarantine categories, it is assumed that 100% is used as fumigants. As for the Other category, although it includes uses for industrial raw material, details are unknown and is therefore assumed that 50% is used as fumigants.

Table A 3-53 The method of establishing activity data for the use of fumigants

Fiscal Year (FY)	Method of establishing activity data
1990-1999	Amount of methyl bromide provided in the domestic shipment amounts by use (Surveyed by the Agricultural Safety Management Section, Food Safety and Consumer Affairs Bureau, MAFF) The Other category is estimated using this data.
2000, 2005-	Amount of methyl bromide used for fumigants provided in the domestic shipment amounts by use from the Methyl Bromide Association.
2001-2004	Amount of methyl bromide provided in the domestic shipment amounts by use (Surveyed by the Agricultural Safety Management Section, Food Safety and Consumer Affairs Bureau, MAFF) The Other category is estimated using this data.

<sup>8</sup> The value of the year with the highest ratio was used to avoid underestimation.



### A3.1.2.2.w. Use of Dampening Solutions

#### a) Category Description

Isopropyl alcohol, included in etch solutions that are added to dampening solutions used in offset printing, is emitted into the atmosphere as a VOC.

#### b) Methodological Issues

##### ● Estimation Method

Emissions were estimated by multiplying the sales amount of planographic printing ink by the NMVOC emissions per sales amount of planographic printing ink.

$$E = AD \times EF$$

*E* : NMVOC emissions from the use of dampening solutions [t-NMVOC]

*AD* : Sales amount of planographic printing ink [t]

*EF* : NMVOC emissions per sales amount of planographic printing ink [t-NMVOC/t]

##### ● Emission factors

The emission factors were established as follows, based on the reported values in the voluntary action plan of the Japan Federation of Printing Industries.

Table A 3-54 The method of establishing emission factors for the use of dampening solutions

Fiscal Year (FY)	Method of establishing emission factor
1990-1999	Emission factor for FY2000 was applied.
2000, 2004-	Emission factors were established by dividing VOC emissions from the use of dampening solutions (estimated values based on the reported values in the voluntary action plan of the Japan Federation of Printing Industries) by sales amounts of planographic printing ink.
2001-2003	Estimated by interpolating between FY2000 and FY2004 EFs.

##### ● Activity data

The sales amounts of planographic printing ink in the *Yearbook of Chemical Industry* (METI) are used.

### A3.1.2.2.x. Use of Fabric Treatment Agents

#### a) Category Description

NMVOCs are emitted into the atmosphere from the use of fabric treatment agents (anti-static agents for fabrics, water repellents, fabric refreshers, and stain removers) through volatilizing or spraying the substances.

#### b) Methodological Issues

##### ● Estimation Method

NMVOC emissions are estimated by multiplying the sales amounts of each type of fabric treatment agent by the VOC content for each type of fabric treatment agent, and by the atmospheric emission rate for each type of fabric treatment agent.

$$E = \sum_i (AD_i \times R_i \times EF_i)$$

$E$  : NMVOC emissions from the use of fabric treatment agents [t -NMVOC]

$AD_i$  : Sales amount of fabric treatment agent  $i$  [t] (Estimated by multiplying the sales amount by specific gravity (0.8) when its unit is in volume)

$R_i$  : VOC content in fabric treatment agent  $i$  [%]

$EF_i$  : Atmospheric emission rate of fabric treatment agent  $i$  [%]

#### ● **Emission factors**

The VOC content and atmospheric emission rate were established as follows, based on how the value in the *Survey by the Tokyo Metropolitan Government* was established. The VOC content was established for each type, using the medium value of minimum and maximum VOC contents in the *Survey by the Tokyo Metropolitan Government*.

Table A 3-55 VOC content and atmospheric emission rate for the use of fabric treatment agents

Type of products	VOC content	Atmospheric emission rate
Anti-static agents for fabrics	50%	100%
Water repellents (for clothing, shoes, etc.)	35%	100%
Fabric refreshers	8%	100%
Stain removers (surfactants)	30%	100%
Stain removers (benzines)	50%	100%

#### ● **Activity data**

Established as follows, based on the method of the [*Expanded*] *National Emission Inventory for Volatile Organic Compounds* (MOE) (hereafter, *Expanded VOC Emission Inventory*)

Table A 3-56 Method of establishing activity data for the use of fabric treatment agents

Fiscal Year (FY)	Method of establishing activity data
2005-2007	Sales amounts of fabric treatment agents in the <i>Survey by the Tokyo Metropolitan Government</i>
Excluding the above	Estimated by multiplying the three-year average of FY2005 to FY2007 in the <i>Survey by the Tokyo Metropolitan Government</i> by each year's growth rate of annual expenditures of all households as compared to the average value of FY2005 to FY2007, where expenditures of all households are calculated by multiplying annual expenditures per household from "Other domestic non-durable goods – Others" etc in the <i>Survey of Household Economy</i> (Ministry of Internal Affairs and Communications) by the number of all households in the <i>Population, vital statistics and number of households survey based on the Basic Resident Registration</i> (Ministry of Internal Affairs and Communications).

### A3.1.2.2.y. Use of Air Fresheners

#### a) **Category Description**

NMVOCs contained in air fresheners are emitted into the atmosphere from the placing and use of air fresheners through volatilizing the substances.

#### b) **Methodological Issues**

##### ● **Estimation Method**

NMVOC emissions are estimated by multiplying the sales amounts of each type of air freshener by the VOC content for each type of air freshener, and by the atmospheric emission rate for each type of air freshener.

$$E = \sum_i (AD_i \times R_i \times EF_i)$$

$E$  : NMVOC emissions from the use of air fresheners [t -NMVOC]

$AD_i$  : Sales amounts of air freshener  $i$  [t] (Estimated by multiplying the sales amounts by specific gravity (0.8) when its unit is in volume)

$R_i$  : VOC content in air freshener  $i$  [%]

$EF_i$  : Atmospheric emission rate of air freshener  $i$  [%]

### ● **Emission factors**

The VOC content and atmospheric emission rate were established as follows, based on how the value in the *Survey by the Tokyo Metropolitan Government* was established. The VOC content was established for each type, using the medium value of minimum and maximum VOC contents in the *Survey by the Tokyo Metropolitan Government*.

Table A 3-57 VOC content and atmospheric emission rate for the use of air fresheners

Type of air freshener		VOC content	Atmospheric emission rate
Air fresheners, etc for rooms	Aerosol	30%	100%
	Plugin air freshener	30%	100%
	Others	30%	100%
Air fresheners, etc for bathrooms	Aerosol	30%	100%
	Mists	30%	100%
	Others	30%	100%
Deodorizers	Refrigerator deodorizers	1%	100%

### ● **Activity data**

Established as follows, based on the method of establishing activity data for the *Expanded VOC Emission Inventory* and the *Survey by the Tokyo Metropolitan Government*.

Table A 3-58 Method of establishing activity data for the use of air fresheners

Year	Method of establishing activity data
2005-2007	Estimated sales amounts of air fresheners by dividing the sales total of air fresheners by the unit price in the <i>Survey by the Tokyo Metropolitan Government</i> .
Excluding the above	Same as the method of establishing activity data for fabric treatment agents excluding FY2005-2007.

## A3.1.2.2.z. Use of Skin Disinfectants / Sanitizers

### a) **Category Description**

Alcohols such as ethanol and isopropanol, etc. contained in skin disinfectants / sanitizers are emitted into the atmosphere during use.

### b) **Methodological Issues**

#### ● **Estimation Method**

Emissions are estimated by multiplying the shipment amounts of each type of skin disinfectant / sanitizer by the VOC content for each type of skin disinfectant / sanitizer, and by the atmospheric emission rate for each type of skin disinfectant / sanitizer.

$$E = \sum_i (AD_i \times 0.8 \times R_i \times EF_i)$$

$E$  : NMVOC emissions from the use of skin disinfectants / sanitizers [t -NMVOC]

$AD_i$  : Shipment amounts of skin disinfectant / sanitizer  $i$  [t]

0.8 : Approximate value of specific gravity of alcohol [t/kL]

$R_i$  : VOC content in skin disinfectant / sanitizer  $i$  [%]

$EF_i$  : Atmospheric emission rate of skin disinfectant / sanitizer  $i$  [%]

### ● Emission factors

The VOC content and atmospheric emission rate were established based on the value established in the *Survey by the Tokyo Metropolitan Government* and the *Expanded VOC Emission Inventory*, etc. The VOC content was established for each type as follows, and the atmospheric emission rate was set to 100%.

Table A 3-59 VOC content for the use of skin disinfectants / sanitizers

Type of skin disinfectant / sanitizer		VOC content	
Disinfectant and sanitizer for external use (drugs, quasi-drugs)		45% (the medium value of the minimum/ maximum values (20%, 70%) in the <i>Survey by the Tokyo Metropolitan Government</i> )	
Skin sanitizers	Alcohol formulations	Isopropanol	100% (Established conservatively, based on the specification tables of manufacturers)
		Isopropanol (liquid) 50%	50% (product specification)
		Isopropanol (liquid) 70%	70% (product specification)
		Ethanol	96% (the medium value of the minimum / maximum values (95.1, 96.9 vol%) of the specification of the <i>Japanese Pharmacopoeia</i> (Ministry of Health, Labour and Welfare))
		Ethanol for sanitization	79% (the medium value of the minimum / maximum value (76.9, 81.4 vol%) of the specification of the <i>Japanese Pharmacopoeia</i> )
		Absolute ethanol	100% (Established conservatively, based on the specification of the <i>Japanese Pharmacopoeia</i> (99.5% or more))
	Ethanol (liquid)	79% (Same as ethanol for sanitization)	
Others		1% (the value established in the <i>Expanded VOC Emission Inventory</i> )	

### ● Activity data

Established as follows, based on the value established in the *Survey by the Tokyo Metropolitan Government* and the shipment amounts, etc. for the “skin disinfectant and sanitizer” in the *Statistics of Production by Pharmaceutical Industry* (Ministry of Health, Labour and Welfare).

Table A 3-60 Method of establishing activity data for the use of skin disinfectants / sanitizers

Calendar Year (CY)	Disinfectant and sanitizer for external use (drugs, quasi-drugs)	Skin sanitizer
2005-2007	The value established in the <i>Survey by the Tokyo Metropolitan Government</i> was used.	Shipment amounts of “skin disinfectant and sanitizer” in the <i>Statistics of Production by Pharmaceutical Industry</i> (Ministry of Health, Labour and Welfare) was used with partial correction.
Excluding the above	Estimated by multiplying the three-year average of FY2005 to FY2007 in the <i>Survey by the Tokyo Metropolitan Government</i> by each year's growth rate of production value of “household medicines” given in the <i>Statistics of Production by Pharmaceutical Industry</i> as compared to the average value of FY2005 to FY2007.	

## A3.1.2.2.aa. Use of Food Trays and Expanded Polystyrene

### a) Category Description

Butanes or isobutanes remaining in food trays (polystyrene paper) or expanded polystyrene, are

emitted into the atmosphere during use.

#### **b) Methodological Issues**

##### ● **Estimation Method**

Emissions are estimated by multiplying the shipment amounts of polystyrene paper and expanded polystyrene by the VOC content, and by the atmospheric emission rate.

$$E = AD \times R \times EF$$

$E$  : NMVOC emissions from the use of food trays and expanded polystyrene [t -NMVOC]

$AD$  : Shipment amounts of polystyrene paper and expanded polystyrene [t]

$R$  : VOC content in polystyrene paper and expanded polystyrene [%]

$EF$  : Atmospheric emission rate [%]

##### ● **Emission factors**

The VOC content was set to 1.0% and the atmospheric emission rate was set to 100%, based on the value established in the *Expanded VOC Emission Inventory*.

##### ● **Activity data**

For food trays, shipment amounts of polystyrene paper provided by the Japan Polystyrene Foamed Sheet Industry Association were used. The value of 1991 was used for 1990 due to the lack of the data for 1990, since it was before the establishment of the industry association.

For expanded polystyrene, recovery amounts for recycling (equal to domestic distribution amounts) of expanded polystyrene by the Japan Expanded Polystyrene Association were used. The value of 1991 was used for 1990 due to lack of the data for 1990.

### **A3.1.2.3. Others – Food and Beverage Industry (2.H.2.) (NMVOCs)**

#### **A3.1.2.3.a. Foods (Fermentation)**

##### **a) Category Description**

NMVOCs are released as a fugitive emission in alcohol in the process of manufacturing foods or beverages. For the estimation of NMVOC emissions from this source category, alcohol which is generated by bread making and alcoholic brewing is included in the calculation; it is considered to be of biogenic-origin.

##### **b) Methodological Issues**

##### ● **Estimation Method**

NMVOC emissions from manufacturing foods or beverages were estimated by multiplying the production amount of bread and alcohol drinks, by the NMVOC emission factor per production amount of bread and alcoholic drinks.

##### ➤ **Calculation of NMVOC emissions from bread making**

$$E = AD \times EF$$

$E$  : NMVOC emissions from bread making [t -NMVOC]

$AD$  : Production amount of bread [1000 t]

$EF$  : Emission factor per production amount of bread [kg-NMVOC/t]

➤ **Calculation of NMVOC emissions from alcohol brewing**

$$E = AD \times ABV \times EF$$

$E$  : NMVOC emissions from alcohol brewing [t -NMVOC]

$AD$  : Production volume of alcoholic drinks [1000 kL]

$ABV$ : Ethyl alcohol content rate [%] (only for Shochu (Japanese distilled spirit), whiskey, spirits, and liqueur)

$EF$  : Emission factor per production amount of alcoholic drinks [kg-NMVOC/kL]

● **Emission factors**

Emission factor (4.5kg/t) for bread making, provided in the European Environment Agency's *EMEP/EEA Air Pollutant Emission Inventory Guidebook 2009*, was used as the emission factor for bread making.

As for emission factor for brewing alcoholic drinks, the ethyl alcohol content provided in European Environment Agency's *EMEP/EEA Air Pollutant Emission Inventory Guidebook 2009* was also used (TableA3-61). The ethyl alcohol contents of the alcoholic drinks were only established for Shochu, whiskey, spirits and liqueurs. The ethyl alcohol contents of Shochu and whiskey were established based on the European Environment Agency's *EMEP/EEA Air Pollutant Emission Inventory Guidebook 2009* (TableA3-62). The ethyl alcohol content provided in the *VOC Emission Inventory* was used for spirits and liquor. (TableA3-63 and TableA3-64).

Table A 3-61 Emission factors for brewing alcoholic drinks

Alcoholic drinks	Emission factor	Unit
Sake	0.08	kg/100L- volume of brewed alcoholic drinks
Sake compound	0.08	kg/100L- volume of brewed alcoholic drinks
Shochu (Japanese distilled spirit)	0.4	kg/100L- volume of brewed ethyl alcohol
Beer	0.035	kg/100L- volume of brewed alcoholic drinks
Fruit wine	0.08	kg/100L- volume of brewed alcoholic drinks brewed volume
Whiskey	15	kg/100L- volume of brewed ethyl alcohol
Spirits	0.4	kg/100L- volume of ethyl alcohol
Liqueurs	0.4	kg/100L- volume of brewed ethyl alcohol
Other liquors (including low-malt beer)	0.035	kg/100L-volume of brewed alcoholic drinks

Note: The *Study on the VOC Emission Inventory*, established based on the *EMEP/EEA Air Pollutant Emission Inventory Guidebook 2009*

Table A 3-62 Ethyl alcohol content for alcoholic drinks (shochu, whiskey)

Alcoholic drinks	Ethyl alcohol content
Shochu (Japanese distilled spirit)	25%
Whiskey	40%

Note: Based on *EMEP/EEA Air Pollutant Emission Inventory Guidebook 2009*

Table A 3-63 Methods of establishing ethyl alcohol content of spirits and liquor

Fiscal year (FY)	Methods of establishing ethyl alcohol content of spirits and liquor
1990-1999	The value of ethyl alcohol content for FY2000 provided in the VOC Emission Inventory was used.
2000	The value of ethyl alcohol content provided in the VOC Emission Inventory was used.
2001-2004	Estimated by interpolating between the ethyl alcohol contents for FY2000 and FY2005.
2005-	The value of ethyl alcohol content for each year provided in the VOC Emission Inventory was used.

Table A 3-64 Ethyl alcohol content for alcoholic drinks (spirits, liquor)

Item	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Spirits	25.9%	25.9%	25.9%	12.7%	10.3%	10.1%	10.1%	10.0%	9.8%	9.7%	9.7%	9.8%	9.9%	9.9%	9.9%
Liqueurs	11.7%	11.7%	11.7%	8.5%	7.0%	6.9%	6.8%	6.7%	6.8%	6.7%	6.5%	6.4%	6.4%	6.4%	6.4%

- **Activity data**

For bread, the production amount of various kinds of bread, provided in *Food Industry Trend Survey* (Ministry of Agriculture, Forestry and Fisheries of Japan), was used for activity data.

For alcoholic drinks, the volume of production of brewed alcoholic drinks, provided in Table of volume of production of brewed alcoholic drinks and volume of stock (The National Tax Administration Agency) was used for activity data.

### A3.1.3 Agriculture

#### A3.1.3.1. Field Burning of Agricultural Residues (3.F: CO, NO<sub>x</sub>)

##### a) Methodological Issues

- **Estimation Method**

CO and NO<sub>x</sub> emissions were calculated by using the method indicated in the *2006 IPCC Guidelines*, which is the same method as that for CH<sub>4</sub> and N<sub>2</sub>O estimation.

$$E = A \times M_B \times C_f \times G_{ef} \times 10^{-3}$$

$E$  : CO and NO<sub>x</sub> emissions from field burning of agriculture residues [t-CO or t-NO<sub>x</sub>]

$A$  : Area burnt [ha]

$M_B$  : Mass of fuel available for combustion [t/ha]

$C_f$  : Combustion factor

$G_{ef}$  : Emission factor [g-CO/kg or g-NO<sub>x</sub>/kg]

- **Emission factors**

CO : 92 g-CO/kg (dry matter) (default value in the *2006 IPCC Guidelines*)

NO<sub>x</sub> : 2.5 g-NO<sub>x</sub>/kg (dry matter) (default value in the *2006 IPCC Guidelines*)

- **Activity data**

Activity data are the same as those used for CH<sub>4</sub> and N<sub>2</sub>O estimation described in “5.7. Field Burning of Agricultural Residues (3.F)”.

### A3.1.4 Land Use, Land-Use Change and Forestry

##### a) Methodological Issues

#### 1) Biomass Burning in Forest Land (4(V))

- **Estimation Method**

For CO and NO<sub>x</sub> emissions due to biomass burning from forest fires, the Tier 1 method is used.

- **CO**

$$bbGHG_f = L_{forest\ fires} \times ER$$

➤ **NO<sub>x</sub>**

$$bbGHG_f = L_{forest\ fires} \times ER \times NC_{ratio}$$

*bbGHG<sub>f</sub>* : CO and NO<sub>x</sub> emissions due to forest biomass burning

*L<sub>forest fires</sub>* : Carbon released due to forest fires [tC/yr]

*ER* : Emission ratio (CO: 0.06, NO<sub>x</sub>: 0.121)

*NC<sub>ratio</sub>* : NC ratio

● **Emission Factor**➤ **Emission ratio**

The following values are applied to emission ratios for CO and NO<sub>x</sub> due to biomass burning.

CO: 0.06, NO<sub>x</sub>: 0.121

(default value stated in the GPG-LULUCF, Table 3A.1.15)

➤ **NC ratio**

The following values are applied to NC ratio of NO<sub>x</sub>.

NC ratio: 0.01 (default value stated in the GPG-LULUCF p.3.50)

● **Activity data**

For activity data in Forest land, carbon released by forest fire is used. For detailed information, see the description on the activity data in section 6.16 in Chapter 6.

**2) From burning of pruned branches from orchard trees (4(V))**● **Estimation Method**

For CO and NO<sub>x</sub> emissions due to biomass burning of pruned branches from orchard trees, the estimation method (Equation 2.27, p2.42, Vol.4) described in the *2006 IPCC Guidelines* is applied. The estimation equation is as follows:

$$L_{fire} = W_B \times C_f \times G_{ef} \times 10^{-6}$$

*L<sub>fire</sub>* : CO and NO<sub>x</sub> emissions from fire [kt]

*W<sub>B</sub>* : Amount burnt [t-d.m.]

*C<sub>f</sub>* : Combustion factor

*G<sub>ef</sub>* : Emission factor [t/kt-d.m.]

● **Parameters**

For the combustion factor, a general value (0.9) which has been used generally in field burning of crop residues in agriculture in Japan is applied. The default emission factors (Agricultural residue value) described in the *2006 IPCC Guidelines* are used.

Table A 3-65 Emission factors [t/kt-d.m.]

Category	CO	NO <sub>x</sub>
Agricultural residue	92	2.5

Reference: *2006 IPCC Guidelines*, Vol.4, chp.2, Table 2.5

● **Activity Data (Amount burned)**

For activity in orchard land, see the description on the activity data in section 6.16 in Chapter 6.

**3) Biomass Burning in Grassland (4(V))**● **Estimation Method**

For CO and NO<sub>x</sub> emissions due to biomass burning of grassland, the estimation method (Equation 2.27, p2.42, Vol.4) described in the *2006 IPCC Guidelines* is applied. The estimation



equation is as follows:

$$L_{fire} = A \times M_B \times C_f \times G_{ef} \times 10^{-6}$$

$L_{fire}$  : CO and NO<sub>x</sub> Emissions from fire [kt]

$M_B$  : Amount burnt [t-d.m.]

$C_f$  : Combustion factor

$G_{ef}$  : Emission factor [t/kt-d.m.]

#### ● **Parameters**

For the combustion factor, value of 0.9 is applied according to expert judgment that considering survey data on burning of grassland in Japan. The default emission factors (Savanna and grassland) described in the 2006 IPCC Guidelines are used.

Table A 3-66 Emission factors [t/kt-d.m.]

Category	CO	NO <sub>x</sub>
Savanna and grassland	65	3.9

Note: 2006 IPCC Guidelines, Vol.4, chp.2, Table 2.5

#### ● **Activity Data (Amount burned)**

For activity data in grassland, see the description on the activity data in section 6.16 in Chapter 6.

### A3.1.5 Waste

#### A3.1.5.1. Incineration and Open Burning of Waste (5.C.)

##### A3.1.5.1.a. Municipal Solid Waste Incineration (5.C.1.–)

#### ● **Estimation Method**

The NO<sub>x</sub>, CO, NMVOCs, and SO<sub>x</sub> emissions from the specified sources were calculated by multiplying the incineration amount of MSW in each incinerator type (Continuous Incinerators, Semi-continuous Incinerators, Batch type Incinerators, Gasification melting furnaces) by Japan's country-specific emission factors. These emissions are categorized following the methods given in chapter 7 based on incinerations either with or without energy recovery. The former emissions are reported in the Energy sector, while the latter are reported in the Waste sector.

#### ● **Emission factors**

##### ➤ **NO<sub>x</sub>, SO<sub>x</sub>**

For incinerators, emission factors were established for each incinerator type by using the emission amount and amount of treated waste identified in the *General Survey of the Emissions of Air Pollutants*. (The categories of incinerator types included: [1301: Waste incinerator (municipal solid waste; continuous system)] and [1302: Waste incinerator (municipal solid waste; batch system)]). The incineration material was [53: Municipal solid waste].) It is noted that while the *General Survey of the Emissions of Air Pollutants* classified the incinerators into two classes (Continuous and Batch), this report classifies incinerators into three classes (“Continuous”, “Semi-continuous”, and “Batch type”) by dividing the Continuous system and assigning those which operated for less than 3,000 hours to the “Semi-continuous” class.

For gasification melting furnaces, the value for Continuous Incinerators with a similar

incineration method was used.

Table A 3-67 NO<sub>x</sub> and SO<sub>x</sub> emission factors for municipal waste by type of incineration method

Furnace type	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
<b>NO<sub>x</sub></b>																
Continuous incinerator	kg-NO <sub>x</sub> /t	1.238	1.213	1.127	1.127	1.127	1.127	1.127	1.127	1.127	1.127	1.127	1.127	1.127	1.127	1.127
Semi-continuous incinerator	kg-NO <sub>x</sub> /t	1.055	1.226	1.226	1.226	1.226	1.226	1.226	1.226	1.226	1.226	1.226	1.226	1.226	1.226	1.226
Batch type incinerator	kg-NO <sub>x</sub> /t	1.137	1.918	1.850	1.850	1.850	1.850	1.850	1.850	1.850	1.850	1.850	1.850	1.850	1.850	1.850
Gasification melting furnace	kg-NO <sub>x</sub> /t	1.238	1.213	1.127	1.127	1.127	1.127	1.127	1.127	1.127	1.127	1.127	1.127	1.127	1.127	1.127
<b>SO<sub>x</sub></b>																
Continuous incinerator	kg-SO <sub>x</sub> /t	0.555	0.539	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361
Semi-continuous incinerator	kg-SO <sub>x</sub> /t	0.627	1.141	0.712	0.712	0.712	0.712	0.712	0.712	0.712	0.712	0.712	0.712	0.712	0.712	0.712
Batch type incinerator	kg-SO <sub>x</sub> /t	1.073	1.625	1.714	1.714	1.714	1.714	1.714	1.714	1.714	1.714	1.714	1.714	1.714	1.714	1.714
Gasification melting furnace	kg-SO <sub>x</sub> /t	0.555	0.539	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361

Note: The data for 2000 were used for 2001 and subsequent years.

Reference: *General Survey of the Emissions of Air Pollutants* (MOE)

### ➤ CO

For incinerators, the emission factors were established for each incinerator class based on the emission factors for individual facilities summarized in Japan Society for Atmospheric Environment (1996) as well as other reports. It is noted that while the Japan Society for Atmospheric Environment report subdivided the facilities by furnace type (e.g., stoker, fluidized bed, etc.), this report determined the emission factors for three classes of “Continuous”, “Semi-continuous” and “Batch type” by taking the average weighted by incinerated amount for each furnace.

For gasification melting furnaces, the value for continuous stoker furnaces with a similar incineration method was used.

Table A 3-68 CO emission factors for municipal waste by type of incineration method

Furnace type	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Continuous incinerator	g-CO/t	557	557	555	554	554	553	553	553	553	553	553	554	554	554	554
Semi-continuous incinerator	g-CO/t	548	548	567	591	611	609	613	609	614	607	600	603	611	603	603
Batch type incinerator	g-CO/t	8,237	8,237	8,298	8,341	8,270	8,272	8,270	8,274	8,274	8,279	8,281	8,239	8,241	8,241	8,241
Gasification melting furnace	g-CO/t	567	567	567	567	567	567	567	567	567	567	567	567	567	567	567

Reference: Japan Society for Atmospheric Environment (1996), and others.

### ➤ NMVOCs

For both incinerators and gasification melting furnaces, NMVOC emission factors were established by multiplying the CH<sub>4</sub> emission factors for each furnace type of each fuel type by “NMVOC/CH<sub>4</sub>”, the emission ratio for fuel type. The ratio was determined by using the reference materials by Japan Environmental Sanitation Center (1989) and Institute of Behavioral Science (1984), which estimated CH<sub>4</sub> and NMVOC emissions per unit calorific value.

Table A 3-69 NMVOC emission factors for municipal waste by type of incineration method

Furnace type	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Continuous incinerator	g-NMVOC/t	0.9	0.9	0.9	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Semi-continuous incinerator	g-NMVOC/t	7.8	7.8	8.5	2.2	2.4	2.3	2.4	2.3	2.4	2.3	2.3	2.3	2.4	2.3	2.3
Batch type incinerator	g-NMVOC/t	9.1	9.1	9.5	1.5	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.2	1.2	1.2	1.2
Gasification melting furnace	g-NMVOC/t	NA	NA	0.6	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8

Reference: Japan Environmental Sanitation Center (1989), Institute of Behavioral Science (1984)

### ● Activity data

For incinerators, the activity data used was the incineration amount for each facility type as calculated by multiplying the incineration amount of municipal waste by the incineration rate for each facility type. The incineration amount data were extracted from the *Report of the Research on the State of Wide-range Movement and Cyclical Use of Wastes (the Volume on Cyclical Use)* (MOE). The incineration rate was calculated by the data in the *Waste Treatment in Japan* (MOE).

For gasification melting furnaces, the activity data used was the amount incinerated in gasification melting furnaces, calculated from data in the *Waste Treatment in Japan* (MOE).

### A3.1.5.1.b. Industrial Wastes Incineration (5.C.1.–)

#### ● *Estimation Method*

NO<sub>x</sub>, CO, NMVOCs, and SO<sub>x</sub> emissions from the specified sources were calculated by multiplying the incineration amount of industrial waste for each waste type by Japan's country-specific emission factors. These emissions are categorized following the methods given in chapter 7 based on incinerations either with or without energy recovery. The former emissions are reported in the Energy sector, while the latter are reported in the Waste sector.

#### ● *Emission factors*

##### ➤ *NO<sub>x</sub>, SO<sub>x</sub>*

An emission factor was established for each type of industrial solid waste using the emission amount and amount of treated industrial solid waste identified by the *General Survey of the Emissions of Air Pollutants*. The categories of incinerator types included: [1303: Waste incinerator (industrial solid waste; continuous system)] and [1304: Waste incinerator (industrial solid waste; batch system)]. The incinerator fuel covered the categories [23: Fuel Wood] and [54: Industrial solid waste]). The six types of industrial waste were “Paper/cardboard, wood”, “Sludge”, “Waste oil”, “Plastics”, “Textiles”, and “Animal and vegetable residues/animal carcasses”. Category [23: Sawn Timber] was used for “Paper/cardboard, wood”, “Waste textiles”, and “Animal and vegetable residues/animal carcasses”, while category [54: Industrial waste] was used for “Sludge”, “Waste oil”, and “Waste plastics”. However, no emission factor was set for the mixed burning of multiple waste types.

Table A 3-70 NO<sub>x</sub> and SO<sub>x</sub> emission factors for industrial waste by waste type

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
NO <sub>x</sub>																
"Fuel Wood 23"	kg-NO <sub>x</sub> /t	1.545	1.312	5.828	5.828	5.828	5.828	5.828	5.828	5.828	5.828	5.828	5.828	5.828	5.828	5.828
"Industrial Waste 54"	kg-NO <sub>x</sub> /t	0.999	1.158	1.415	1.415	1.415	1.415	1.415	1.415	1.415	1.415	1.415	1.415	1.415	1.415	1.415
SO <sub>x</sub>																
"Fuel Wood 23"	kg-SO <sub>x</sub> /t	1.528	1.274	2.118	2.118	2.118	2.118	2.118	2.118	2.118	2.118	2.118	2.118	2.118	2.118	2.118
"Industrial Waste 54"	kg-SO <sub>x</sub> /t	1.179	1.882	1.352	1.352	1.352	1.352	1.352	1.352	1.352	1.352	1.352	1.352	1.352	1.352	1.352

Note: The data for 2000 were used for 2001 and subsequent years.

Reference: *General Survey of the Emissions of Air Pollutants* (MOE)

##### ➤ *CO*

Based on the emission factors for individual facilities summarized in Japan Society for Atmospheric Environment (1996) as well as other reports, an emission factor was established for each type of industrial solid waste. The six types of industrial waste were “Paper/cardboard, wood”, “Sludge”, “Waste oil”, “Plastics”, “Textiles”, and “Animal and vegetable residues/animal carcasses”. The emission factor for “Wood” was used for “Waste textiles” and “Animal and vegetable residues/animal carcasses”, for which there are no measurements. No emission factor was set for the mixed burning of multiple waste types.

Table A 3-71 CO emission factors for industrial waste by waste type

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Paper/cardboard, wood	g-CO/t	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334
Waste oil	g-CO/t	127	127	127	127	127	127	127	127	127	127	127	127	127	127	127
Plastics	g-CO/t	1,790	1,790	1,790	1,790	1,790	1,790	1,790	1,790	1,790	1,790	1,790	1,790	1,790	1,790	1,790
Sludge	g-CO/t	2,285	2,285	2,285	2,285	2,285	2,285	2,285	2,285	2,285	2,285	2,285	2,285	2,285	2,285	2,285
Textile	g-CO/t	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334
Animal and vegetable residues/ animal carcasses	g-CO/t	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334

Reference: Japan Society for Atmospheric Environment (1996) and others

#### ➤ **NMVOCs**

NM VOC emission factors were established by multiplying the CH<sub>4</sub> emission factors for each furnace type of each fuel type by “NMVOC/CH<sub>4</sub>”, the emission ratio for fuel type. The ratio was determined by using the reference materials by Japan Environmental Sanitation Center (1986) and Institute of Behavioral Science (1984), which estimated CH<sub>4</sub> and NMVOC emissions per unit calorific value.

Table A 3-72 NMVOC emission factors for industrial waste by waste type

Item	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Paper/cardboard, wood	g-NMVOC/t	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48
Waste oil	g-NMVOC/t	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54
Plastics	g-NMVOC/t	3.40	3.40	3.40	3.40	3.40	3.40	3.40	3.40	3.40	3.40	3.40	3.40	3.40	3.40	3.40
Sludge	g-NMVOC/t	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61
Textile	g-NMVOC/t	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48
Animal and vegetable residues/ animal carcasses	g-NMVOC/t	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48

Reference: Japan Environmental Sanitation Center (1989), Institute of Behavioral Science (1984)

#### ● **Activity data**

The activity data used the incineration amount data for each type of waste extracted from the *Report of the Research on the State of Wide-range Movement and Cyclical Use of Wastes (the Volume on Cyclical Use)* (MOE).

### A3.1.5.1.c. Open Burning of Industrial Waste (5.C.2.–)

#### ● **Estimation Method**

NO<sub>x</sub>, CO, NMVOCs, and SO<sub>x</sub> emissions from the specified sources were calculated by multiplying the amount of industrial waste burned in the open air for each waste type by Japan's country-specific emission factors.

#### ● **Emission factors**

As no knowledge is obtained for making it possible to set emission factors specific to open burning of waste in Japan, the country-specific emission factors for industrial waste incineration were substituted. For detail, the NO<sub>x</sub>, CO, NMVOC and SO<sub>x</sub> emission factors for plastics incineration as for plastics burned in the open air, and those for wood incineration as for other waste burned in the open air were adopted respectively. See also section “A3.1.5.1.b. Industrial Wastes Incineration (5.C.1.–)”.

#### ● **Activity data**

The amount of industrial waste burned in the open air obtained from the *Report on Survey of Organizations in Industrial Waste Administration* (MOE) was used as the activity data in and after FY1996. As for the past activity data from FY1990 to 1995 for which the survey data is not

available, the data of FY1996 was uniformly used as a substitute since there are no other appropriate way to estimate.

#### A3.1.5.1.d. Incineration in Conjunction with Use of Waste as Fuel and Raw Material (1.A.-)

##### ● *Estimation Method*

CO and NMVOC emissions from this source were estimated by multiplying the amounts of fuel/raw material burned for each waste type by a Japan-specific emission factor. These emissions are reported in Energy sector (1.A.) following the methodologies given in chapter 7 (Waste).

##### ● *Emission Factors*

###### ➤ *CO*

The CO emission factors were established by converting the emission factors (energy unit basis) by furnace type, which are used for estimating emissions from 1.A Stationary Sources, to weight-based emission factors by multiplying the calorific values in the *General Energy Statistics*.

Table A 3-73 CO emission factors from incineration in conjunction with use of waste as fuel and raw material

Application	Units	Waste oil	RDF	RPF	Waste tires (FY2004 and before)	Waste tires (FY2005 and after)	Plastics	Plastics (Liquefaction)	Wood
Simple incineration	kg-CO/t	0.13	1.79	1.79	1.79	1.79	-	-	-
Boilers	kg-CO/t	0.052	0.24	0.39	0.28	0.44	0.39	0.034	3.64
Cement kilns	kg-CO/t	-	19.8	32.2	23.0	36.5	32.2	-	-
Other furnaces	kg-CO/t	0.052	0.24	0.39	0.28	0.44	-	-	-
Pyrolysis furnaces	kg-CO/t	-	-	-	0.021	0.033	-	-	-
Gasification	kg-CO/t	-	-	-	0.015	0.024	-	-	-

###### ➤ *NMVOCs*

Just as for the incineration of municipal solid waste and industrial waste, emission factors were determined from documents with estimates of emissions of CH<sub>4</sub> and NMVOCs per unit calorific values.

Table A 3-74 NMVOC emissions factors from incineration in conjunction with use of waste as fuel and raw material

Application	Units	Waste oil	RDF	RPF	Waste tires (FY2004 and before)	Waste tires (FY2005 and after)	Plastics	Plastics (Liquefaction)	Wood
Boilers	kg-NMVOC/t	0.015	0.00027	0.00043	0.00031	0.00049	0.00043	0.010	0.12
Cement kilns	kg-NMVOC/t	-	-	0.043	0.031	0.049	0.043	-	-
Pyrolysis furnaces	kg-NMVOC/t	-	-	-	0.0051	0.0080	-	-	-
Gasification	kg-NMVOC/t	-	-	-	0.0187	0.0297	-	-	-

##### ● *Activity data*

Same activity data that were used when estimating CH<sub>4</sub> emissions for the use of waste as fuel and raw material were used.

### A3.1.6 Other sectors

#### A3.1.6.1. Smoking (6.–: CO)

- **Estimation Method**

CO emissions were calculated by multiplying the amount of cigarette sales by Japan's country-specific emission factor.

$$E_{CO} = S \times EF$$

$E_{CO}$  : CO emissions from smoking

$S$  : Cigarette sales

$EF$  : Emission factor [g-CO/cigarette]

- **Emission factors**

The emission factor (0.055 [g-CO/cigarette]) was provided by Japan Tobacco Inc.

- **Activity data**

The amount of cigarette sales published on Tobacco Institute of Japan website (<https://www.tioj.or.jp>) was used for activity data.

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## Annex 4. The National Energy Balance for the Most Recent Inventory Year

### A4.1. Discrepancies between the figures reported in the CRF tables and the IEA statistics

In the report of the individual review of the greenhouse gas inventory of Japan submitted in 2006 (FCCC/ARR/2006/JPN), which was conducted from January to February 2007, the ERT (Expert Review Team) recommended that in the next NIR submission Japan provide a clear explanation for the discrepancies found between the data in the CRF tables and the IEA statistics. In response to this recommendation, Japan has provided the detailed information on the Annex of the NIR regarding the discrepancies of the FY2005 data between the CRF tables and the IEA statistics. Also, in the individual review report of the GHG inventory of Japan submitted in 2010 (FCCC/ARR/2010/JPN), the updating of this information with the latest available inventory year data was recommended by the ERT. In response to this recommendation, the detailed information regarding the discrepancies of the reported value between the CRF and the IEA statistics is hereby updated with the FY2019 actual data. The IEA statistical data used in the explanation were extracted from the *World Energy Statistics*, July 2021 Edition, OECD/IEA.

In summary, these discrepancies occurred; because (a) the CRF tables and the IEA statistics treat international aviation and marine bunker fuels (bonded exports) differently, and (b) fuel oil A is classified in a different way. The figures for imports and exports of fuels reported in the CRF tables include the bonded exports, whereas the figures for imports and exports of fuels in the IEA statistics do not. With respect to fuel oil A, Japan includes it under “heavy fuel oil” in its energy balances but reports it to the IEA under gas/diesel oil according to the classifications used in Europe and the United States.

According to Japanese definition, fuel oil A has a flash point of more than 60 °C, kinematic viscosity of below 20 mm<sup>2</sup>/s, carbon residue content of below 4% and sulfur content of below 2.0 %. Fuel oil B has a flash point of more than 60 °C, kinematic viscosity of below 50 mm<sup>2</sup>/s, carbon residue content of below 8% and sulfur content of below 3.0 %. Fuel oil B is rarely used nowadays in Japan, for this reason, fuel oil B is treated as “fuel oil B/C” together with fuel oil C in Japanese statistics. Fuel oil C has a flash point of more than 70 °C, kinematic viscosity of less than 1,000 mm<sup>2</sup>/s and sulfur content of less than 3.5%.

In addition, the preliminary figures of reporting year (*y*) based on the *General Energy Statistics* are used for reporting to the IEA in fall of the next fiscal year (*y*+1), which starts in April and ends in March; on the other hand, the final figures based on the *General Energy Statistics* are used for reporting to the UNFCCC since the final figures are available in the CRF submission period in spring of the next year (*y*+2). Therefore, there are discrepancies of the reported values between the IEA statistics (preliminary figures) and the CRF tables (final figures) at the time of review under the UNFCCC in summer of the next year (*y*+2). The preliminary figures reported to the IEA are updated to the final figures in fall of the next year (*y*+2) and are published in the IEA statistics in summer of the year after next (*y*+3); the discrepancies between the data in the CRF tables and the IEA statistics are dissolved at the time, except for discrepancies resulted from the definitions or different estimation methods mentioned below.

Further explanations are provided below for each of the discrepancies noted by the ERT.

**a) Differences in exports of jet kerosene and residual fuel oil**

<ERT findings on FCCC/ARR/2006/JPN>

Exports of liquid fuels are between 40 and 70 per cent lower in the IEA data; the differences are due in particular to differences in the figures for jet kerosene and residual fuel oil, with the largest errors occurring in recent years.

<Explanation 1: Exports of jet kerosene>

The figures for jet kerosene exports reported in the CRF tables are different from those in the IEA statistics because the CRF figures include bonded exports whereas the export figures in the IEA statistics do not. The IEA statistics accounted the consumption of jet kerosene by international aviation bunkers as an aggregate of the bonded exports and imports. (See Chapter 3, for bonded exports and imports.) Note that there is a flaw in the reported value to the IEA in 2019, where the amount of exports to Vanuatu, Solomon Islands, and New Caledonia (France) (total  $2.05 \times 10^3$  kL) and bonded imports ( $1,184.62 \times 10^3$  kL) were omitted; this was corrected in the reporting in FY2020.

Table A 4-1 Exports of jet kerosene in FY2019 (reference)

CRF Table 1.A(b)
Exports: $10,607.85 \times 10^3$ kL
IEA statistics
Exports: $2,449.05 \times 10^3$ t $[10,605.80 \times 10^3$ kL (Exports) - $7,479.62 \times 10^3$ kL (Bonded exports) = $3,126.18 \times 10^3$ kL. $3,126.18 \times 10^3$ kL $\times 0.7834$ t/kL (density) = $2,449.05 \times 10^3$ t]
<Remarks>
International aviation: $5,859.53 \times 10^3$ t $[7,479.62 \times 10^3$ kL (bonded exports) + $0.00 \times 10^3$ kL (bonded imports) = $7,479.62 \times 10^3$ kL. $7,479.62 \times 10^3$ kL $\times 0.78$ t/kL (density) = $5,859.53 \times 10^3$ t]

<Explanation 2: Exports of residual fuel oil>

The figures for exports of residual fuel oil reported in the CRF tables are different from those in the IEA statistics because the CRF figures for residual fuel oil include the bonded exports, whereas the export figures for fuel oil in the IEA statistics do not. The bonded exports portion of the fuel oil was reported in the IEA statistics as an aggregate of the bonded exports and imports of fuel oil under international marine bunkers. (See Chapter 3, for bonded exports and imports.)

Further, the figures for exports of residual fuel oil reported in the CRF include fuel oil A, whereas the figures reported under fuel oil in the IEA statistics do not. The IEA reports fuel oil A together with gas oil under gas/diesel oil in its statistics. Because fuel oil A, which is treated as a fuel oil that is distinguished from diesel oil in Japan, is grouped together with diesel oil in Europe and the United States, the fuel oil A data have been included in the diesel oil data in Japan's report to the IEA.

Table A 4-2 Exports of residual fuel oil in FY2019 (reference)

CRF Table 1.A(b)
Exports: $9,793.50 \times 10^3$ kL [ $1,809.65 \times 10^3$ kL (fuel oil A) + $0.00 \times 10^3$ kL (fuel oil B) + $7,983.85 \times 10^3$ kL (fuel oil C for general use) + $0.00 \times 10^3$ kL (fuel oil C for power generation) = $9,793.50 \times 10^3$ kL]
IEA statistics
Exports: $2,977.82 \times 10^3$ t [ $0.00 \times 10^3$ kL (fuel oil B) + $7,983.85 \times 10^3$ kL (fuel oil C for general use) + $0.00 \times 10^3$ kL (fuel oil C for power generation) - $4,675.16 \times 10^3$ kL (bonded exports of fuel oils B and C) = $3,308.69 \times 10^3$ kL. $3,308.69 \times 10^3$ kL $\times$ 0.9000 t/kL (density) = $2,977.82 \times 10^3$ t ] <Remarks> International marine bunkers: $4,750.03 \times 10^3$ t [ $4,675.16 \times 10^3$ kL (bonded exports of fuel oils B and C) + $74.87 \times 10^3$ kL (bonded imports of fuel oils B and C) = $4,750.03 \times 10^3$ kL. $4,750.03 \times 10^3$ kL $\times$ 0.9000 t/kL (density) = $4,275.03 \times 10^3$ t ]

**b) Differences in imports of jet kerosene and gas/diesel oil**

&lt;ERT findings on FCCC/ARR/2006/JPN&gt;

Imports of jet kerosene have been reported to the IEA, but are shown as zero in the CRFs for the years 1990–1997, while imports of gas/diesel oil are systematically about 80 per cent lower in the CRF tables than in the IEA figures.

&lt;Explanation 1: Imports of jet kerosene&gt;

The figures for jet kerosene imports reported in the CRF tables are different from those in the IEA statistics because the CRF figures are the sums of imports including bonded imports and bonded exports while the IEA statistics figures are the imports including bonded imports. (See Chapter 3, for bonded exports and imports.) Note that there is a flaw in the reported value to the IEA in 2019, where the amount of bonded imports was omitted; this was corrected in the reporting in FY2020.

Table A 4-3 Imports of jet kerosene in FY2019 (reference)

CRF Table 1.A(b)
Imports: $8,873.78 \times 10^3$ kL [ $209.54 \times 10^3$ kL (imports) + $1,184.62 \times 10^3$ kL (bonded imports) + $7,479.62 \times 10^3$ kL (bonded exports) = $8,873.78 \times 10^3$ kL.
IEA statistics
Imports: $164.15 \times 10^3$ t [ $209.54 \times 10^3$ kL (imports) + $0.00 \times 10^3$ kL (bonded imports) = $209.54 \times 10^3$ kL. $209.54 \times 10^3$ kL $\times$ 0.7834 t/kL (density) = $164.15 \times 10^3$ t ]

&lt;Explanation 2: Imports of gas/diesel oil&gt;

The figures for imports of gas/diesel oil reported in the CRF tables are different from those in the IEA statistics, because the CRF figures are the sums of imports (including bonded imports) and bonded exports of diesel oil, which excludes fuel oil A, while the figures for imports of gas/diesel oil in the IEA statistics are the aggregate of imports of diesel oil and fuel oil A, both of which included the bonded imports.

Table A 4-4 Imports of gas/diesel oil in FY2019 (reference)

CRF Table 1.A(b)
Imports: $829.12 \times 10^3$ kL $[796.66 \times 10^3$ kL (imports of gas/diesel oil) + $5.86 \times 10^3$ kL (bonded imports of gas/diesel oil) + $26.60 \times 10^3$ kL (bonded exports of gas/diesel oil) = $829.12 \times 10^3$ kL.
IEA statistics
Imports: $780.29 \times 10^3$ t $[796.66 \times 10^3$ kL (imports of gas/diesel oil) + $5.86 \times 10^3$ kL (bonded imports of gas/diesel oil) + $123.10 \times 10^3$ kL (imports of fuel oil A) + $0.00 \times 10^3$ kL (bonded imports of fuel oil A) = $925.62 \times 10^3$ kL. $925.62 \times 10^3$ kL $\times$ 0.8430 t/kL (density) = $780.29 \times 10^3$ t ]

**c) Differences in imports of coking coal**

<ERT findings on FCCC/ARR/2006/JPN>

Furthermore, the figures for imports of coking coal are systematically lower in the CRF tables than those in the IEA statistics, with the largest discrepancy occurring in 1999.

<Explanation: Imports of coking coal>

The imported amounts of coking coal in the CRF and the IEA statistics in physical units are basically the same.

Table A 4-5 Imports of coking coal in FY2019 (reference)

CRF Table 1.A(b)
Imports: $46,512.52 \times 10^3$ t
IEA statistics
Imports: $46,512.52 \times 10^3$ t

**d) Differences in stock changes in liquid and gaseous fuels**

<ERT findings on FCCC/ARR/2006/JPN>

In addition, the data on stock changes are not consistent for liquid and gaseous fuels.

It should be noted that the plus-minus signs of stock changes in the CRF differ from those of the IEA. The changes in the CRF are defined as plus for stock increase and as minus for stock release, while the changes in the IEA are defined as minus for stock increase and as plus for stock release.

<Explanation 1: Changes in crude oil stock>

The difference between the CRF table and the IEA statistics with respect to changes in crude oil stock occurred because the figures reported in the CRF were calculated using the stock of crude oil after customs clearance (or more precisely, after inspection in the presence of customs officers). The stock changes reported in the IEA statistics were calculated based on stock that included crude oil carried by oil tankers in Japanese territorial waters but which was yet to clear customs as well as the crude oil in the national stockpile. This discrepancy arose because the UNFCCC and the IEA had different objectives. Note that there is a flaw in the reported value to the IEA in FY2019, where the value in May

2020 was used as the value of closing stock; this was corrected in reporting in FY2020. Also, the value in MOS report (rounded to the nearest whole number in kt) are used as the value of opening stock (some of the volume figures in the table are calculated backwards from this).

Table A 4-6 Changes in crude oil stock in FY2019 (reference)

CRF Table 1.A(b)
Stock changes: $-394.20 \times 10^3$ kL $[-(577.75 \times 10^3 \text{ kL (crude oil for refining)} + -183.54 \times 10^3 \text{ kL (crude oil for power generation)})$ $= -394.20 \times 10^3 \text{ kL}]$
IEA statistics
Stock changes: $-202.76 \times 10^3$ t $[(12,772.54 \times 10^3 \text{ kL (opening stock)} + 47,012.00 \times 10^3 \text{ kL (opening national stockpile)}$ $+ 2,380.00 \times 10^3 \text{ kL (opening stock carried by oil tankers)}$ $- 947.00 \times 10^3 \text{ kL (opening joint stockpile with Abu Dhabi)}$ $- (14,084.69 \times 10^3 \text{ kL (closing stock)} + 46,744.00 \times 10^3 \text{ kL (closing national stockpile)}$ $+ 1,563.00 \times 10^3 \text{ kL (closing stock carried by oil tankers)}$ $- 937.00 \times 10^3 \text{ kL (closing joint stockpile with Abu Dhabi)}) = -237.15 \times 10^3 \text{ kL.}$ $-237.15 \times 10^3 \text{ kL} \times 0.8550 \text{ t/kL (density)} = -202.76 \times 10^3 \text{ t}]$

<Explanation 2: Changes in NGL stock>

Stock changes concerning NGL in FY2019 were reported as 0 in the CRF and the IEA Statistics. The NGL stock changes reported in the IEA statistics were 0 because the NGL stock figure in the Monthly Oil Statistics (MOS) of the IEA was 0. This discrepancy resulted from the direction given by the IEA that the figures in the IEA statistics must be consistent with the MOS figures. Furthermore, the MOS requires figures for opening stock and closing stock, but Japan does not collect such statistical data for NGL. As a result, Japan reported 0 values to the IEA for both opening stock and closing stock data for the MOS. Due to lack of statistical data for stock changes in NGL, the estimated value calculated as a difference between supply and consumption amount is reported as stock change in the CRF tables. The estimated value is 0 in FY2019.

<Explanation 3: Changes in gasoline stock>

The figures for stock of gasoline reported in the CRF tables are changes of gasoline stock only, whereas the values relating to the stock of gasoline in the IEA statistics are changes of gasoline stock plus national stockpile minus other gasoline stock. Other gasoline stock is reported as stock change of white spirit in the IEA statistics. Note that there is a flaw in the reported value to the IEA in 2019, where the value in February 2019 and the value in February 2020 (as published in the *Monthly Report of Mineral Resources and Petroleum Products Statistics*) were used as the value of opening gasoline stock and the closing gasoline stock, respectively; this was corrected in the reporting in FY2020.

Table A 4-7 Changes in gasoline stock in FY2019 (reference)

CRF Table 1.A(b)
Stock changes: $190.14 \times 10^3$ kL
IEA statistics
Stock changes: $-100.14 \times 10^3$ kL [( $1,659.46 \times 10^3$ kL (opening stock) + $585.00 \times 10^3$ kL (opening national stockpile) - $8.18 \times 10^3$ kL (end of previous term gasoline inventories for others ( <i>Monthly Report of Current Production Statistics</i> , METI)) - $5.98 \times 10^3$ kL (end of previous term gasoline inventories for others ( <i>Monthly Report of Mineral Resources and Petroleum Products Statistics</i> , METI)) - ( $1,795.52 \times 10^3$ kL (closing stock) + $585.42 \times 10^3$ kL (closing national stockpile) - $7.11 \times 10^3$ kL (term-end gasoline inventories for others ( <i>Monthly Report of Current Production Statistics</i> , METI)) - $7.66 \times 10^3$ kL (term-end gasoline inventories for others ( <i>Monthly Report of Mineral Resources and Petroleum Products Statistics</i> , METI)) = $-135.87 \times 10^3$ kL. $-135.87 \times 10^3$ kL $\times$ 0.7370 t/kL (density) = $-100.14 \times 10^3$ t]

<Explanation 4: Changes in jet kerosene stock>

The figures for changes in jet kerosene stock reported in the CRF tables are basically the same as the figures in the IEA statistics. In the reported value to the IEA in FY 2019, the MOS reported values (rounded to the nearest whole number in kt) are used as the opening stock (some of the volume figures in the table are back-calculated from this).

Table A 4-8 Changes in jet kerosene stock in FY2019 (reference)

CRF Table 1.A(b)
Stock changes: $8.62 \times 10^3$ kL
IEA statistics
Stock changes: $-7.05 \times 10^3$ t [ $806.74 \times 10^3$ kL (opening stock) - $815.74 \times 10^3$ kL (closing stock) = $-9.00 \times 10^3$ kL. $-9.00 \times 10^3$ kL $\times$ 0.7834 t/kL (density) = $-7.05 \times 10^3$ t]

<Explanation 5: Changes in kerosene stock>

The figures reported in the CRF tables are changes in kerosene stock only, while the figures in the IEA statistics are the sum of the changes in kerosene stock and national stockpile of kerosene. Note that there is a flaw in the reported value to the IEA in FY2019, where the value in February 2019 and the value in February 2020 (as published in the *Monthly Report of Mineral Resources and Petroleum Products Statistics*, METI), were used as the value of opening stock and closing stock, respectively; this was corrected in the reporting in FY2020.



Table A 4-9 Changes in kerosene stock in FY2019 (reference)

CRF Table 1.A(b)
Stock changes: $95.34 \times 10^3$ kL
IEA statistics
Stock changes: $-10.78 \times 10^3$ t $[(1,568.39 \times 10^3$ kL (opening stock) $+ 317.00 \times 10^3$ kL (opening national stockpile)) $- (1,581.31 \times 10^3$ kL (closing stock) $+ 317.33 \times 10^3$ kL (closing national stockpile) ) $= -13.25 \times 10^3$ kL. $-13.25 \times 10^3$ kL $\times 0.8140$ t/kL (density) $= -10.78 \times 10^3$ t]

## &lt;Explanation 6: Changes in gas/diesel oil stock&gt;

The figures for gas/diesel stock reported in the CRF tables did not include stock changes in fuel oil A, while the figures in the IEA statistics included stock changes in fuel oil A and change of national stockpile of gas/diesel oil and fuel oil A. Note that there is a flaw in the reported value to the IEA in FY2019, where the values in February 2019 and the value in February 2020 (as published in the *Monthly Report of Mineral Resources and Petroleum Products Statistics*, METI), were used as the opening stock and closing stock, respectively; this was corrected in the reporting in FY2020.

Table A 4-10 Changes in gas/diesel oil stock in FY2019 (reference)

CRF Table 1.A(b)
Stock changes: $61.46 \times 10^3$ kL
IEA statistics
Stock changes: $79.23 \times 10^3$ t $[(1,435.53 \times 10^3$ kL (gas/diesel oil, opening stock) $+ 797.78 \times 10^3$ kL (fuel oil A, opening stock) $+ 374.00 \times 10^3$ kL (gas/diesel oil, opening national stockpile) $+ 152.00 \times 10^3$ kL (fuel oil A, opening national stockpile)) $- (1,432.50 \times 10^3$ kL (gas/diesel oil, closing stock) $+ 721.23 \times 10^3$ kL (fuel oil A, closing stock) $+ 374.16 \times 10^3$ kL (gas/diesel oil, closing national stockpile) $+ 152.18 \times 10^3$ kL (fuel oil A, closing national stockpile)) $= 79.23 \times 10^3$ kL. $79.23 \times 10^3$ kL $\times 0.8430$ t/kL (density) $= 66.79 \times 10^3$ t]

## &lt;Explanation 7: Changes in residual fuel oil stock&gt;

The figures for residual fuel oil stock reported in the CRF tables were different from those in the IEA statistics because the CRF figures included changes in fuel oil A stock, whereas stock change data under fuel oil in the IEA statistics did not include fuel oil A. (See the explanation for the gas/diesel oil data above.) In the reported value to the IEA in FY2019, the MOS reported values (rounded to the nearest whole number in kt) are used as opening stock (some of the volume values in the table are back-calculated from this).

Table A 4-11 Changes in residual fuel oil stock in FY2019 (reference)

CRF Table 1.A(b)
Stock changes: $-360.72 \times 10^3$ kL $[94.24 \times 10^3$ kL (fuel oil A) + $0.00 \times 10^3$ kL (fuel oil B) + $266.48 \times 10^3$ kL (fuel oil C for general use) + $0.00 \times 10^3$ kL (fuel oil C for power generation) = $-360.72 \times 10^3$ kL]
IEA statistics
Stock changes: $240.26 \times 10^3$ t $[1,326.67 \times 10^3$ kL (fuel oil B and C, opening stock) - $1,059.71 \times 10^3$ kL (fuel oil B and C, opening stock) = $266.95 \times 10^3$ kL. $266.95 \times 10^3$ kL $\times$ 0.9000 t/kL (density) = $240.26 \times 10^3$ t]

## &lt;Explanation 8: Changes in LPG stock&gt;

The figures for changes in LPG stock reported in the CRF tables differ from those reported in IEA statistics, because the LPG stock in IEA includes the national stock. In the reported value to the IEA in FY2019, the MOS reported value (rounded to the nearest whole number in kt) are used as the opening stock (some of the volume figures in the table are back-calculated from this).

Table A 4-12 Changes in LPG stock in FY2019 (reference)

CRF Table 1.A(b)
Stock changes: $143.22 \times 10^3$ t
IEA statistics
Stock changes: $-143.56 \times 10^3$ t $[(1,467.00 \times 10^3$ t (opening stock) + $1,396.00 \times 10^3$ t (opening national stockpile) - $(1,611.56 \times 10^3$ t (closing stock) + $1,395.00 \times 10^3$ t (closing national stockpile)) = $-143.56 \times 10^3$ t]

## &lt;Explanation 9: Changes in naphtha stock&gt;

The figures for changes in naphtha stock reported in the CRF tables are the same as the figures in the IEA statistics. In the reported value to the IEA in FY2019, the MOS reported value (rounded to the nearest whole number in kt) are used as of opening stock (some of the volume figures in the table are back-calculated from this).

Table A 4-13 Changes in naphtha stock in FY2019 (reference)

CRF Table 1.A(b)
Stock changes: $98.66 \times 10^3$ kL
IEA statistics
Stock changes: $-72.69 \times 10^3$ t $[1,325.64 \times 10^3$ kL (opening stock) - $1,424.28 \times 10^3$ kL (closing stock) = $-98.64 \times 10^3$ kL. $-98.64 \times 10^3$ kL $\times$ 0.7370 t/kL (density) = $-72.69 \times 10^3$ t]

## &lt;Explanation 10: Changes in bitumen stock&gt;

The figures for changes in bitumen stock reported in the CRF tables were slightly different from the figures reported under bitumen in the IEA statistics because the bitumen data in the CRF tables included asphalt and other heavy oil and paraffin products. The IEA statistics reported figures for only asphalt

under bitumen, and the figures for other heavy oil and paraffin products reported in the CRF tables under bitumen were included in the figures reported under paraffin waxes in the IEA statistics. Note that there is a flaw in the reported value to the IEA in FY2019, where the value in February 2019 and the value in February 2020 (as published in the *Monthly Report of Mineral Resources and Petroleum Products Statistics*, METI), were used as the value of opening stock and closing stock, respectively; this was corrected in the reporting in FY2020.

Table A 4-14 Changes in bitumen stock in FY2019 (reference)

CRF Table 1.A(b)
Stock changes: $39.24 \times 10^3$ t
IEA statistics
Stock changes in bitumen: $12.40 \times 10^3$ t [ $198.22 \times 10^3$ t (opening stock) - $185.82 \times 10^3$ t (closing stock) = $12.40 \times 10^3$ t]

## &lt;Explanation 11: Changes in lubricants stock&gt;

The figures for changes in lubricants stock reported in the CRF tables are basically the same as the figures in the IEA statistics. Note that there is a flaw in the reported of final figures to the IEA in FY2019, where the figures in February 2019 and the figures in February 2020 (as published in the *Monthly Report of Mineral Resources and Petroleum Products Statistics*, METI), were used as the opening stock and closing stock, respectively; this was corrected in the reporting in FY2020.

Table A 4-15 Changes in lubricants stock in FY2019 (reference)

CRF Table 1.A(b)
Stock changes: $17.51 \times 10^3$ kL
IEA statistics
Stock changes: $-10.25 \times 10^3$ t [ $466.73 \times 10^3$ kL (opening stock) - $478.24 \times 10^3$ kL (closing stock) = $-11.51 \times 10^3$ kL. $-11.51 \times 10^3$ kL $\times$ 0.8910 t/kL (density) = $-10.25 \times 10^3$ t]

## &lt;Explanation 12: Changes in petroleum coke stock&gt;

The figures for changes in petroleum coke stock reported in the CRF tables are the same as the figures in the IEA statistics.

Table A 4-16 Changes in petroleum coke stock in FY2019 (reference)

CRF Table 1.A(b)
Stock changes: $-1.58 \times 10^3$ t
IEA statistics
Stock changes: $1.58 \times 10^3$ t [ $11.67 \times 10^3$ t (opening stock) - $10.09 \times 10^3$ t (closing stock) = $1.58 \times 10^3$ t]

## &lt;Explanation 13: Changes in refinery feedstock stock&gt;

The figures for changes in refinery feedstock stock reported in the CRF were different from those in the IEA statistics because the IEA statistics included the figures for stock changes in slack wax and slack coke in addition to the semi-refined products reported in the CRF tables. In the reported value to the

IEA in FY2019, the MOS reported values (rounded to the nearest whole number in kt) are used as the opening stock.

The changes in slack wax and coke stocks were not reported in the CRF tables because the both items were solids used as raw materials for the production of paraffin and petroleum coke, and unlikely to be returned to oil refining processes. In addition, shipments of paraffin and petroleum coke produced using slack wax and slack coke were separately accounted for.

Table A 4-17 Changes in refinery feedstock stock in FY2019 (reference)

CRF Table 1.A(b)
Stock changes: $724.56 \times 10^3$ kL $[18.00 \times 10^3$ kL (slack gasoline) + $-146.97 \times 10^3$ kL (slack kerosene) + $-24.57 \times 10^3$ kL (slack diesel oil or gas oil) + $-571.02 \times 10^3$ kL (slack fuel oil) + $0.00 \times 10^3$ kL (feedstock oil for refinery and mixing) = $724.56 \times 10^3$ kL]
IEA statistics
Stock changes: $-642.89 \times 10^3$ t $[(2,261.84 \times 10^3$ kL (slack gasoline, opening stock) - $2,243.84 \times 10^3$ kL (slack gasoline, closing stock)) $\times 0.7370$ t/kL (density) + $(449.14 \times 10^3$ kL (slack kerosene, opening stock) - $596.12 \times 10^3$ kL (slack kerosene, closing stock) ) $\times 0.8140$ t/kL (density) + $(777.68 \times 10^3$ kL (slack diesel oil or gas oil, opening stock) - $802.25 \times 10^3$ kL (slack diesel oil or gas oil, closing stock) ) $\times 0.8430$ t/kL (density) + $(3,562.60 \times 10^3$ kL (slack fuel oil, opening stock) - $4,141.55 \times 10^3$ kL (slack fuel oil, closing stock) ) $\times 0.9000$ t/kL (density) + $(466.10 \times 10^3$ kL (slack lubricant, opening stock) - $458.17 \times 10^3$ kL (slack lubricant, closing stock) ) $\times 0.8910$ t/kL (density) + $(37.56 \times 10^3$ kL (slack wax, opening stock) - $42.37 \times 10^3$ kL (slack wax, closing stock) ) $\times 0.8160$ t/kL (density) + $(23.54 \times 10^3$ kL (slack coke, opening stock) - $21.67 \times 10^3$ kL (slack coke, closing stock) ) $\times 0.9436$ t/kL (density) = $-642.89 \times 10^3$ t]

<Explanation 14: Changes in natural gas stock>

The figures for changes in natural gas stock (imported liquefied natural gas (LNG) and domestic natural gas) reported in the CRF tables were different from those in the IEA statistics because of the differences in the methods used for estimation of changes in the imported LNG stock and the treatment of changes in city gas stock. The source figures for the domestic natural gas stock were the same for reporting of the CRF and the IEA statistics because the statistical data existed in Japan. The estimation method for imported LNG were different between the CRF tables and the IEA statistics. The figures for stock changes reported to the CRF tables were the difference between the stock of imported LNG at the end of the previous fiscal year and the stock at the end of the current fiscal year, both from national statistics. The figures for stock changes reported to the IEA were the difference between the stock of imported LNG at the end of the previous fiscal year and the stock at the end of the current fiscal year, with the former calculated as one-half of the LNG import in March of the previous year, and the latter as one-half of the LNG import in March of the current year. One reason for reporting the estimated data to IEA is that the national statistics did not catch stocks of LNG in the past and the stock data have been estimated in this way since then. The figures for stock of natural gas reported in the CRF tables include the city gas stock, whereas the figures for stock of natural gas in the IEA statistics do not. Note that

there is a flaw in the reported value to the IEA in FY2019. The value was converted from the standard condition (15.6°C, 101.325 kPa, saturated with water vapor) [ $\text{Sm}^3$ ] to the normal condition (0°C, 101.325 kPa, dry condition) [ $\text{Nm}^3$ ] by  $1.0571\text{Sm}^3/\text{Nm}^3$  without considering water vapor, although  $1.0759\text{Sm}^3/\text{Nm}^3$  is specified in the reporting guidelines of *Current Production Statistics* by METI. This was corrected in the reporting in FY2020.

Table A 4-18 Changes in natural gas stock in FY2019 (reference)

CRF Table 1.A(b)
Stock changes: 1,647.45 TJ $[3.63 \times 10^3 \text{ t (LNG)} \times 54.71 \text{ MJ/kg (GCV)}$ $+ -36.735 \times 10^6 \text{ m}^3\text{-SATP (indigenous natural gas)} \times 38.38 \text{ MJ/m}^3\text{-SATP (GCV)}$ $+ -10.918 \times 10^6 \text{ m}^3\text{-SATP (city gas)} \times 39.96 \text{ MJ/m}^3\text{-SATP (GCV)}$ $= 1,647.45 \text{ TJ}]$
IEA statistics
Stock changes: 897.24 TJ $[3,647.62 \times 10^3 \text{ t (LNG, opening stock)} \times 54.70 \text{ MJ/kg (GCV in previous year)}$ $+ 176.098 \times 10^6 \text{ Sm}^3 \text{ (natural gas, opening stock)} / 1.0571 \text{ Sm}^3/\text{Nm}^3 \times 1.1060 \text{ m}^3\text{-SATP}/\text{Nm}^3$ $\times 38.38 \text{ MJ/m}^3\text{-SATP (GCV in previous year)}$ $= 206,610.90 \text{ TJ (opening stock)}$ $3,604.38 \times 10^3 \text{ t (LNG, closing stock)} \times 54.71 \text{ MJ/kg (calorific value in current year)}$ $+ 211.834 \times 10^6 \text{ Sm}^3 \text{ (natural gas, closing stock)} / 1.0571 \text{ Sm}^3/\text{Nm}^3$ $\times 1.1060 \text{ m}^3\text{-SATP}/\text{Nm}^3 \times 38.38 \text{ MJ/m}^3\text{-SATP (calorific value in current year)}$ $= 205,713.66 \text{ TJ (closing stock)}$ $206,610.90 \text{ TJ (opening stock)} - 205,713.66 \text{ TJ (closing stock)}$ $= 897.24 \text{ TJ}]$

## A4.2. General Energy Statistics

### A4.2.1 General Energy Statistics Overview

The data given in the *General Energy Statistics* compiled by the Agency for Natural Resources and Energy were used for the activity data of fuel combustion in energy sector.

The *General Energy Statistics* (Energy Balance Table) provides a comprehensive overview of domestic energy supply and demand to grasp what are converted from energy sources, such as coal, oil, natural gas and others, provided in Japan and what are consumed in what sectors. The supply/conversion and consumption data in *General Energy Statistics* use official statistics and are structured with the minimum of estimation and adjustment. (Kainou, 2012)

*General Energy Statistics* (Energy Balance Table) indicates an overview of domestic energy supply and demand, shows the main energy sources used in Japan as “Columns” and the supply, conversion and consumption sectors as “Rows”, in a matrix. Specifically, columns comprise 13 major categories (coal [\$0100]<sup>1</sup>, coal products [\$0200], crude oil [\$0300], oil products [\$0400], natural gas [\$0500], city gas [\$0600], renewable energy (excl. hydro) [\$0700], hydraulic power generation (excl. pumped) [\$0800], pumped storage [\$0900], effective recovery use of wasted energy [\$1000], nuclear power generation [\$1100], electricity [\$1200], and heat [\$1300]) and the necessary sub-categories and a more detailed breakdown of the sub-categories. The *General Energy Statistics* supply and demand sectors (rows) comprise 3 major sectors — primary energy supply [#01], energy transformation & own use [#08], and final energy consumption [#19] — plus the necessary sub-categories and a more detailed breakdown of the sub-categories. (Refer to the following *General Energy Statistics* simplified table.)

The *General Energy Statistics* (complete Energy Balance Tables) for the years since FY1990 is available on the following internet site:

[https://www.enecho.meti.go.jp/statistics/total\\_energy/results.html#headline2](https://www.enecho.meti.go.jp/statistics/total_energy/results.html#headline2)

The following is the energy balance simplified table (Table A 4-19 –Table A 4-22).

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<sup>1</sup> Code number of the *General Energy Statistics* (Energy Balance Table)

Table A 4-19 Energy balance simplified table (General Energy Statistics, FY1990, 1995)

1990FY	Row S	\$0100	\$0200	\$0300	\$0400	\$0500	\$0600	\$0700	\$0800	\$0900	\$1000	\$1100	\$1200	\$1300	\$1400	\$1401	\$1402		
<< General Energy Statistics >>		Coal	Coal Products	Crude Oil	Oil Products	Natural Gas	City Gas	Renewable (excl. hydro)	Hydraulic Power Generation (excl. pumped)	Pumped Storage	Effective Recovery Use of Wasted Energy	Nuclear Power Generation	Electricity	Heat	Total	Energy Use Total	Non-Energy Use Total		
Simplified energy unit table GCV (gross calorific value) basis Display unit: TJ																			
Line #																			
#01	Primary Energy Supply	3,357,112	-39,341	8,981,710	2,026,265	2,056,326		267,189	818,519		317,978	1,883,500	0	0	19,669,259	18,066,871	1,602,388		
#02	Indigenously Produced	193,762	0	24,484	0	89,203		266,070	818,519		317,978	1,883,500	0	0	3,593,516	0	0		
#03	Import	3,161,715	15,352	9,139,187	2,341,006	1,967,475		1,119			0	0	0	0	16,625,854	0	0		
#04	Total Primary Energy Supply	3,355,476	15,352	9,163,671	2,341,006	2,056,678		267,189	818,519		317,978	1,883,500	0	0	20,219,371	18,616,982	1,602,388		
#05	Export	-53	-56,644	0	-292,955	0	0	-1			0	0	0	0	-349,653	0	0		
#06	Stockpile Change / Supply (+: withdrawal/-: build-up)	1,689	1,951	-181,961	-21,786	-352	0	0	0	0	0	0	0	0	-200,458	0	0		
#07	Domestic Primary Energy Supply (Supply) (Demand)	3,357,112	-39,341	8,981,710	2,026,265	2,056,326		267,189	818,519		317,978	1,883,500	0	0	19,669,259	18,066,871	1,602,388		
#08	Energy Transformation & Own Use	-3,151,561	1,278,447	-8,961,984	5,499,151	-1,980,245		510,901	-210,804	-818,519	0	-317,978	-1,883,500	2,785,372	1,017,841	-6,232,881	-6,170,659	-62,222	
#09	Manufacture of Coal Products (+: output/-: input)	-2,142,047	1,934,969	0	-27,085	0	0	0	0	0	0	0	0	0	0	-234,162	-234,162	0	
#10	Oil Products (+: output/-: input)	0	0	-8,073,053	8,125,199	5,121		-61,907	-109,183	0	0	0	0	-94,149		-36,882	0	-36,882	
#11	Gas Conversion and Production (+: output/-: input)	0	-19,178	0	-161,220	-503,899	683,704	-101			-445	0	0	0	-1,139	-1,139	0	0	
#12	Power Generation	-673,045	-209,619	-874,209	-1,052,475	-1,529,799	-65	-13,827	-752,524	0	0	-1,882,503	2,679,366	0	-4,308,700	-4,308,700	0	0	
#13	Auto Power Generation	-162,252	-132,541	0	-432,341	-4,367	-27,139	-87,643	-65,995	0	-170,247	-997	407,089	0	-676,433	-676,433	0	0	
#14	Auto Steam Generation	-147,046	-135,509	0	-640,424	-4,241	-61,907	-109,183	0	0	-145,775	0	0	1,106,341	-137,744	-137,744	0	0	
#15	District Heat Supply	-824	0	0	-2,592	0	-6,169	-37	0	0	-1,511	0	-1,229	8,361	-4,000	-4,000	0	0	
#16	Own Use and Loss	-3,015	-161,697	-1,017	-319,060	-238	-20,889	0	0	0	0	0	-299,854	-2,712	-808,481	-808,481	0	0	
#17	Transformation and Consumption Stockpile Change (+: withdrawal/-: build-up)	-20,454	-858	-13,705	1,607	542	0	-13	0	0	0	0	0	0	-32,881	0	-32,881	0	
#18	Statistical Discrepancy (+: excess/-: shortage)	-195,600	12,361	19,725	653,205	18,443	967	7,989	0	0	0	0	0	32,053	-3,916	545,228	429,484	115,744	
#19	Final Energy Consumption	401,151	1,226,745	0	7,525,416	57,638	510,901	56,385	0	0	0	2,753,319	1,021,756	13,553,311	12,013,145	1,540,166			
#20	Industry	401,119	1,223,865	0	3,901,385	57,638	167,823	7,989	0	0	0	2,054,311	1,020,472	8,834,602	7,335,187	1,499,414			
#21	Agriculture, Fishery, Mining and Construction	133	5,090	0	615,958	1,753	2,182	0	0	0	0	83,252	2,276	710,645	521,338	189,306			
#22	Manufacturing	400,852	1,218,775	0	2,187,376	55,885	100,469	0	0	0	0	1,462,951	935,052	6,361,360	5,166,996	1,194,364			
#23	Food, Beverages, Tobacco and Feed	48	0	0	52,848	0	8,102	0	0	0	0	56,462	49,454	166,915	166,915	0	0	0	
#24	Textile Mill Products	544	0	0	50,417	0	4,699	0	0	0	0	71,268	92,180	219,108	219,108	0	0	0	
#25	Pulp, Paper and Paper Products	126	0	0	31,995	2	4,731	0	0	0	0	130,845	274,119	441,819	441,819	0	0	0	
#26	Chemical and Allied Products, Oil and Coal Products	6,633	46,779	0	1,458,730	25,021	9,582	0	0	0	0	210,838	234,151	1,991,735	810,784	1,180,951			
#27	Ceramic, Stone and Clay Products	236,521	37,016	0	202,577	854	13,546	0	0	0	0	111,187	42,437	644,140	631,411	12,728			
#28	Iron and Steel	140,959	1,109,711	0	126,640	24,987	11,084	0	0	0	0	272,173	110,581	1,796,135	1,795,449	685			
#29	Non-Ferrous Metals	15,811	11,378	0	56,332	322	9,162	0	0	0	0	62,110	17,411	172,526	172,526	0	0	0	
#30	Machinery	15	13,891	0	170,851	4,698	33,072	0	0	0	0	398,766	76,719	698,012	698,012	0	0	0	
#31	Miscellaneous	194	0	0	36,985	0	6,489	0	0	0	0	149,302	38,000	230,971	230,971	0	0	0	
#32	Commercial Industry	133	0	0	1,098,051	0	65,172	7,989	0	0	0	508,107	83,144	1,762,597	1,646,853	115,744			
#33	Residential	0	2,880	0	606,330	0	343,074	48,395	0	0	0	638,494	1,284	1,640,458	1,640,458	0	0	0	
#34	Transportation	33	0	0	3,017,702	0	3	0	0	0	0	60,514	0	3,078,252	3,037,500	40,752			
#35	Passenger	33	0	0	1,516,269	0	1	0	0	0	0	56,610	0	1,572,912	1,540,989	31,923			
#36	Freight	0	0	0	1,501,433	0	3	0	0	0	0	3,905	0	1,505,340	1,496,511	8,829			
#37	Non-energy and Feedstock Use	6,063	26,437	0	1,493,632	13,997	38	0	0	0	0	0	0	0	1,540,166	0	1,540,166		
1995FY	Row S	\$0100	\$0200	\$0300	\$0400	\$0500	\$0600	\$0700	\$0800	\$0900	\$1000	\$1100	\$1200	\$1300	\$1400	\$1401	\$1402		
<< General Energy Statistics >>		Coal	Coal Products	Crude Oil	Oil Products	Natural Gas	City Gas	Renewable (excl. hydro)	Hydraulic Power Generation (excl. pumped)	Pumped Storage	Effective Recovery Use of Wasted Energy	Nuclear Power Generation	Electricity	Heat	Total	Energy Use Total	Non-Energy Use Total		
Simplified energy unit table GCV (gross calorific value) basis Display unit: TJ																			
Line #																			
#01	Primary Energy Supply	3,725,382	-91,908	10,166,812	1,642,449	2,477,257		280,834	728,509		380,411	2,693,458	0	0	22,003,203	20,202,409	1,800,794		
#02	Indigenously Produced	153,374	0	32,455	0	95,250		278,350	728,509		380,411	2,693,458	0	0	4,361,806	0	0		
#03	Import	3,575,648	18,016	10,171,504	2,226,338	2,382,172		2,491			0	0	0	0	18,376,169	0	0		
#04	Total Primary Energy Supply	3,729,022	18,016	10,203,959	2,226,338	2,477,422		280,841	728,509		380,411	2,693,458	0	0	22,737,975	20,937,181	1,800,794		
#05	Export	-75	-103,811	0	-717,045	0	0	-6			0	0	0	0	-820,938	0	0		
#06	Stockpile Change / Supply (+: withdrawal/-: build-up)	-3,565	-6,113	-37,147	133,156	-165	0	0	0	0	0	0	0	0	86,166	0	0		
#07	Domestic Primary Energy Supply (Supply) (Demand)	3,725,382	-91,908	10,166,812	1,642,449	2,477,257		280,834	728,509		380,411	2,693,458	0	0	22,003,203	20,202,409	1,800,794		
#08	Energy Transformation & Own Use	-3,316,691	1,148,397	-10,063,320	6,946,881	-2,418,050	685,997	-224,089	-728,509	0	-380,411	-2,693,458	3,146,438	1,055,422	-6,841,393	-6,776,341	-65,052		
#09	Manufacture of Coal Products (+: output/-: input)	-1,899,695	1,792,057	0	-24,231	0	0	0	0	0	0	0	0	0	-131,869	-131,869	0		
#10	Oil Products (+: output/-: input)	0	0	-9,375,750	9,417,456	5,773	0	0	0	0	0	0	0	-103,260	-55,781	0	-55,781		
#11	Gas Conversion and Production (+: output/-: input)	0	-12,205	0	-180,538	-723,679	915,060	-37			0	0	0	0	-1,400	-1,400	0		
#12	Power Generation	-1,072,304	-219,914	-669,401	-835,632	-1,750,119	-663	-27,002	-667,399	0	0	-2,691,935	3,054,038	0	-4,880,332	-4,880,332	0		
#13	Auto Power Generation	-182,384	-138,015	-539	-439,106	-5,482	-45,424	-97,713	-61,110	0	-202,462	-1,523	440,633	0	-733,126	-733,126	0		
#14	Auto Steam Generation	-160,158	-127,828	-669	-672,326	-4,887	-98,261	-99,257	0	0	-174,443	0	1,145,850	-191,980	-191,980	0	0		
#15	District Heat Supply	-638	0	0	-1,601	0	-11,101	-99	0	0	-3,505	0	-2,548	15,823	-3,669	-3,669	0		
#16	Own Use and Loss	-2,978	-139,799	-1,058	-322,242	-86	-19,128	0	0	0	0	0	-345,686	-2,990	-833,968	-833,968	0		
#17	Transformation and Consumption Stockpile Change (+: withdrawal/-: build-up)	3,103	-7,537	-15,903	-3,893	5,944	0	20	0	0	0	0	0	0	-18,265	0	-18,265		
#18	Statistical Discrepancy (+: excess/-: shortage)	-45,916	425	103,492	636,132	991	1,724	7,063	0	0	0	8,299	-32,390	679,820	563,198	116,622			
#19	Final Energy Consumption	454,606	1,056,064	0	8,589,329	58,216	685,997	56,745	0	0	0	3,138,139	1,087,812	15,126,909	13,391,167	1,735,742			
#20	Industry	454,575	1,054,427	0	4,275,478	58,216	286,618	7,099	0	0	0	2,251,832	1,086,444	9,474,690	7,771,448	1,703,242			
#21	Agriculture, Fishery, Mining and Construction	82	1,590	0	581,369	1,571	2,963	0	0	0	0	79,742	1,944	669,260	497,671	171,589			
#22	Manufacturing	454,325	1,052,837	0	2,523,875	56,645	160,422	36	0	0	0	1,407,011	969,692	6,624,844	5,209,813	1,415,031			
#23	Food, Beverages, Tobacco and Feed	82	0	0	63,054	0	14,756	0	0	0	0	65,038	70,106	213,037	213,037	0	0	0	
#24	Textile Mill Products	823	0	0	46,242	14	6,320	0	0	0	0	64,730	92,448	210,577	210,577	0	0	0	
#25	Pulp, Paper and Paper Products	0	0	0	35,625	5	10,330	36	0	0	0	132,158	274,405	452,559	452,559	0	0	0	
#26	Chemical and Allied Products, Oil and Coal Products	6,103	31,971	0	1,779,429	21,427	16,674	0	0	0	0	210,026	248,201	2,313,831	914,655	1,399,176			
#27	Ceramic, Stone and Clay Products	236,215	3																

Table A 4-20 Energy balance simplified table (General Energy Statistics, FY2000, 2005)

2000FY	Row #	\$0100	\$0200	\$0300	\$0400	\$0500	\$0600	\$0700	\$0800	\$0900	\$1000	\$1100	\$1200	\$1300	\$1400	\$1401	\$1402	
		Coal	Coal Products	Crude Oil	Oil Products	Natural Gas	City Gas	Renewable (excl. hydro)	Hydraulic Power Generation (excl. pumped)	Pumped Storage	Effective Recovery Use of Wasted Energy	Nuclear Power Generation	Electricity	Heat	Total	Energy Use Total	Non-Energy Use Total	
<< General Energy Statistics >>		Simplified energy unit table																
		GCV (gross calorific value) basis																
		Display unit: TJ																
Line #																		
#01	Primary Energy Supply	4,203,202	-3,821	9,634,832	1,528,928	3,058,878	0	273,860	745,903	0	409,621	2,858,092	0	0	22,709,495	20,834,947	1,874,549	
#02	Indigenously Produced	66,912	0	28,034	0	106,340	0	269,127	745,903	0	409,621	2,858,092	0	0	4,484,028	0	0	
#03	Import	4,139,375	76,219	9,733,303	2,252,207	2,952,403	0	4,746	0	0	0	0	0	19,158,252	21,767,731	1,874,549		
#04	Total Primary Energy Supply	4,206,287	76,219	9,761,337	2,252,207	3,058,742	0	273,873	745,903	0	409,621	2,858,092	0	0	23,642,280	21,767,731	1,874,549	
#05	Export	-112	-78,077	0	-617,396	0	0	-13	0	0	0	0	0	-695,597	0	0		
#06	Stockpile Change / Supply (+: withdrawal/-: build-up)	-2,972	-1,963	-126,505	-105,883	136	0	0	0	0	0	0	0	-237,187	0	0		
#07	Domestic Primary Energy Supply (Supply) (Demand)	4,203,202	-3,821	9,634,832	1,528,928	3,058,878	0	273,860	745,903	0	409,621	2,858,092	0	0	22,709,495	20,834,947	1,874,549	
#08	Energy Transformation & Own Use	-3,705,208	1,114,629	-9,622,842	7,213,348	-3,022,830	806,834	-223,800	-745,903	0	-403,364	-2,858,092	3,414,115	1,158,073	-6,874,841	-6,769,290	-105,551	
#09	Manufacture of Coal Products (+: output/-: input)	-1,738,478	1,664,686	0	-33,697	0	0	0	0	0	0	0	0	-107,489	-107,489	0		
#10	Oil Products (+: output/-: input)	0	0	-9,331,059	9,412,940	6,972	0	0	0	0	0	0	0	-137,327	-48,474	0	-48,474	
#11	Gas Conversion and Production (+: output/-: input)	0	-9,573	0	-150,046	-925,341	1,084,614	-31	0	0	0	0	0	0	-377	-377	0	
#12	Power Generation	-1,513,154	-219,155	-301,245	-544,697	-2,130,517	-1,632	-27,676	-679,439	0	0	-2,851,772	3,320,803	0	-4,948,485	-4,948,485	0	
#13	Auto Power Generation	-222,305	-114,011	-83	-431,513	-9,034	-71,592	-99,374	-66,464	0	-178,038	-6,320	457,645	0	-741,088	-741,088	0	
#14	Auto Steam Generation	-198,902	-69,828	-135	-672,981	-7,845	-128,034	-96,581	0	0	-220,572	0	0	1,276,053	-118,825	-118,825	0	
#15	District Heat Supply	-708	0	0	-1,692	0	-14,515	-116	0	0	-4,755	0	-3,940	22,648	-3,078	-3,078	0	
#16	Own Use and Loss	-4,240	-132,502	-518	-335,537	-519	-13,139	0	0	0	0	0	-360,392	-3,302	-849,949	-849,949	0	
#17	Transformation and Consumption Stockpile Change (+: withdrawal/-: build-up)	-27,422	-4,989	10,199	3,549	-5,414	0	-22	0	0	1	0	0	-24,098	0	-24,098		
#18	Statistical Discrepancy (+: excess/-: shortage)	76,007	60,164	11,990	592,827	-14,343	1,900	5,078	0	0	0	0	-87,528	-66,148	579,948	492,044	87,904	
#19	Final Energy Consumption	421,987	1,050,644	0	8,742,476	50,391	806,634	50,059	0	6,256	0	3,501,643	1,224,220	15,854,510	14,085,513	1,768,998		
#20	Industry	421,941	1,050,644	0	4,211,861	50,391	386,796	17,219	0	6,256	0	2,531,853	1,222,914	9,899,876	8,165,041	1,734,835		
#21	Agriculture, Fishery, Mining and Construction	47	1,744	0	533,670	1,930	2,959	0	0	0	0	75,049	1,530	616,930	463,427	153,503		
#22	Manufacturing	421,754	1,048,900	0	2,495,178	48,461	178,537	12,142	0	6,256	0	1,441,577	1,076,657	6,729,262	5,235,834	1,493,428		
#23	Food, Beverages, Tobacco and Feed	34	0	0	66,373	0	21,171	0	0	0	0	75,932	79,504	243,015	243,015	0		
#24	Textile Mill Products	257	0	0	34,473	1	5,858	0	0	0	0	56,816	79,810	177,214	177,214	0		
#25	Pulp, Paper and Paper Products	0	0	0	26,153	71	8,250	12,142	0	0	0	140,731	287,154	474,501	474,501	0		
#26	Chemical and Allied Products, Oil and Coal Products	556	36,239	0	1,880,427	23,397	22,408	0	0	0	0	212,761	352,672	2,528,459	1,036,347	1,492,113		
#27	Ceramic, Stone and Clay Products	185,818	24,256	0	170,732	1,681	19,036	0	0	0	6,235	0	96,376	33,996	538,130	536,966	1,164	
#28	Iron and Steel	230,744	973,938	0	109,213	22,154	36,208	0	0	0	0	261,809	109,404	1,743,470	1,743,318	152		
#29	Non-Ferrous Metals	4,209	10,185	0	49,230	238	14,836	0	0	19	0	56,982	23,072	158,770	158,770	0		
#30	Machinery	0	4,282	0	122,206	919	37,437	0	0	0	2	389,189	65,343	619,377	619,377	0		
#31	Miscellaneous	137	0	0	36,370	0	13,133	0	0	0	0	150,982	45,703	246,325	246,325	0		
#32	Commercial Industry	140	0	0	1,183,013	0	205,500	5,078	0	0	0	1,015,227	144,727	2,553,685	2,465,781	87,904		
#33	Residential	0	0	0	768,778	0	418,897	32,840	0	0	0	902,926	1,306	2,124,747	2,124,747	0		
#34	Transportation	46	0	0	3,761,837	0	1,141	0	0	0	0	66,864	0	3,829,887	3,795,725	34,162		
#35	Passenger	46	0	0	2,190,118	0	172	0	0	0	0	63,385	0	2,253,720	2,227,912	25,808		
#36	Freight	0	0	0	1,571,719	0	969	0	0	0	0	3,479	0	1,576,167	1,567,813	8,354		
#37	Non-energy and Feedstock Use	19	19,641	0	1,740,814	8,523	0	0	0	0	0	0	0	1,768,998	0	1,768,998		

2005FY	Row #	\$0100	\$0200	\$0300	\$0400	\$0500	\$0600	\$0700	\$0800	\$0900	\$1000	\$1100	\$1200	\$1300	\$1400	\$1401	\$1402	
		Coal	Coal Products	Crude Oil	Oil Products	Natural Gas	City Gas	Renewable (excl. hydro)	Hydraulic Power Generation (excl. pumped)	Pumped Storage	Effective Recovery Use of Wasted Energy	Nuclear Power Generation	Electricity	Heat	Total	Energy Use Total	Non-Energy Use Total	
<< General Energy Statistics >>		Simplified energy unit table																
		GCV (gross calorific value) basis																
		Display unit: TJ																
Line #																		
#01	Primary Energy Supply	4,765,771	15,805	9,517,554	1,173,834	3,291,376	0	380,850	671,487	0	428,091	2,660,242	0	0	22,905,011	20,957,082	1,947,930	
#02	Indigenously Produced	28,110	0	33,051	0	134,612	0	375,440	671,487	0	428,091	2,660,242	0	0	4,331,033	0	0	
#03	Import	4,737,747	81,303	9,473,040	2,127,563	3,156,903	0	5,461	0	0	0	0	0	19,582,017	20,957,082	1,947,930		
#04	Total Primary Energy Supply	4,765,856	81,303	9,506,092	2,127,563	3,291,515	0	380,901	671,487	0	428,091	2,660,242	0	0	23,913,050	21,965,120	1,947,930	
#05	Export	-85	-49,269	-4	-880,259	0	0	-51	0	0	0	0	0	-929,668	0	0		
#06	Stockpile Change / Supply (+: withdrawal/-: build-up)	0	-16,228	11,466	-73,470	-138	0	0	0	0	0	0	0	-78,371	0	0		
#07	Domestic Primary Energy Supply (Supply) (Demand)	4,765,771	15,805	9,517,554	1,173,834	3,291,376	0	380,850	671,487	0	428,091	2,660,242	0	0	22,905,011	20,957,082	1,947,930	
#08	Energy Transformation & Own Use	-4,310,565	1,121,057	-9,510,672	7,253,909	-3,227,280	966,321	-354,038	-671,487	0	-421,786	-2,660,242	3,561,797	1,199,658	-7,053,329	-6,930,529	-122,800	
#09	Manufacture of Coal Products (+: output/-: input)	-1,730,636	1,633,464	0	-18,801	0	0	0	0	0	0	0	0	0	-115,974	-115,974	0	
#10	Oil Products (+: output/-: input)	0	0	-9,209,723	9,278,313	8,203	0	0	0	0	0	0	0	-139,784	-62,992	0	-62,992	
#11	Gas Conversion and Production (+: output/-: input)	0	-1,994	0	-99,300	-1,315,246	1,414,464	-46	0	0	0	0	0	0	-2,121	-2,121	0	
#12	Power Generation	-2,146,038	-189,378	-301,537	-546,895	-1,910,075	-58,869	-52,804	-614,127	0	0	-2,660,242	3,440,790	0	-5,039,177	-5,039,177	0	
#13	Auto Power Generation	-250,929	-106,559	-20	-400,617	-16,206	-115,803	-132,042	-57,360	0	-178,129	0	502,550	0	-755,114	-755,114	0	
#14	Auto Steam Generation	-215,125	-66,543	-37	-572,779	-12,856	-183,042	-168,956	0	0	-238,466	0	0	1,317,573	-140,231	-140,231		
#15	District Heat Supply	-633	0	0	-1,023	0	-18,102	-146	0	0	-5,124	0	-4,129	25,072	-4,085	-4,085		
#16	Own Use and Loss	-6,994	-129,554	-91	-331,117	-16,279	-9,176	0	0	0	0	0	-377,413	-3,203	-873,827	-873,827		
#17	Transformation and Consumption Stockpile Change (+: withdrawal/-: build-up)	39,791	-18,378	736	86	-27,972	0	-44	0	0	-68	0	0	0	-5,850	0	-5,850	
#18	Statistical Discrepancy (+: excess/-: shortage)	33,648	93,728	6,882	704,727	-566	2,003	4,253	0	0	0	0	-127,656	-55,638	661,381	578,117	83,264	
#19	Final Energy Consumption	421,558	1,043,135	0	8,427,743	64,662	966,321	26,812	0	6,305	0	3,689,453	1,255,296	15,901,284	14,076,155	1,825,130		
#20	Industry	421,521	1,043,135	0	4,155,720	64,662	526,270	4,278	0	6,305	0	2,624,065	1,253,971	10,099,926	8,310,469	1,789,456		
#21	Agriculture, Fishery, Mining and Construction	34	524	0	458,565	2,758	3,115	0	0	0	0	60,986	1,350	527,331	426,504	100,828		
#22	Manufacturing	421,249	1,042,611	0	2,443,486	61,905	259,987	25	0	6,305	0							



Table A 4-21 Energy balance simplified table (General Energy Statistics, FY2010, 2015)

2010FY	Row 5	\$0100	\$0200	\$0300	\$0400	\$0500	\$0600	\$0700	\$0800	\$0900	\$1000	\$1100	\$1200	\$1300	\$1400	\$1401	\$1402	
<< General Energy Statistics >>		Coal	Coal Products	Crude Oil	Oil Products	Natural Gas	City Gas	Renewable (excl. hydro)	Hydraulic Power Generation (excl. pumped)	Pumped Storage	Effective Recovery Use of Wasted Energy	Nuclear Power Generation	Electricity	Heat	Total	Energy Use Total	Non-Energy Use Total	
Simplified energy unit table		GCV (gross calorific value) basis																
Display unit: TJ																		
Line #																		
01	Primary Energy Supply	4,983,144	14,115	8,127,286	730,774	3,994,127	1,105	436,391	715,871	0	529,798	2,462,243	0	0	21,994,855	20,126,593	1,868,262	
02	Indigenously Produced	25,764	0	30,637	0	149,324	0	421,586	715,871	0	529,798	2,462,243	0	0	4,335,224	0	0	
03	Import	4,957,466	29,909	8,140,499	1,946,768	3,844,997	0	14,857	0	0	0	0	0	0	18,934,496	0	0	
04	Total Primary Energy Supply	4,983,230	29,909	8,171,136	1,946,768	3,994,321	0	436,443	715,871	0	529,798	2,462,243	0	0	23,269,720	21,401,458	1,868,262	
05	Export	-87	-19,695	0	-1,187,778	0	0	-51	0	0	0	0	0	0	-1,207,611	0	0	
06	Stockpile Change / Supply (+: withdrawal-: build-up)	0	3,901	-43,851	-28,216	-194	1,105	0	0	0	0	0	0	0	-67,255	0	0	
07	Domestic Primary Energy Supply (Supply) (Demand)	4,983,144	14,115	8,127,286	730,774	3,994,127	1,105	436,391	715,871	0	529,798	2,462,243	0	0	21,994,855	20,126,593	1,868,262	
08	Energy Transformation & Own Use	-4,523,260	1,090,966	-8,133,969	6,532,803	-3,960,650	1,087,984	-415,108	-715,871	0	-522,602	-2,462,243	3,799,519	1,003,399	-72,919,031	-7,081,798	-137,233	
09	Manufacture of Coal Products (+: output-: input)	-1,704,578	1,611,327	0	-20,407	0	0	0	0	0	-87	0	0	0	-113,745	-113,745	0	
10	Oil Products (+: output-: input)	0	0	-7,949,128	8,038,382	5,579	0	-8,588	0	0	0	0	0	-146,978	-60,732	0	-60,732	
11	Gas Conversion and Production (+: output-: input)	0	0	0	-73,311	-1,646,183	1,719,690	0	0	0	0	0	0	0	196	196	0	
12	Power Generation	-2,087,400	-207,076	-189,297	-374,290	-2,342,899	-59,859	-49,324	-574,862	0	-5,678	-2,462,243	3,474,987	0	-4,877,940	-4,877,940	0	
13	Auto Power Generation	-440,814	-104,816	-46	-309,172	-149,028	-133,884	-172,142	-141,010	0	-282,311	0	704,765	0	-1,028,457	-1,028,457	0	
14	Auto Steam Generation	-240,628	-76,411	-90	-378,618	-27,268	-168,223	-184,754	0	0	-229,472	0	0	1,130,683	-174,781	-174,781	0	
15	District Heat Supply	0	0	0	-822	0	-17,003	-331	0	0	-4,068	0	0	-4,126	24,418	-1,932	-1,932	
16	Own Use and Loss	-20,471	-134,613	-62	-293,998	-4,773	-50,390	0	0	0	0	0	-376,108	-4,724	-885,138	-885,138	0	
17	Transformation and Consumption Stockpile Change (+: withdrawal-: build-up)	-29,368	2,555	4,654	-9,526	1,573	0	278	0	0	-987	0	0	0	-30,821	0	-30,821	
18	Statistical Discrepancy (+: excess-: shortage)	68,210	49,980	-6,683	312,244	-34,148	108,374	4,485	0	0	0	0	72,012	-86,048	488,426	423,963	64,463	
19	Final Energy Consumption	391,674	1,055,101	0	7,263,710	67,624	1,089,888	21,284	0	0	7,196	0	3,727,507	1,089,447	147,126,632	12,981,604	1,731,028	
20	Industry	391,630	1,055,101	0	3,300,853	67,624	657,371	4,834	0	0	7,196	0	2,588,231	1,088,165	9,161,006	7,465,453	1,695,552	
21	Agriculture, Fishery, Mining and Construction	87	140	0	388,845	5,064	2,672	0	0	0	0	0	45,746	1,392	443,947	370,579	73,368	
22	Manufacturing	391,306	1,052,992	0	2,203,042	62,560	281,280	350	0	0	7,196	0	1,329,679	976,583	6,304,979	4,747,258	1,557,722	
23	Food, Beverages, Tobacco and Feed	28	91	0	49,050	0	39,753	0	0	0	0	0	91,205	99,108	279,235	279,235	0	
24	Textile Mill Products	153	0	0	13,306	0	7,678	0	0	0	0	0	35,686	49,765	106,588	106,588	0	
25	Pulp, Paper and Paper Products	322	0	0	19,946	333	5,171	344	0	0	89	0	123,818	228,675	378,697	378,697	0	
26	Chemical and Allied Products, Oil and Coal Products	1,051	49,884	0	1,854,151	34,826	27,260	0	0	0	0	0	204,863	365,689	2,537,905	980,551	1,557,354	
27	Ceramic, Stone and Clay Products	128,254	17,780	0	96,373	4,255	28,179	6	0	0	6,582	0	72,152	19,889	373,471	373,290	181	
28	Iron and Steel	258,193	972,911	0	77,186	20,273	76,514	0	0	0	387	0	258,516	118,085	1,782,065	1,781,879	186	
29	Non-Ferrous Metals	2,314	8,661	0	23,718	1,024	16,292	0	0	0	137	0	52,542	10,665	115,353	115,353	0	
30	Machinery	76	3,587	0	50,855	1,849	65,643	0	0	0	0	0	373,471	58,690	554,171	554,171	0	
31	Miscellaneous	915	78	0	18,457	0	14,790	0	0	0	0	0	117,417	25,837	177,494	177,494	0	
32	Commercial Industry	237	1,970	0	708,965	0	373,418	4,485	0	0	0	0	1,212,816	110,189	2,412,079	2,347,616	64,463	
33	Residential	0	0	0	646,431	0	427,050	16,449	0	0	0	0	1,073,597	1,282	2,164,810	2,164,810	0	
34	Transportation	43	0	0	3,316,427	0	4,667	0	0	0	0	0	65,679	0	3,386,816	3,351,340	35,476	
35	Passenger	43	0	0	1,962,870	0	640	0	0	0	0	0	62,568	0	2,026,122	1,999,526	26,596	
36	Freight	0	0	0	1,353,557	0	4,027	0	0	0	0	0	3,111	0	1,360,695	1,351,815	8,880	
37	Non-energy and Feedstock Use	16	17,902	0	1,696,536	16,575	0	0	0	0	0	0	1,731,028	0	1,731,028	0	1,731,028	
2015FY	Row 5	\$0100	\$0200	\$0300	\$0400	\$0500	\$0600	\$0700	\$0800	\$0900	\$1000	\$1100	\$1200	\$1300	\$1400	\$1401	\$1402	
<< General Energy Statistics >>		GCV (gross calorific value) basis																
Simplified energy unit table		GCV (gross calorific value) basis																
Display unit: TJ																		
Line #																		
01	Primary Energy Supply	5,096,871	57,471	7,406,284	731,279	4,658,056	-833	726,484	725,930	0	535,685	78,638	0	0	20,015,863	18,217,801	1,798,062	
02	Indigenously Produced	31,982	0	20,896	0	110,598	0	694,411	725,930	0	535,685	78,638	0	0	2,198,141	0	0	
03	Import	5,064,950	80,375	7,414,496	1,952,126	4,551,428	0	32,118	0	0	0	0	0	0	19,095,492	0	0	
04	Total Primary Energy Supply	5,096,932	80,375	7,435,391	1,952,126	4,662,026	0	726,529	725,930	0	535,685	78,638	0	0	21,293,632	19,495,571	1,798,062	
05	Export	-62	-22,999	0	-1,265,963	0	0	-45	0	0	0	0	0	0	-1,289,068	0	0	
06	Stockpile Change / Supply (+: withdrawal-: build-up)	0	95	-29,108	45,115	-3,970	-833	0	0	0	0	0	0	0	11,299	0	0	
07	Domestic Primary Energy Supply (Supply) (Demand)	5,096,871	57,471	7,406,284	731,279	4,658,056	-833	726,484	725,930	0	535,685	78,638	0	0	20,015,863	18,217,801	1,798,062	
08	Energy Transformation & Own Use	-4,717,988	946,675	-7,406,973	5,870,508	-4,603,419	1,072,604	-711,325	-725,930	0	-510,425	-78,638	3,464,390	883,439	-65,170,082	-6,401,239	-115,843	
09	Manufacture of Coal Products (+: output-: input)	-1,523,216	1,436,363	0	-19,673	0	0	0	0	0	-4,893	0	0	0	-111,419	-111,419	0	
10	Oil Products (+: output-: input)	0	0	-7,191,157	7,208,201	4,204	0	-14,525	0	0	0	0	0	-119,254	-112,532	0	-112,532	
11	Gas Conversion and Production (+: output-: input)	0	0	0	-68,503	-1,669,358	1,738,071	-116	0	0	0	0	0	0	95	95	0	
12	Power Generation	-2,375,953	-201,063	-226,562	-382,134	-2,924,727	-121,063	-52,323	-588,695	0	-5,484	-78,638	2,945,950	0	-4,010,691	-4,010,691	0	
13	Auto Power Generation	-502,927	-101,086	-39	-262,099	-159,588	-136,847	-472,130	-137,236	0	-297,981	0	843,721	0	-1,226,213	-1,226,213	0	
14	Auto Steam Generation	-243,912	-70,119	-74	-317,268	-24,529	-181,391	-171,077	0	0	-199,185	0	986,116	0	-221,438	-221,438	0	
15	District Heat Supply	0	0	0	-225	0	-14,096	-578	0	0	-2,631	0	-3,609	21,309	169	169	0	
16	Own Use and Loss	-20,270	-120,506	-83	-304,499	-13,393	-46,590	0	0	0	0	0	-321,672	-4,730	-831,743	-831,743	0	
17	Transformation and Consumption Stockpile Change (+: withdrawal-: build-up)	-51,710	3,085	10,941	11,383	18,491	0	-128	0	0	-250	0	0	0	-8,188	0	-8,188	
18	Statistical Discrepancy (+: excess-: shortage)	-52,944	48,096	-690	199,925	-7,176	75,252	4,838	0	0	0	0	46,221	-60,858	252,665	203,844	48,821	
19	Final Energy Consumption	431,827	956,049	0	6,602,227	61,813	1,071,770	15,159	0	0	25,260	0	3,418,170	944,297	13,526,572	11,844,353	1,682,219	
20	Industry	431,788	956,049	0	2,988,944	61,813	668,128	5,229	0	0	25,260	0	2,389,850	943,195	8,470,256	6,824,470	1,645,786	
21	Agriculture, Fishery, Mining and Construction	28	291	0	363,295	4,695	3,082	0	0	0	0	0	38,140	1,095	410,626	355,900	54,726	
22	Manufacturing	431,413	952,800	0	2,065,504	57,118	248,435	390	0	0	25,260	0	1,214,517	878,520	5,873,957	4,331,718	1,542,239	
23	Food, Beverages, Tobacco and Feed	245	80	0	32,811	0	31,205	0	0	0	0	0	91,746	83,786	239,874	239,874	0	
24	Textile Mill Products	112	0	0	7,149	10	5,463	0	0	0	0	0	33,417	50,873	97,022	97,022	0	
25	Pulp, Paper and Paper Products	1,793	0	0	15,758	534	4,531	324	0	0	1,018	0	112,140	205,821	341,918	341,918	0	
26	Chemical and Allied Products, Oil and Coal Products	4,215	49,754	0	1,797,179	27,107	21,360	0	0	0	2,008	0	188,334	332,954	2,422,911	880,925	1,541,985	
27	Ceramic, Stone and Clay Products	130,671	12,652	0	84,661	5,002	25,789	67	0	0	19,110	0	61,848	19,240	358,839	358,700	139	
28	Iron and Steel	291,655	879,851	0	60,409	21,522	80,446	0	0	0	1,707	0	250,808	99,610	1,685,609	1,685,494	114	
29	Non-Ferrous Metals	2,283	7,412	0	16,339	1,317	12,808	0	0	0	1,417	0	43,1					

Table A 4-22 Energy balance simplified table (General Energy Statistics, FY2019, 2020)

2019FY	Row #	\$0100 Coal	\$0200 Coal Products	\$0300 Crude Oil	\$0400 Oil Products	\$0500 Natural Gas	\$0600 City Gas	\$0700 Renewable (excl. hydro)	\$0800 Hydraulic Power Generation (excl. pumped)	\$0900 Pumped Storage	\$1000 Effective Recovery Use of Wasted Energy	\$1100 Nuclear Power Generation	\$1200 Electricity	\$1300 Heat	\$1400 Total	\$1401 Energy Use Total	\$1402 Non-Energy Use Total	
<b>&lt;&lt; General Energy Statistics &gt;&gt;                      Simplified energy unit table                      GCV (gross calorific value) basis                      Display unit: TJ</b>																		
Line #																		
#01	Primary Energy Supply	4,872,473	-24,566	6,631,570	469,314	4,281,580	-436	1,115,835	675,795		0	575,847	538,813	0	0	19,136,224	17,414,287	1,721,937
#02	Indigenously Produced	18,794	0	19,007	0	97,325	0	1,042,390	675,795	0	0	575,847	538,813	0	0	2,967,971	0	0
#03	Import	4,853,711	20,774	6,597,923	1,820,328	4,185,466	0	73,471	0	0	0	0	0	0	0	17,551,733	0	0
#04	Total Primary Energy Supply	4,872,565	20,774	6,616,930	1,820,328	4,282,791	0	1,115,861	675,795	0	0	575,847	538,813	0	0	20,519,704	18,797,767	1,721,937
#05	Export	-92	-46,291	0	-1,310,973	0	0	-26	0	0	0	0	0	0	0	-1,357,381	0	0
#06	Stockpile Change / Supply (+: withdrawal/-: build-up)	0	950	14,640	-40,041	-1,211	-436	0	0	0	0	0	0	0	0	-26,098	0	0
#07	Domestic Primary Energy Supply (Supply) (Demand)	4,872,473	-24,566	6,631,570	469,314	4,281,580	-436	1,115,835	675,795	0	0	575,847	538,813	0	0	19,136,224	17,414,287	1,721,937
#08	Energy Transformation & Own Use	-4,432,689	992,787	-6,634,120	5,557,553	-4,203,899	1,088,517	-1,104,472	-675,795	0	-544,749	-538,813	3,336,196	872,705	-6,286,778	-6,154,120	-132,658	
#09	Manufacture of Coal Products (+: output/-: input)	-1,519,876	1,432,996	0	-16,148	0	0	0	0	0	-5,129	0	0	0	-108,157	-108,157	0	
#10	Oil Products (+: output/-: input)	0	0	-6,613,057	6,605,641	2,243	0	-18,287	0	0	0	0	0	-117,405	-140,864	0	-140,864	
#11	Gas Conversion and Production (+: output/-: input)	0	0	-77,626	-1,658,960	1,735,556	-87	0	0	0	0	0	0	0	-1,117	-1,117	0	
#12	Power Generation	-2,524,177	-141,622	-28,430	-200,918	-2,646,532	-144,315	-326,345	-647,675	0	-142,387	-538,813	3,122,481	0	-4,218,734	-4,218,734	0	
#13	Auto Power Generation	-176,303	-114,045	-39	-167,322	-42,104	-105,749	-575,970	-28,119	0	-204,774	0	579,058	0	-835,367	-835,367	0	
#14	Auto Steam Generation	-225,672	-68,116	-71	-287,206	-21,962	-194,364	-181,348	0	0	-189,936	0	0	973,731	-194,945	-194,945	0	
#15	District Heat Supply	0	0	0	-120	0	-13,720	-444	0	0	-2,503	0	-3,573	22,638	2,277	2,277	0	
#16	Own Use and Loss	-6,945	-119,483	-1,992	-266,087	-10,946	-24,503	-93	0	0	0	0	-361,769	-6,259	-798,079	-798,079	0	
#17	Transformation and Consumption Stockpile Change (+: withdrawal/-: build-up)	20,286	3,057	9,468	7,442	2,432	0	-1,525	0	0	0	-21	0	0	41,139	0	41,139	
#18	Statistical Discrepancy (+: excess/-: shortage)	34,553	62,108	-2,550	42,402	18,870	90,825	4,203	0	0	0	-1,933	-79,049	169,429	144,427	25,002		
#19	Final Energy Consumption	405,231	906,113	0	6,165,055	58,811	1,088,080	11,363	0	0	31,098	0	3,338,129	951,754	12,955,634	13,366,355	1,589,279	
#20	Industry	405,193	906,113	0	2,729,636	58,811	680,368	4,393	0	0	31,098	0	2,368,435	950,677	8,134,724	6,583,832	1,550,892	
#21	Agriculture, Fishery, Mining and Construction	0	0	114	0	346,713	4,812	2,717	0	0	0	0	36,703	1,107	392,167	349,629	42,538	
#22	Manufacturing	405,184	900,889	0	1,921,633	53,999	256,906	190	0	0	31,098	0	1,192,980	879,972	5,642,851	4,159,499	1,483,352	
#23	Food, Beverages, Tobacco and Feed	29	0	0	19,480	0	29,084	0	0	0	0	0	90,769	116,716	256,078	256,078	0	
#24	Textile Mill Products	0	0	0	4,743	68	5,972	0	0	0	0	0	29,264	44,505	84,552	84,552	0	
#25	Pulp, Paper and Paper Products	0	0	0	13,772	485	4,264	153	0	0	525	0	104,885	197,870	321,954	321,954	0	
#26	Chemical and Allied Products, Oil and Coal Products	3,271	50,326	0	1,697,974	26,570	2,202	0	0	0	2,346	0	186,463	316,259	2,305,236	822,367	1,482,869	
#27	Ceramic, Stone and Clay Products	122,281	14,572	0	76,858	4,661	26,261	37	0	0	25,302	0	61,075	19,572	350,619	350,257	362	
#28	Iron and Steel	277,739	827,166	0	48,831	18,894	78,679	0	0	0	1,553	0	242,558	96,943	1,592,363	1,592,242	121	
#29	Non-Ferrous Metals	1,353	6,512	0	14,457	1,323	14,408	0	0	0	1,372	0	-40,828	11,787	92,040	92,040	0	
#30	Machinery	212	2,259	0	34,551	1,997	63,510	0	0	0	0	0	328,141	35,628	466,297	466,297	0	
#31	Miscellaneous	299	55	0	10,968	0	12,700	0	0	0	0	0	108,998	40,690	173,710	173,710	0	
#32	Commercial Industry	8	5,109	0	461,290	0	420,745	4,203	0	0	0	0	1,138,752	69,598	2,099,706	2,074,704	25,002	
#33	Residential	0	0	0	498,720	0	406,158	6,970	0	0	0	0	907,424	1,077	1,820,349	1,820,349	0	
#34	Transportation	39	0	0	2,936,699	0	1,554	0	0	0	0	0	62,270	0	3,000,562	2,962,175	38,387	
#35	Passenger	39	0	0	1,710,853	0	96	0	0	0	0	0	59,682	0	1,770,670	1,741,105	29,565	
#36	Freight	0	0	0	1,225,846	0	1,458	0	0	0	0	0	2,588	0	1,229,892	1,221,070	8,822	
#37	Non-energy and Feedstock Use	12	18,301	0	1,560,919	10,047	0	0	0	0	0	0	0	0	1,589,279	0	1,589,279	
2020FY	Row #	\$0100 Coal	\$0200 Coal Products	\$0300 Crude Oil	\$0400 Oil Products	\$0500 Natural Gas	\$0600 City Gas	\$0700 Renewable (excl. hydro)	\$0800 Hydraulic Power Generation (excl. pumped)	\$0900 Pumped Storage	\$1000 Effective Recovery Use of Wasted Energy	\$1100 Nuclear Power Generation	\$1200 Electricity	\$1300 Heat	\$1400 Total	\$1401 Energy Use Total	\$1402 Non-Energy Use Total	
<b>&lt;&lt; General Energy Statistics &gt;&gt;                      Simplified energy unit table                      GCV (gross calorific value) basis                      Display unit: TJ</b>																		
Line #																		
#01	Primary Energy Supply	4,488,170	-68,861	5,320,691	1,222,416	4,271,624	722	1,195,671	666,042	0	540,551	327,511	0	0	17,964,537	16,428,521	1,536,016	
#02	Indigenously Produced	18,136	0	18,636	0	90,329	0	1,106,679	666,042	0	0	540,551	327,511	0	0	2,767,883	0	0
#03	Import	4,470,126	25,693	5,209,373	1,933,350	4,178,883	0	89,024	0	0	0	0	0	0	0	15,906,450	0	0
#04	Total Primary Energy Supply	4,488,262	25,693	5,228,010	1,933,350	4,269,212	0	1,195,703	666,042	0	540,551	327,511	0	0	0	18,674,333	17,138,316	1,536,016
#05	Export	-92	-94,390	0	-744,068	0	0	-32	0	0	0	0	0	0	0	-838,582	0	0
#06	Stockpile Change / Supply (+: withdrawal/-: build-up)	0	-164	92,682	33,134	2,413	722	0	0	0	0	0	0	0	0	128,787	0	0
#07	Domestic Primary Energy Supply (Supply) (Demand)	4,488,170	-68,861	5,320,691	1,222,416	4,271,624	722	1,195,671	666,042	0	540,551	327,511	0	0	0	17,964,537	16,428,521	1,536,016
#08	Energy Transformation & Own Use	-4,157,767	887,393	-5,320,424	4,405,918	-4,220,775	991,631	-1,185,388	-666,042	0	-510,702	-327,511	3,253,829	815,984	-6,033,853	-5,927,401	-106,453	
#09	Manufacture of Coal Products (+: output/-: input)	-1,337,102	1,261,810	0	-13,474	0	0	0	0	0	-5,165	0	0	0	-93,930	-93,930	0	
#10	Oil Products (+: output/-: input)	0	0	-5,301,697	5,256,447	1,502	0	-19,630	0	0	0	0	0	-112,550	-175,927	0	-175,927	
#11	Gas Conversion and Production (+: output/-: input)	0	0	0	-77,530	-1,603,656	1,679,642	-66	0	0	0	0	0	0	-1,609	-1,609	0	
#12	Power Generation	-2,457,503	-112,324	-25,047	-204,865	-2,673,009	-196,375	-379,649	-640,695	0	-130,836	-327,511	3,043,355	0	-4,104,459	-4,104,459	0	
#13	Auto Power Generation	-171,702	-95,717	-31	-155,909	-42,506	-111,301	-617,533	-25,347	0	-193,255	0	573,916	0	-839,386	-839,386	0	
#14	Auto Steam Generation	-212,003	-58,276	-55	-273,098	-21,720	-188,214	-165,389	0	0	-177,630	0	0	913,545	-182,840	-182,840	0	
#15	District Heat Supply	0	0	0	-127	0	-12,836	-471	0	0	-3,066	0	-3,243	21,261	1,519	1,519	0	
#16	Own Use and Loss	-12,903	-107,198	-1	-183,537	-13,115	-23,252	-217	0	0	0	0	-360,199	-6,273	-706,695	-706,695	0	
#17	Transformation and Consumption Stockpile Change (+: withdrawal/-: build-up)	33,446	-902	6,407	27,280	-30,670	0	-2,117	0	0	-749	0	0	0	32,695	0	32,695	
#18	Statistical Discrepancy (+: excess/-: shortage)	-4,779	35,245	268	80,936	-4,259	1,005	3,813	0	0	0	0	-34,852	-41,813	35,564	7,853	27,711	
#19	Final Energy Consumption	335,182	783,286	0	5,729,909	55,108	992,354	10,283	0	0	29,848	0	3,288,681	857,797	12,082,448	10,652,884	1,429,564	
#20	Industry	335,166	783,286	0	2,586,739	55,108	557,934	3,959	0	0	29,848	0	2,273,983	856,702	7,482,725	6,088,144	1,394,582	
#21	Agriculture, Fishery, Mining and Construction	0	18	0	366,503	4,490	2,925	0	0	0	0	0	38,648	849	413,434	362,328	51,106	
#22	Manufacturing	335,161	774,756	0	1,735,915	50,619	242,567	146	0	0	29,848	0	1,137,969	790,810	5,097,790	3,782,025	1,315,765	
#23	Food, Beverages, Tobacco and Feed	17	0	0	25,769	0	31,600	0	0	0	0	0	88,253	91,530	237,170	237,170	0	
#24	Textile Mill Products	0	0	0	4,506	39	5,408	0	0	0	0	0	26,009	37,777	73,738	73,738	0	
#25	Pulp, Paper and Paper Products	0	0	0	12,763	400	4,580	113	0	0	760	0	96,401	175,512	290,529	290,529	0	
#26	Chemical and Allied Products, Oil and Coal Products	1,860	48,209	0	1,517,774	26,214	22,561	0	0	0	2,000	0	179,187	302,327	2,100,132	784,945	1,315,186	
#27	Ceramic, Stone and Clay Products	120,170	12,481	0	73,892	4,641	26,240	32	0	0	24,621	0	60,022	19,520	341,621	341,164	456	
#28	Iron and Steel	211,670	705,801	0	37,736	16,216	69,225	0	0	0	1,290	0	218,190	84,793	1,344,922	1,344,800	122	
#29	Non-Ferrous Metals	1,426	6,654	0	13,870	1,312	12,662	0	0	0	1							

### A4.2.2 General Energy Statistics and CRF

In order to report CO<sub>2</sub> emissions in CRF, emissions reported under the sectors in *General Energy Statistics* (Energy Balance Table) were reported under each sector in CRF. The correspondence of categories between *General Energy Statistics* and CRF table 1.A(a) ‘sectoral approach’ is indicated in Table A 4-23.

Values subtracting energy consumption reported under ‘non-energy and feedstock use’ [#950000] from energy consumption reported under ‘energy transformation & own use’ [#200000], ‘industry’ [#600000], ‘residential’ [#700000], and ‘transportation’ [#800000] in *General Energy Statistics* (Energy Balance Table) are used for activity data. Because energy consumption reported under ‘non-energy and feedstock use’ [#950000] was used for the purposes other than combustion and was considered not emitting CO<sub>2</sub>, these values were deducted. However, out of this amount deducted as feedstock and non-energy use, the emissions from what is used or collected as energy during waste incineration are separately estimated and reported.

The 2006 IPCC Guidelines requires carbon dioxide emitted from auto power generation, etc., to be counted in the corresponding sector. In Japan’s Energy Balance Table (*General Energy Statistics*), fuel consumption used for auto power generation and auto steam generation are presented under ‘auto power generation’ [#250000], ‘auto steam generation’ [#260000] in the energy transformation sector. However, auto power generation and auto steam generation actually belong to industry sector. Hence, carbon dioxide emissions from “auto power generation” and “auto steam generation” are allocated to each section of ‘1.A.2 Manufacturing industries and construction’ and ‘1.A.4 Other sectors’.

In ‘energy transformation & own use’, ‘manufacture of coal products’ [#210000], ‘oil products’ [#220000], ‘gas conversion and production’ [#230000], ‘power generation’ [#240000], ‘auto power generation’ [#250000], ‘auto steam generation’ [#260000], ‘district heat supply’ [#270000], and ‘own use & loss’ [#300000] are calculated, and other sectors (‘other energy transformation’ and ‘transformation and consumption stockpile change’) are excluded from calculations.

The category ‘manufacture of coal products’ [#210000] corresponds to the balance between input amount of feedstock and output amount of coal products under coke manufacturing process. The difference between the coke-making carbon input and carbon output is considered to be the portion that is oxidized in the atmosphere (burned) from the time that red-hot coke is extruded from a coke oven until it enters the coke dry quenching facility. It was considered appropriate to count this as CO<sub>2</sub> emissions, and it was calculated as carbon emissions from this category. (Ministry of the Environment, 2006)

The category ‘oil products’ [#220000] corresponds to the balance between input amount of feedstock and output amount of oil products under oil refining process. The difference between the carbon input and carbon output is considered to be the burned carbon precipitated on catalysts in fluid catalytic cracking facilities (so-called FCC coke). The burning is aimed at recovering the catalytic activities lowered by the cracking reaction of slack fuel oil. The difference is also considered to be heat recovery at boilers of the off-gas, mainly consisting of CO, generated in the fluid catalytic cracking facilities. The difference is also regarded as CO<sub>2</sub> as by-product of hydrogen generating facilities. It was considered appropriate to count the difference as CO<sub>2</sub> emissions, and it was calculated as carbon emissions from this category. (Ministry of the Environment, 2015)

Table A 4-23 Correspondence between sectors of General Energy Statistics (Detailed Sector) and of the CRF table 1.A(a)

CRF		General Energy Statistics	
1A1	Energy industries		
1A1a	Public electricity and heat production	Public Power generation	#240000
		Own use; Public Power generation	#301400
		District heat supply	#270000
		Own use; District heat supply	#301500
		Auto power generation; Production, transmission and distribution of electricity (until 2015)	#255330
1A1b	Petroleum refining	Oil products	#220000
		Own use; Oil products	#301200
		Auto power generation; Manufacture of petroleum products	#253171
		Auto steam generation; Manufacture of petroleum products	#263171
		Final energy consumption; Manufacture of petroleum products	#626510
1A1c	Manufacture of solid fuels and other energy industries	Non-energy and feedstock use; Manufacture of petroleum products	#951540
		Manufacture of coal products	#210000
		Own use; Coal products	#301100
		Auto power generation; Manufacture of coal products and miscellaneous	#253175
		Auto steam generation; Manufacture of coal products and miscellaneous	#263175
1A1c	Manufacture of solid fuels and other energy industries	Final energy consumption; Manufacture of coal products and miscellaneous	#626550
		Gas conversion and production	#230000
		Own use; Gas conversion and production	#301300
1A2	Manufacturing industries and construction		
1A2a	Iron and steel	Auto power generation; Manufacture of iron and steel	#253250
		Auto steam generation; Manufacture of iron and steel	#263220
		Final energy consumption; Manufacture of iron and steel	#629100
		Non-energy and feedstock use; Manufacture of iron, steel and steel products	#951560
1A2b	Non-ferrous metals	Auto power generation; Manufacture of non-ferrous metals and products	#253230
		Auto steam generation; Manufacture of non-ferrous metals and products	#263260
		Final energy consumption; Manufacture of non-ferrous metals and products	#629300
		Non-energy and feedstock use; Primary smelting and refining of copper, lead, zinc and aluminium	#951570
1A2c	Chemicals	Auto power generation; Manufacture of chemical and allied products	#253160
		Auto steam generation; Manufacture of chemical and allied products	#263160
		Final energy consumption; Manufacture of chemical and allied products	#626100
		Non-energy and feedstock use; Manufacture of petrochemical, ammonia, soda products	#951530
1A2d	Pulp, paper and print	Auto power generation; Manufacture of pulp, paper and paper products	#253140
		Auto power generation; Printing and allied industries	#253150
		Auto steam generation; Manufacture of pulp, paper and paper products	#263140
		Auto steam generation; Printing and allied industries	#263150
		Final energy consumption; Manufacture of pulp, paper and paper products	#624000
		Final energy consumption; Printing and allied industries	#625000
1A2e	Food processing, beverages and tobacco	Non-energy and feedstock use; Manufacture of pulp, paper and paper products, large scale	#951520
		Auto power generation; Manufacture of food	#253090
		Auto power generation; Manufacture of beverages, tobacco and feed	#253100
		Auto steam generation; Manufacture of food	#263090
		Auto steam generation; Manufacture of beverages, tobacco and feed	#263100
1A2f	Non-metallic minerals	Final energy consumption; Manufacture of food, beverages, tobacco and feed	#621000
		Auto power generation; Manufacture of ceramic, stone and clay products	#253210
		Auto steam generation; Manufacture of ceramic, stone and clay products	#263210
		Final energy consumption; Manufacture of ceramic, stone and clay products	#628100
1A2g	Other	Non-energy and feedstock use; Manufacture of ceramic, stone and clay products	#951550
		Auto power generation; Agriculture, fishery, mining and construction (except for Agriculture, forestry and fishery [#251010-#251040])	#251000
		Auto power generation; Manufacturing (except for the industries listed in 1A1b, 1A1c, 1A2a through 1A2f)	#252000
		Auto steam generation; Agriculture, fishery, mining and construction (except for Agriculture, forestry and fishery [#261010-#261040])	#261000
		Auto steam generation; Manufacturing (except for the industries listed in 1A1b, 1A1c, 1A2a through 1A2f)	#262000
		Final energy consumption; Agriculture, fishery, mining and construction (except for Agriculture, forestry and fishery [#611000])	#610000
		Final energy consumption; Manufacturing (except for the industries listed in 1A1b, 1A1c, 1A2a through 1A2f)	#620000
		Non-energy and feedstock use; Agriculture, fishery, mining and construction (except for agriculture, forestry and fishery)	#951100
		Non-energy and feedstock use; Manufacturing industry, large scale (except for the industries listed in 1A1b, 1A1c, 1A2a through 1A2f)	#951500
		Non-energy and feedstock use; Manufacturing industry, small and medium scale	#951700

Table A 4-23 Correspondence between sectors of General Energy Statistics (Detailed Sector) and of the CRF table 1.A(a) (cont.)

CRF		General Energy Statistics	
1A3	Transport		
1A3a	Domestic aviation	Final energy consumption; Passenger; Air passenger transport	#815000
		Final energy consumption; Freight; Air freight transport	#854000
		Non-energy and feedstock use; Transportation (air)	#953000
1A3b	Road transportation		
i	Cars	Final energy consumption; Passenger; Passenger vehicle	#811000
		Non-energy and feedstock use; Transportation (passenger vehicle)	#953000
ii	Light duty trucks	IE (1A3biii)	-
iii	Heavy duty trucks and buses	Final energy consumption; Passenger; Bus	#811500
		Final energy consumption, Freight; Freight truck and lorry	#851000
		Non-energy and feedstock use; Transportation (bus, freight truck and lorry)	#953000
iv	Motorcycles	Final energy consumption; Passenger; Motorcycles	#812000
		Non-energy and feedstock use; Transportation (Motorcycles)	#953000
v	Other	IE (1A3biii)	-
1A3c	Railways	Final energy consumption; Passenger; Railway passenger transport	#813000
		Final energy consumption; Freight; Railway freight transport	#852000
		Non-energy and feedstock use; Transportation (railways)	#953000
1A3d	Domestic navigation	Final energy consumption; Passenger; Water passenger transport	#814000
		Final energy consumption; Freight; Water freight transport	#853000
		Non-energy and feedstock use; Transportation (water)	#953000
1A3e	Other transportation	NO	-
1A4	Other sectors		
1A4a	Commercial/institutional	Auto power generation (except for Production, transmission and distribution of electricity [#255330] (until 2015), Agriculture, fishery, mining and construction [#251000] and Manufacturing [#252000])	#250000
		Auto steam generation (except for Agriculture, fishery, mining and construction [#261000] and Manufacturing [#262000])	#260000
		Final energy consumption; Commercial industry	#650000
		Non-energy and feedstock use; Commercial	#951800
1A4b	Residential	Final energy consumption; Residential	#700000
		Non-energy and feedstock use; Household	#952000
1A4c	Agriculture/forestry/fishing		
i	Stationary	Auto power generation; Agriculture, fishery, mining and construction (agriculture, forestry and fishery)	#251000
		Auto steam generation; Agriculture, fishery, mining and construction (agriculture, forestry and fishery)	#261000
		Final energy consumption; Agriculture, forestry and fishery [#610000]; stationary sources (estimates)	
		Non-energy and feedstock use; Agriculture, fishery, mining and construction (agriculture, forestry and fishery)	#951100
		Final energy consumption; Agriculture [#611000]; mobile sources (estimates)	
ii	Off-road vehicles and other machinery	Final energy consumption; Forestry [#611200]; mobile sources (estimates)	
		Final energy consumption; Fishery, except aquaculture [#611300]; mobile sources (estimates)	
iii	Fishing	Final energy consumption; Aquaculture [#611400]; mobile sources (estimates)	
1A5	Other	NO	-

Note: #9xxxxx items are subtracted as a Non-energy use activity.

The ERT recommended that Japan provide a table in the NIR mapping the various types of fuels as reported in the energy balance with the corresponding fuels as reported in CRF table 1.A(d) (FCCC/ARR/2014/JPN). Table A 4-24 shows the correspondence of fuels among *General Energy Statistics*, CRF table 1.A(b) 'reference approach' and CRF table 1.A(d) 'non-energy use of fuels'.

Table A 4-24 Correspondence of fuels among *General Energy Statistics*, CRF table 1.A(b) and (d)

Fuel in CRF table 1.A(b) and (d)		Fuel in General Energy Statistics	Code	
Liquid fossil	Primary fuels	Crude oil	Crude oil for refinery use	\$0310
			Crude oil for power generation use	\$0320
		Orimulsion	Bituminous mixture fuel	\$0321
		Natural gas liquids	Natural gas liquid (NGL) & condensate	\$0330
	Secondary fuels	Gasoline	Gasoline	\$0431
		Jet kerosene	Jet fuel oil	\$0432
		Other kerosene	Kerosene	\$0433
		Gas/diesel oil	Gas oil or diesel oil	\$0434
		Residual fuel oil	Fuel oil A	\$0436
			Fuel oil B	\$0438
			Fuel oil C for general use	\$0439
			Fuel oil C for power generation use	\$0440
		Liquefied petroleum gas	Liquefied petroleum gas (LPG)	\$0458
		Naphtha	Pure naphtha	\$0420
			Reformate	\$0421
		Bitumen	Other heavy oil products	\$0452
		Lubricants	Lubricant oil	\$0451
		Petroleum coke	Oil coke	\$0455
		Refinery feedstocks	Slack gasoline	\$0412
			Slack kerosene	\$0413
Slack diesel oil or gas oil	\$0414			
Slack fuel oil	\$0415			
Cracked gasoline	\$0416			
Cracked diesel oil or gas oil	\$0417			
Feedstock oil for refinery and mixing	\$0418			
Other oil	Refinery gas	\$0457		
Solid fossil	Primary fuels	Anthracite	Hard coal, anthracite & lignite	\$0130
		Coking coal	Steel making coal	\$0110
		Other bituminous coal	Imported steam coal for general use	\$0121
			Imported steam coal for power generation use	\$0123
		Sub-bituminous coal	Indigenous produced steam coal	\$0124
	Secondary fuels	BKB and patent fuel	Coal briquette	\$0213
		Coke oven/gas coke	Coke	\$0211
			Coke oven gas	\$0221
			Blast furnace gas	\$0222
			Converter furnace gas	\$0225
Coal tar	Coal tar	\$0212		
Gaseous fossil	Natural gas	Liquefied natural gas (LNG)	\$0510	
		Indigenous natural gas	\$0521	
		Coal mining gas	\$0522	
		Boil off gas from crude oil	\$0523	
		City gas	\$0610	
		Small scale community gas	\$0620	
Biomass	Solid biomass	Woods	\$N131	
		Waste Woods	\$N132	
		Thermal Use of Black Liquor	\$N136	
	Liquid biomass	Bioethanol	\$N134	
		Biodiesel	\$N135	
	Gas biomass	Gas Biomass	\$N137	

### A4.3. Quality Standard for Diesel Oil

The carbon emission factor for liquid fuels (diesel oil) in 1.A.3.b (Road transportation) is the lowest in Annex I Parties for two reasons. One is because the quality standard for diesel oil in Japan is different from other countries. Crude oil with high sulfur content imported from the Middle East must be decomposed and go through ultra-deep desulfurization to become low-sulfur diesel oil (<10 ppm) according to Japanese automobile exhaust gas regulations. The other reason is because gas oil used for purposes other than road transport is called "fuel oil A" to distinguish it from diesel oil. The carbon balance of Japanese petroleum refineries including diesel oil and fuel oil A nearly matches according to statistics, so these carbon emission factors are not irregular.

In the individual review on Japanese greenhouse gas inventory conducted in September 2012, the ERT (Expert Review Team) asked Japan for the possibility of involving the information on Japanese quality standard of diesel oil in the future NIR. In correspondence to the question, Japan has provided the information on Japanese quality requirement of diesel oil mainly used for automobile engine in the Table A 4-25 below. In this standard, the diesel oil is classified into five types based on the pour point difference. Also, the standard meets with the Japanese law "Act on the Quality Control of Gasoline and Other Fuel" as a matter of course.

Table A 4-25 Required quality of diesel oil in Japan

Test item	Unit	Type				
		S1	1	2	3	S3
Flash point	°C	50 or more			45 or more	
90 % distilling temperature	°C	360 or less		350 or less	330 or less <sup>1)</sup>	330 or less
Pour point	°C	+5 or less	-2.5 or less	-7.5 or less	-20 or less	-30 or less
Cold filter plugging point	°C	-	-1 or less	-5 or less	-12 or less	-19 or less
Residual carbon ratio in 10 % residual oil	% in weight	0.1 or less				
Cetane index <sup>2)</sup>	-	50 or more		45 or more		
Kinetic viscosity at 30 °C	mm <sup>2</sup> /s	2.7 or more		2.5 or more	2.0 or more	1.7 or more
Sulfur ratio	% in weight	0.0010 or less				
Density at 15 °C	g/cm <sup>3</sup>	0.86 or less				

1) 350 or less, if the kinetic viscosity at 30 °C is 4.7 mm<sup>2</sup>/s or less.

2) Cetane number is also available for cetane index.

Reference: Japanese Industrial Standards, Diesel Fuel (JIS K 2204:2007)

### A4.4. Conversion factors of calorific values

The ERT recommended that Japan include in the NIR detailed information on the conversion factors used to convert gross calorific values (GCV) to net calorific values (NCV) for all fuels (FCCC/ARR/2014/JPN). For reference, the following table provides the ratio of NCV to GCV, which are derived from GCV and NCV obtained from the standard values of FY2018.

Table A 4-26 Ratio of NCV to GCV for selected fuels (for reference)

Fuel	NCV/GCV	Fuel	NCV/GCV
Coal		Oil	
Imported steel making coal	0.92	Crude oil	0.94
Coking coal	0.92	NGL/condensate	0.94
PCI coal	0.92	Crude Oil - Power Generation Use	0.94
Imported steam coal	0.95	Bituminous Mixture Fuel / Orimulsion	-
Indigenous Produced Steam Coal	0.94	Oil Products	
Imported anthracite	0.97	LPG	0.93
Coal products		Propane	0.93
Coke	0.98	Butane	0.93
Coal Tar	-	Naphtha	0.94
Coke oven gas	0.90	Reformate	0.94
Blast furnace gas	0.98	Gasoline	0.94
Blast Furnace Gas - Power Generation Use	0.98	Premium Gasoline	0.94
Converter furnace gas	1.00	Regular Gasoline	0.94
Combustible natural gas		Jet fuel oil	0.94
Imported natural gas (LNG)	0.91	Jet fuel oil -Gasoline based	0.94
Indigenous natural gas	0.91	Jet fuel oil -Kerosene based	0.94
Imported natural gas (Vaporized LNG)	0.91	Kerosene	0.94
Indigenous Natural Gas	0.91	Diesel oil	0.94
Boil Off Gas from Crude Oil	0.91	Fuel oil A	0.94
City gas	0.91	Fuel oil C	0.95
Direct Supply LPG	0.93	Fuel oil B	0.94
Renewable Energy		Fuel Oil C - Power Generation Use	0.95
Black Liquor	0.87	Lubricants	0.94
Waste Woods	0.90	Other heavy oil products	0.95
Woods	0.95	Asphalt	0.95
Bioethanol	0.91	Petroleum coke	0.98
Biodiesel	0.91	Galvanic Furnace Gas	1.00
Gas Biomass	0.92	Refinery gas	0.92

Reference: Calculated from Agency for Natural Resources and Energy (2020)

## References

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9. Ministry of the Environment, Committee for the Greenhouse Gases Emissions Estimation Methods, *GHGs Estimation Methods Committee Report FY2014*, 2015.
10. Japanese Industrial Standards, Diesel Fuel (JIS K 2204:2007).
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## Annex 5 Assessment of Completeness, Definition of Notation Keys, and Sources and Sinks Reported as “NE”

### A5.1. Assessment of Completeness

Current inventory is submitted in accordance with the common reporting format (CRF), which requires entering emissions/removals data or a notation key such as “NO”, “NE”, or “NA” for all sources. This chapter presents the definition of notation keys and decision trees for the application of them (including applicability criteria of “NE” when the emissions are considered insignificant), both of which are based on the UNFCCC reporting guidelines (Decision 24/CP.19) and the results of Committee for Greenhouse Gases Emissions Estimation Methods in FY2002, 2012, and 2014.

This chapter also indicates classification of emission source categories reported as “NE” into one which are considered insignificant and the other which are not estimated.

### A5.2. Definition of Notation Keys

In Japan, notation keys are used in accordance with UNFCCC reporting guidelines (Decision 24/CP.19). The following table A5-1 indicates definitions of notation keys provided in the UNFCCC reporting guidelines.

Table A 5-1 Definitions of notation keys indicated in UNFCCC reporting guidelines

Notation Key	Explanation
NO (Not Occurring)	“NO” (not occurring) for categories or processes, including recovery, under a particular source or sink category that do not occur within an Annex I Party.
NE (Not Estimated)	“NE” (not estimated) for AD and/or emissions by sources and removals by sinks of GHGs which have not been estimated but for which a corresponding activity may occur within a Party. Where “NE” is used in an inventory to report emissions or removals of CO <sub>2</sub> , N <sub>2</sub> O, CH <sub>4</sub> , HFCs, PFCs, SF <sub>6</sub> and NF <sub>3</sub> , the Annex I Party shall indicate in both the NIR and the CRF completeness table why such emissions or removals have not been estimated. Furthermore, a Party may consider that a disproportionate amount of effort would be required to collect data for a gas from a specific category that would be insignificant in terms of the overall level and trend in national emissions and in such cases use the notation key “NE”. The Party should in the NIR provide justifications for exclusion in terms of the likely level of emissions. An emission should only be considered insignificant if the likely level of emissions is below 0.05 per cent of the national total GHG emissions, and does not exceed 500 kt CO <sub>2</sub> eq. The total national aggregate of estimated emissions for all gases and categories considered insignificant shall remain below 0.1 per cent of the national total GHG emissions. Parties should use approximated AD and default IPCC EFs to derive a likely level of emissions for the respective category. Once emissions from a specific category have been reported in a previous submission, emissions from this specific category shall be reported in subsequent GHG inventory submissions.
NA (Not Applicable)	“NA” (not applicable) for activities under a given source/sink category that do occur within the Party but do not result in emissions or removals of a specific gas. If the cells for categories in the CRF tables for which “NA” is applicable are shaded, they do not need to be filled in.
IE (Included Elsewhere)	“IE” (included elsewhere) for emissions by sources and removals by sinks of GHGs estimated but included elsewhere in the inventory instead of under the expected source/sink category. Where “IE” is used in an inventory, the Annex I Party should indicate, in the CRF completeness table, where in the inventory the emissions or removals for the displaced source/sink category have been included, and the Annex I Party should explain such a deviation from the inclusion under the expected category, especially if it is due to confidentiality.
C (Confidential)	“C” (confidential) for emissions by sources and removals by sinks of GHGs of which the reporting could lead to the disclosure of confidential information, given the provisions of paragraph 36. (Paragraph 36: Emissions and removals should be reported at the most disaggregated level of each source/sink category, taking into account that a minimum level of aggregation may be required to protect confidential business and military information.)

Source : UNFCCC reporting guidelines on annual greenhouse gas inventories (Decision 24/CP.19)

Applicability criteria for “NE” when the emissions are considered insignificant was stipulated by the Committee for the Greenhouse Gas Emissions Estimation Methods in FY2012 and FY2014, as shown in the following decision tree (Figure A5-2).

If the UNFCCC reporting guidelines are revised in the future, the definition of notation keys and the reporting method will be reviewed.

### A5.3. Decision Tree for Application of Notation Keys

Decision tree for the application of notation keys, based on UNFCCC reporting Guidelines (Decision 24/CP.19) and the results of Committee for Greenhouse Gases Emissions Estimation Methods in FY2002, FY2012, and FY2014, is shown in Figure A5-1.

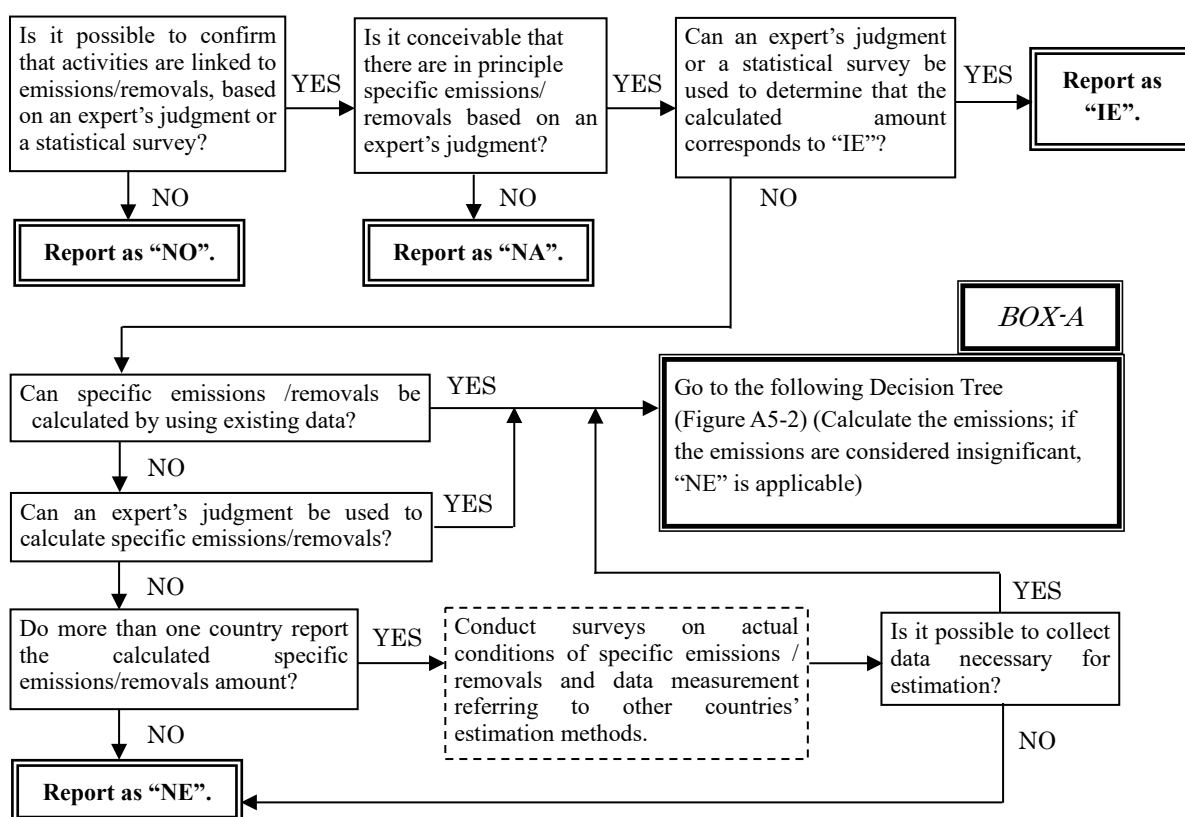


Figure A 5-1 Decision tree for application of notation keys

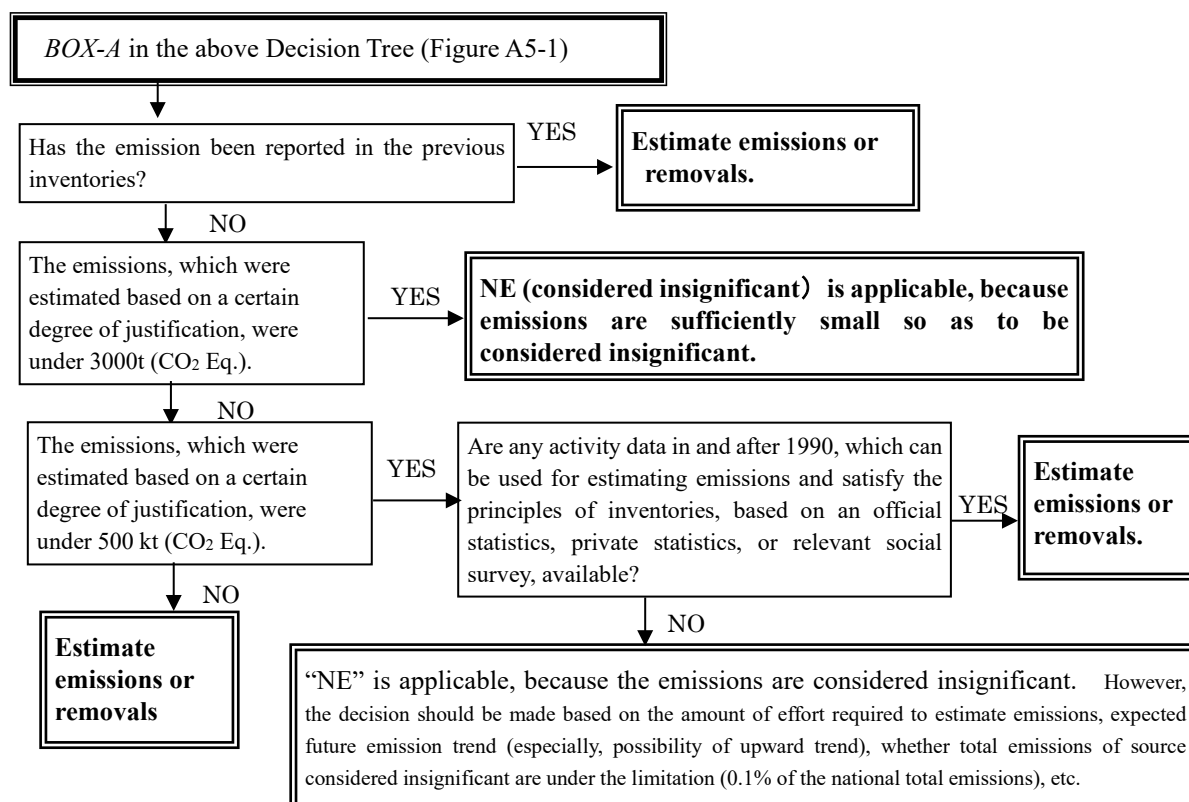


Figure A 5-2 Decision tree for determining applicability of “NE” when the emissions are considered insignificant

When emissions by sources and removals by sinks of GHGs could be confidential information, they are reported as “C”.

#### A5.4. Emission sources reported as “NE” (considered insignificant) in Japan

The notation key NE (considered insignificant) was used for the source/sink categories indicated in the following Table A5-2, because the emissions are sufficiently small so as to be considered insignificant. Since the approximate total amount of emissions from these emission sources (excluding removals) is 123 kt (in CO<sub>2</sub> eq.) at maximum, it is not expected to exceed 0.1% of the national total emissions (approximately 1.15 Mt in CO<sub>2</sub> eq. for Japan), which is stipulated in paragraph 37(b) in the UNFCCC reporting guidelines (Decision 24/CP.19) as the upper limit of applicability of “NE” for being considered insignificant.

Table A 5-2 Emission sources reported as “NE” (considered insignificant)

Code	Category No.	Sector and Category			Gas	Likely Level of Emissions [kt-CO <sub>2</sub> eq]
1	1.C.	Energy	CO <sub>2</sub> transport and storage		CO <sub>2</sub>	<0.007
2	2.C.7	IPPU	Rare Earths Production		CO <sub>2</sub>	<0.6
3	2.C.7	IPPU	Rare Earths Production		PFCs	<0.4
4	2.D.3.	IPPU	NMVOC incineration		CH <sub>4</sub>	<0.2
5	2.D.3.	IPPU	NMVOC incineration		N <sub>2</sub> O	<1
6	2.F.1.	IPPU	Refrigeration and Air Conditioning Equipment	Fugitive emissions from refrigerant containers	HFCs	<63
7	2.F.4.	IPPU	Product uses as substitutes for ODS	Aerosols	HFCs	<1.8
8	2.G.2.	IPPU	SF <sub>6</sub> and PFCs from other product use	Soundproof windows	SF <sub>6</sub>	<0.3
9	3.A.4.-	Agriculture	Enteric Fermentation	Deer	CH <sub>4</sub>	<2.3
10	3.A.4.-	Agriculture	Enteric Fermentation	Alpaca	CH <sub>4</sub>	<0.07
11	3.B.4.-	Agriculture	Manure Management	Deer	CH <sub>4</sub>	<0.03
12	3.B.4.-	Agriculture	Manure Management	Reindeer	CH <sub>4</sub>	<0.01
13	3.B.4.-	Agriculture	Manure Management	Silver Fox	CH <sub>4</sub>	<0.04
14	3.B.4.-	Agriculture	Manure Management	Other Poultry (Duck, Turkey, Quail, Goose, Guinea Fowl, Pheasant)	CH <sub>4</sub>	<0.8
15	3.B.4.-	Agriculture	Manure Management	Deer	N <sub>2</sub> O	<0.6
16	3.B.4.-	Agriculture	Manure Management	Reindeer	N <sub>2</sub> O	<0.02
17	3.B.4.-	Agriculture	Manure Management	Silver Fox	N <sub>2</sub> O	<0.01
18	3.B.4.-	Agriculture	Manure Management	Other Poultry (Duck, Turkey, Quail, Goose, Guinea Fowl, Pheasant)	N <sub>2</sub> O	<0.3
19	4.D.	LULUCF	Wetlands	Peat extraction	CO <sub>2</sub>	<50
20	4.D.	LULUCF	Wetlands	Biomass Burning	CH <sub>4</sub>	<0.14
21	4.D.	LULUCF	Wetlands	Biomass Burning	N <sub>2</sub> O	<0.16
22	5.B.2	Waste	Anaerobic digestion at biogas facilities		CH <sub>4</sub>	<1.4
<b>Total</b>						<b>&lt;123</b>

Note: Maximum possible amount of emissions between FY 1990 and the latest year, under certain assumptions and based on simple estimation methods such as Tier 1

### A5.5. Source and sink categories not estimated in Japan’s inventory

The following table A5-3 indicates source and sink categories which were not estimated, excluding “NE” applicable categories for being “considered insignificant” as described above.

Table A 5-3 Source and sink categories which were not estimated in Japan’s inventory

Code	Sector	Source and sink category				GHG
1	Energy	Fuel Combustion, Transportaion	Liquid Fuels	Domestic Aviation	Cruise	CH <sub>4</sub>
2	Energy	Fuel Combustion	Liquid Fuels	Lubricants		CH <sub>4</sub>
3	Energy	Fuel Combustion	Liquid Fuels	Lubricants		N <sub>2</sub> O
4	Energy	Fugitive Emissions from Fuels	Solid Fuels	Coal Mining and Handling	Recovery/Flaring	CH <sub>4</sub>
5	Energy	Fugitive Emissions from Fuels	Solid Fuels	Others (Uncontrollable Combustion)		CO <sub>2</sub>
6	Energy	Fugitive Emissions from Fuels	Oil and Natural Gas	Oil	Refining/Storage	CO <sub>2</sub>
7	Energy	Fugitive Emissions from Fuels	Oil and Natural Gas	Oil	Distribution of Oil Products	CO <sub>2</sub>
8	Energy	Fugitive Emissions from Fuels	Oil and Natural Gas	Oil	Distribution of Oil Products	CH <sub>4</sub>
9	IPPU	Chemical Industry	Ammonia Production			CH <sub>4</sub>
10	LULUCF	Wetlands	Wetlands remaining Wetlands	Flooded land	Living Biomass	Carbon Stock Change
11	LULUCF	Wetlands	Wetlands remaining Wetlands	Flooded land	Dead Organic Matter	Carbon Stock Change
12	LULUCF	Wetlands	Wetlands remaining Wetlands	Flooded land	Soil	Carbon Stock Change
13	LULUCF	Wetlands	Land converted to Wetlands	Cropland converted to Wetlands	Soil	Carbon Stock Change
14	LULUCF	Wetlands	Land converted to Wetlands	Grassland converted to Wetlands	Soil	Carbon Stock Change
15	LULUCF	Wetlands	Land converted to Wetlands	Settlements converted to Wetlands	Soil	Carbon Stock Change
16	LULUCF	Wetlands	Land converted to Wetlands	Other Land converted to Wetlands	Soil	Carbon Stock Change
17	LULUCF	Settlements	Settlements remaining Settlements	Other than Urban Green Areas	Living Biomass	Carbon Stock Change
18	LULUCF	Settlements	Settlements remaining Settlements	Other than Urban Green Areas	Dead Organic Matter	Carbon Stock Change
19	LULUCF	Settlements	Settlements remaining Settlements	Other than Urban Green Areas	Soil	Carbon Stock Change
20	LULUCF	Settlements	Settlements remaining Settlements	Urban Green Areas not subject to RV	Dead Organic Matter	Carbon Stock Change
21	LULUCF	Settlements	Settlements remaining Settlements	Urban Green Areas not subject to RV	Soil	Carbon Stock Change

## Annex 6. Hierarchical Structure of Japan's National GHG Inventory File System

Multiple MS Excel files have been used when estimating the Japanese inventory. The explanation of each MS Excel file and the hierarchical structure of the Japanese National GHGs Inventory (JNGI) file system are shown below.

Table A6-1 Explanation of each MS Excel file

Category	Excel file name	Contents
	JPN 20xx 1990 - JPN 20xx 20yy	Common reporting format generated by CRF reporter
1. Energy	1A-L3-CO2-1990-20xx - 1A-L3-CO2-20yy-20xx	CO <sub>2</sub> emissions from fuel combustions
	1A-L3-CRF-20xx	CRF format data of GHG emissions from fuel combustion (including emissions by energy use of waste)
	1A-L3-timeseries-20xx	Time-series data of GHG emissions from fuel combustion
	1A-L2-MAP EB-1990-20xx - 1A-L2-MAP EB-20yy-20xx	Activity Data for furnaces
	1A-L3-Biomass-20xx	GHG emissions from biomass combustion
	1A-L3-CO-20xx	CO emissions from furnace and off-road vehicle
	1A-L3-HC-20xx	CH <sub>4</sub> , NMVOC emissions from furnace and off-road vehicle
	1A-L3-N2O-20xx	N <sub>2</sub> O emissions from furnace and off-road vehicle
	1A-L3-NOxSO2-20xx	NO <sub>x</sub> , SO <sub>2</sub> emissions from fuel combustion (except transport sector)
	1A-L2-nonCO2-ADEF-20xx	Activity Data and Emission Factors of Non-CO <sub>2</sub> from fuel combustion (except transport sector)
	1A-L2-NOxSO2-ADEF-20xx	Activity Data and Emission Factors of NO <sub>x</sub> , SO <sub>2</sub> from fuel combustion (except transport sector)
	1A-L3-Lub-20xx	CO <sub>2</sub> emissions from lubricant
	1A-L2-EBEF-20xx	Emission Factors for CO <sub>2</sub> from fuel combustion
	1A-L1-EB-20xx	Data of the General Energy Statistics using in categories other than stationary combustion
	1A3-L3-CH4N2O-20xx	GHG emissions from Mobile Combustion (transport sector) (except CO <sub>2</sub> )
	1A3-L2-ADEF-20xx	Activity Data and Emission Factors for Mobile Combustion (transport sector)
	1A3-L2-2wADEF-20xx	Activity Data and Emission Factors for Motorcycles
	1B-L3-20xx	Fugitive GHG emissions from fuels
	1B-L2-ADEF-20xx	Activity Data and Emission Factors for Fugitive Emissions from Fuels
	2. Industrial processes and other product use (IPPU)	2-L2-ADEF-20xx
2-L3-20xx		GHG emissions from Sector 2 (IPPU) (except F-gases)
2-L3-Fgas-20xx		F-gas (HFCs, PFCs, SF <sub>6</sub> , NF <sub>3</sub> ) emissions
2-L3-NMVOC-20xx		NMVOC emissions from Sector 2 (IPPU)
2-L2-NMVOC-20xx		AD and EF for NMVOC emissions from Sector 2 (IPPU)
3. Agriculture	3A-L3-CH4-20xx	CH <sub>4</sub> emissions from enteric fermentation
	3B-L3-CH4N2O-20xx	GHG emissions from manure management
	3C-L3-CH4-20xx	CH <sub>4</sub> emissions from rice cultivation
	3D-L3-N2O-20xx	N <sub>2</sub> O emissions from agricultural soils
	3F-L3-CH4N2OCO-20xx	GHG emissions from field burning of agricultural residues
	3GH-L3-CO2-20xx	CO <sub>2</sub> emissions from lime application and urine application to agricultural soil
	3-L2-ADEF-20xx	Activity Data and Emission Factors of Sector 3 (Agriculture)
	3AB-L2-EF-20xx	Emission factors of livestock
	4-L3-nonCSC-20xx	GHG emissions excluding carbon stock change
4. LULUCF	4-L3-4A-CO2-20xx	CO <sub>2</sub> emissions and removals from forest land
	4-L3-4B-CO2-20xx	CO <sub>2</sub> emissions and removals from cropland
	4-L3-4C-CO2-20xx	CO <sub>2</sub> emissions and removals from grassland
	4-L3-4D-CO2-20xx	CO <sub>2</sub> emissions and removals from wetlands
	4-L3-4E-CO2-20xx	CO <sub>2</sub> emissions and removals from settlements
	4-L3-4F-CO2-20xx	CO <sub>2</sub> emissions and removals from other land
	4-L3-4G-CO2-20xx	CO <sub>2</sub> emissions and removals from HWP
	4-L2-Area(Pref)-20xx	Area of mineral and organic soils
	4-L2-LandArea-20xx	Land area for each land use category
	4-L2-LandArea-Matrix-20xx	Land-use matrix
	4-L2-Orchard-20xx	Carbon stock changes in orchard
	4-L2-Parameter-20xx	Parameters for each land use category
	4-L2-Soil-20xx	Land area and carbon stock changes in cropland and grassland
	4-L2-Biochar-20xx	Organic carbon stocks from biochar amendments in mineral soil in cropland
5. Waste	5A-L3-20xx	GHG emissions from solid waste disposal
	5A-L2-AD-20xx	Activity data of solid waste disposal (managed disposal site)
	5A3-L2-AD-20xx	Activity data of solid waste disposal (other)
	5B-L3-20xx	GHG emissions from biological treatment of solid waste
	5B-L2-AD-20xx	Activity data of biological treatment of solid waste
	5C-L3-20xx	GHG emissions from incineration and open burning of waste
	5C-L3-Energy-20xx	GHG emissions from waste incineration and energy use (reported in the energy sector)
	5C-L2-AD-20xx	Activity data of incineration and open burning of waste
	5D-L3-20xx	GHG emissions from waste water treatment and discharge
	5D-L2-AD-20xx	Activity data of waste water treatment and discharge
	5E-L3-20xx	GHG emissions from other
	5E-L2-AD-20xx	Activity data of other
	5-L2-EF-20xx	Emission factors of Sector 5 (Waste)
	6. Other	6-L3-20xx
7. Indirect CO <sub>2</sub>	7-L3-Indirect CO2-20xx	Indirect CO <sub>2</sub> emissions
Memo item	1D-L3-bunker-20xx	GHG emissions from international bunker fuels
KP-LULUCF	4KP-3-Summary-20xx	GHG emissions and removals from KP3.3 and 3.4 activities
	4KP-2-AR-20xx	GHG emissions and removals from Afforestation/Reforestation
	4KP-2-CM-20xx	GHG emissions and removals from Cropland Management
	4KP-2-D-20xx	GHG emissions and removals from Deforestation
	4KP-2-FM-20xx	GHG emissions and removals from Forest Management
	4KP-2-HWP-20xx	CO <sub>2</sub> emissions and removals from HWP in Forest Management
	4KP-2-GM-20xx	GHG emissions and removals from Grazing Land Management
	4KP-2-RV-20xx	GHG emissions and removals from Revegetation

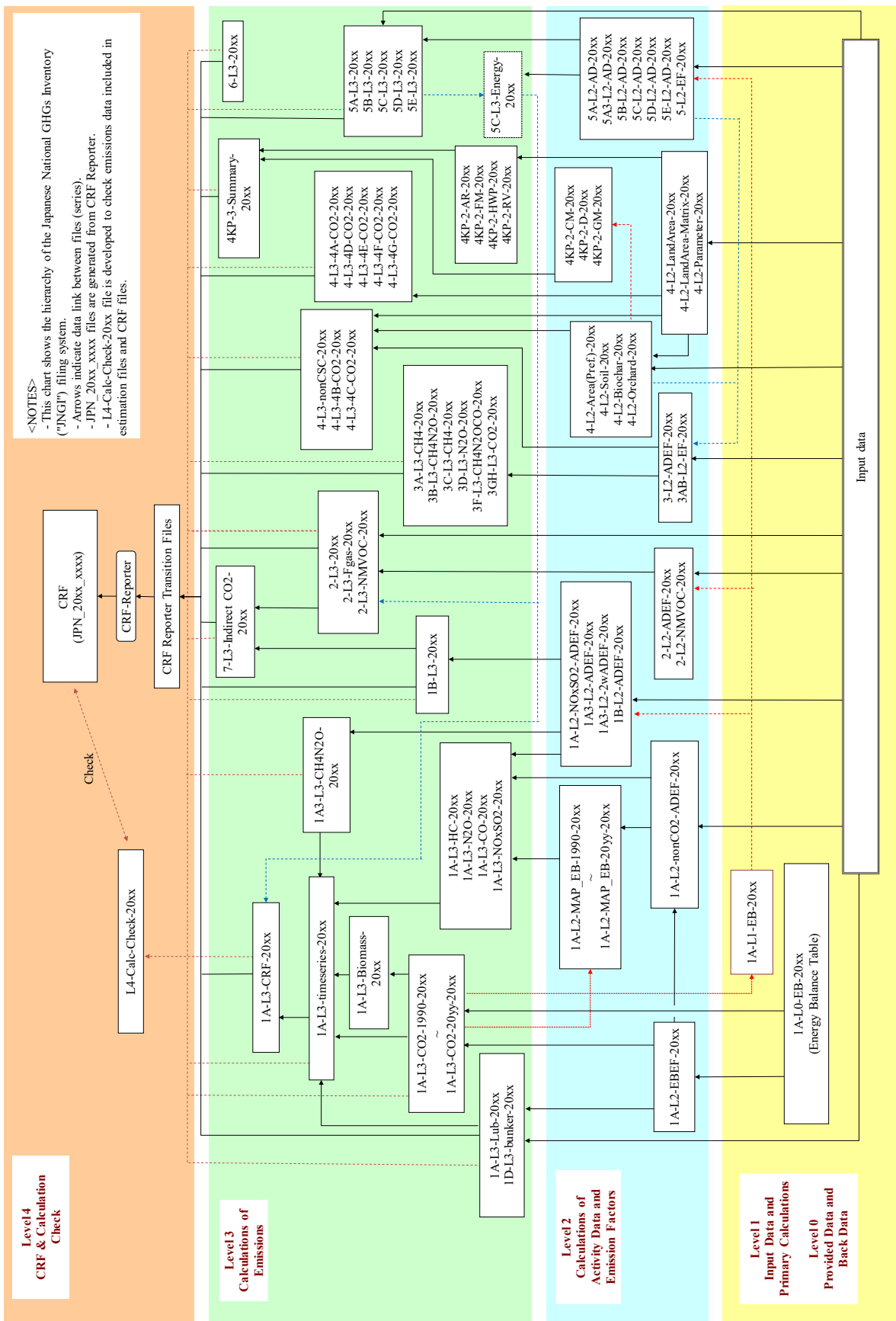


Figure A 6-1 Hierarchical structure of Japan's National GHG Inventory File System

## Abbreviations

### 1. Greenhouse Gases

Table AB-1 Greenhouse Gases

Term	Gas
CO <sub>2</sub>	Carbon dioxide
CH <sub>4</sub>	Methane
N <sub>2</sub> O	Nitrous oxide
HFCs	Hydrofluorocarbons
PFCs	Perfluorocarbons
SF <sub>6</sub>	Sulfur hexafluoride
NF <sub>3</sub>	Nitrogen trifluoride

Table AB-2 Precursors and SO<sub>x</sub>

Term	Gas
NO <sub>x</sub>	Nitrogen oxides
CO	Carbon monoxide
NMVOOC	Non-methane volatile organic compounds
SO <sub>x</sub>	Sulfur oxide

### 2. Prefixes and Units

Table AB-3 Prefixes

Term	Prefix	Definition
P	peta	10 <sup>15</sup>
T	tera	10 <sup>12</sup>
G	giga	10 <sup>9</sup>
M	mega	10 <sup>6</sup>
k	kilo	10 <sup>3</sup>
h	hecto	10 <sup>2</sup>
da	deca	10 <sup>1</sup>
d	deci	10 <sup>-1</sup>
c	centi	10 <sup>-2</sup>
m	milli	10 <sup>-3</sup>
μ	micro	10 <sup>-6</sup>

Table AB-4 Units

Term	Definition
m <sup>3</sup>	cubic metre
L	litter
a	are
ha	hectare
g	gram
t	tonne
J	joule
°C	degree Celsius
yr	year
cap	capita
d.m.	dry matter

### 3. Notation Keys

Table AB-5 Notation keys (See Annex 5 for details)

Notation Key	Definition
NO	Not Occurring
NE	Not Estimated
NA	Not Applicable
IE	Included Elsewhere
C	Confidential



## 4. Other Abbreviations

Table AB-6 Abbreviations

	Terms	Definition	
A	AAU	Assigned Amount Units	
	AD	Activity Data	
	ARD	Afforestation, Reforestation and Deforestation	
B	BFG	Blast Furnace Gas	
	BOD	Biochemical Oxygen Demand	
C	CFG	Converter Furnace Gas	
	CGER	Center for Global Environmental Research	
	CM	Cropland Management	
	CO <sub>2</sub> eq.	Gas Emission in CO <sub>2</sub> equivalent	
	COD	Chemical Oxygen Demand	
	COG	Coke Oven Gas	
	CRF	Common Reporting Format	
	CS-EF	Country-Specific Emission Factor	
	CY	Calendar Year	
E	EEA	European Environment Agency	
	EF	Emission Factor	
	EMEP	European Monitoring and Evaluation Programme	
F	FM	Forest Management	
	FY	Fiscal Year	
G	GCV	Gross Calorific Value	
	GHG	Greenhouse Gas	
	GIO	Greenhouse Gas Inventory Office	
	GM	Grazing Land Management	
	GPG	Good Practice Guidance	
	GPG (2000)	Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (2000)	
	GPG-LULUCF	Good Practice Guidance for Land Use, Land-Use Change and Forestry	
	GWP	Global Warming Potential	
	I	IEA	International Energy Agency
		IEF	Implied Emission Factor
	IPCC	Intergovernmental Panel on Climate Change	
J	JNGI	Japanese National GHG Inventory	
K	KP	Kyoto Protocol	
L	LNG	Liquefied Natural Gas	
	LPG	Liquefied Petroleum Gas	
	LTO	Landing and Take-off	
	LULUCF	Land Use, Land-Use Change and Forestry	
M	MAFF	Ministry of Agriculture, Forestry and Fisheries	
	MDI	Metered Dose Inhalers	
	METI	Ministry of Economy, Trade and Industry	
	MOE	Ministry of the Environment	
	MIC	Ministry of Internal Affairs and Communications	
	MLIT	Ministry of Land, Infrastructure and Transport and Tourism	
	MSW	Municipal Solid Waste	
	N	NCV	Net Calorific Value
NFRDB		National Forest Resource Data Base	
NGL		Natural Gas Liquids	
NIES		National Institute for Environmental Studies	
NIR		National Inventory Report	
Q	QA/QC	Quality Assurance / Quality Control	
	QAWG	Quality Assurance Working Group	

Table AB-6 Abbreviations (Continued)

	Terms	Definition
R	RDF	Refuse Derived Fuel
	RPF	Refuse Paper and Plastic Fuel
	RV	Revegetation
S	SEF	Standard Electronic Format
T	THC	Total Hydrocarbon
U	UNFCCC	United Nations Framework Convention on Climate Change