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LATEST UPDATE ON ENVIRONMENTAL EMERGENCY RESEARCH

environmental renovation-based reconstruction and community development that leverages local resources

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About the theme of this issue - environmental renovation-based reconstruction and community development that leverages local resources

1. Introduction

In the years following the Great East Japan Earthquake (GEJE) of 2011, various initiatives have been taken to tackle housing infrastructure, radiation protection, and other disaster-related restoration and reconstruction issues. However, many areas affected by the GEJE were already facing issues such as population decline and de-industrialization even before the disaster struck. The subsequent evacuation of local residents and suspension of business activities as a result of the disaster only exacerbated these issues, creating very tough circumstances for reconstruction efforts. (→ See Addendum at the end of this issue for institutional background.)

From the perspective of population composition and industrial structure, the creation of sustainable communities is vital to the reconstruction of affected areas. This requires an integrated approach to the reconstruction of local communities that encompasses the natural environment as well as socio-economic aspects, since nature and society are interrelated, and both need to be considered to resolve issues. These issues include, for example, increasingly serious damage by wildlife as a result of declining use and management of the natural environment, the loss of tourism resources as a result of scenic degradation, and increasing inefficiency of waste management systems owing to population decline; hence, we consider community development focused on environmental policy to be vital to reconstruction.

2. The value of environmental renovation-based reconstruction community development —an approach focused on energy resources

In post-disaster reconstruction, tackling local issues that were manifest before the disaster is essential to creating a more sustainable community. In other words, we should aim not to merely restore a community to its pre-disaster state, but rather to leverage local resources and advanced technology to create a community with greater vitality than before. To this end, the National Institute for Environmental Studies (NIES) has proposed environmental renovation-based community development as an approach to local development that generates new value by prioritizing low carbon technology, resource recycling, and other measures that benefit the environment (Togawa et al. 2017: 9). If the area in question is a disaster-affected area, we use the term "environmental renovation-based reconstruction community development" (Figure 1). This could also be interpreted as an embodiment of the concept of the "Regional and Circular Ecological Sphere" proposed in Japan's Fifth Basic Environment Plan whereby individual regions endeavor to resolve environmental, economic and social issues and maximize their potential by making the most of local resources to build decentralized, self-reliant communities that also support each other.

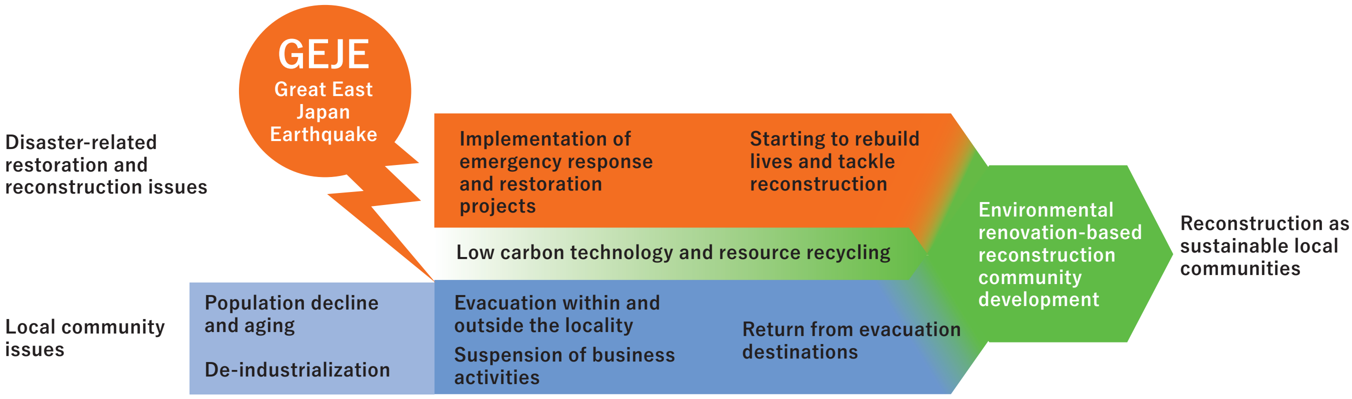

Figure 1. Environmental renovation-based reconstruction community development in disaster-stricken areas

In recent years, energy resources have attracted increasing attention as local resources for promoting sustainable community development. Since the Fukushima Daiichi Nuclear Power Plant accident, Japan's government has been promoting renewable energy in addition to its goals of creating a low-carbon society, resource recycling, and coexistence with nature. In March 2012, Fukushima Prefecture, the prefecture most affected by the nuclear power plant accident, announced the Fukushima Prefecture Vision for Promoting Renewable Energy. The vision set the ambitious targets of supplying about 40% of primary energy demand in Fukushima Prefecture from renewable energy by 2020, and 100% by around 2040.

In conjunction with such central and local government initiatives, various businesses and research institutes with funds, technology and R&D capabilities have since the accident joined this effort to supply Fukushima Prefecture with renewable energy; these organizations are increasing their cooperation (Kuji 2016: 30-46) on achieving this goal. Local companies with diverse technologies and expertise have also established a council for promoting efforts to supply renewable energy, and local industrial organizations are working with outside organizations to drive renewable energy business. For example, in the Shirakawa region of Fukushima Prefecture, the Shirakawa Renewable Energy Promotion Council established in January 2012 is involved in solar and biomass power generation projects with the participation of construction and various other companies (Ohira 2018: 254–255).

In the affected areas, local residents, local governments, and experts are working together to identify and evaluate various resources that have always been a part of the nature and culture of the local community. These resources can hopefully be put to use in long-term local community development. Environmental renovation-based reconstruction community development that utilizes local energy resources requires the involvement of local governments, businesses, residents, research institutions, and various other organizations and people. As such, it can be regarded as sustainable local development that provides both environmental benefits such as the reduction or elimination of GHG emissions, and socio-economic benefits such as the nurturing of local community ties and creation of jobs and industries.

The use of local energy resources to build self-supporting and distributed energy systems that balance supply and demand within the local community also boosts the disaster resilience of such communities.[1] Major disasters such as the GEJE and the 2018 Hokkaido Eastern Iburi Earthquake have made people aware of the risk of power

[1] The Fifth Strategic Energy Plan approved by the cabinet on July 3, 2018 states on pg. 16 that "effectively utilizing the energy resources present in the regions to build an independent and distributed energy system leads to the economic revitalization of the regions and their greater resilience including disaster management, etc."

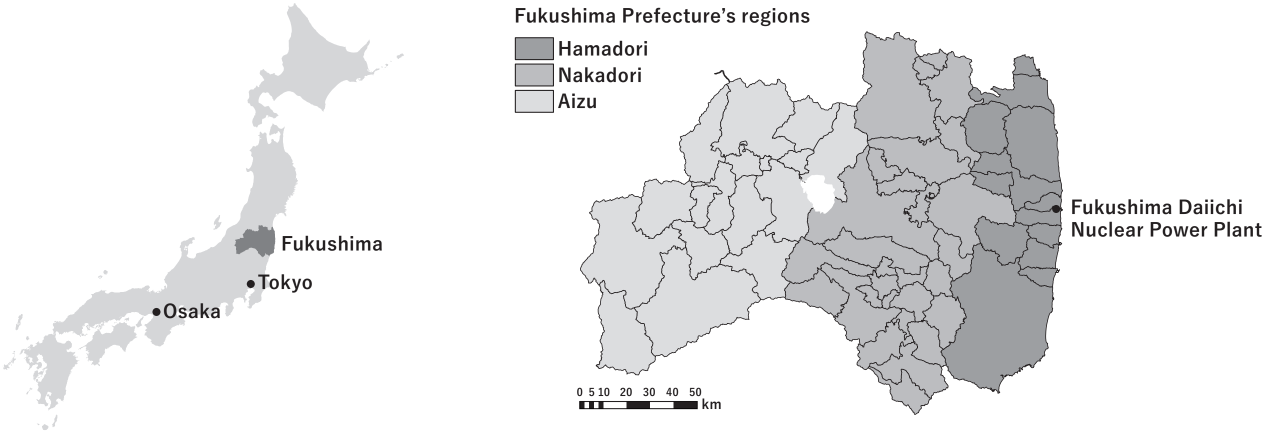

Figure 2. Fukushima Prefecture's location and regions

outages and brownouts posed by centralized large-scale energy systems based on large power plants. For such reasons, implementing environmental renovation-based reconstruction community development that leverages local energy resources in disaster-stricken areas such as Fukushima is meaningful in many different ways.

3. Research on environmental renovation-based reconstruction community development based on local issues

As stated above, environmental renovation-based reconstruction community development involves the participation of various organizations and people with their respective positions. For this reason, such stakeholders need to share information and views on the availability and business potential of local resources and other relevant topics but doing so is not easy. An effective methodology for achieving this end would be to accurately present the interrelationships between people, resources, businesses and other elements within and outside the locality in a way that enables the circumstances of the locality to be understood objectively from environmental, economic and social perspectives.

Based on its understanding of the above issues, NIES Fukushima Branch is supporting environmental renovation-based reconstruction community development that leverages local energy resources by conducting research on forecasting energy resource use in Fukushima Prefecture and on developing local sites that use local energy resources. We are focusing in particular on the reconstruction status of the three regions of Hamadori, Nakadori and Aizu and the differing needs of their respective inhabitants (Figure 2). Taking forest resources as an example, radioactive contamination associated with the nuclear accident has had particularly serious impacts in Hamadori, as a result of which utilization of the region's forest resources has been hampered by difficulties in monitoring radiation levels and providing information on radioactivity and radiation to local residents. In the Nakadori and Aizu regions, however, the impact of such radioactive contamination has been relatively small; local governments, forest owners' cooperatives, local businesses, and other stakeholders have come together to start looking into biomass power generation and other ways of utilizing forest resources. Where research on forestry resource utilization is concerned, ensuring safety and providing appropriate information to local residents are the main issues in the Hamadori region, whereas in the Nakadori and Aizu regions, our research is focused more on ascertaining resource availability and the economic feasibility of power generation projects from a scientific perspective.

Example	Shinchi Town	Mishima Town	Koriyama City
Article	1・3	2・4	3
Fukushima Prefecture's regions	Hamadori	Aizu	Nakadori
Population 2010 National Census	8,224	1,926	338,712
Percentage of workers by industry 2010 National Census	Primary industry 13.1% Secondary industry 34.3% Tertiary industry 51.3%	Primary industry ：13.6% Secondary industry ：28.0% Tertiary industry ：57.7%	Primary industry ：3.6% Secondary industry ：23.8% Tertiary industry ：68.9%
Air dose rate Environmental radioactivity measurement results in northern Fukushima Prefecture（Provisional value ・1st time)※2011.4.1	0.43μSv/h Shinchi Town Hall	0.15μSv/h Miharu Town Hall	2.14μSv/h Koriyama City Hall

Table 1. The target regions of articles in this issue

We believe that gathering information on the needs of various people who are active in disaster-stricken areas through collaboration with local governments, businesses, and residents is a vital part of research on environmental renovation-based reconstruction community development. A solid understanding of people's needs also enables us to better utilize and apply the results of our research to resolving the issues faced by people in the affected areas. To this end, NIES Fukushima Branch has collaborated with the local governments shown in Table 1 to conduct research on environmental renovation-based reconstruction community development grounded in the communities of the affected areas. In this issue, we report on the results of the research that we are conducting with these local governments.

We will promote environmental renovation-based reconstruction community development by ascertaining the current circumstances (potential) of each region and formulating projects and plans in line with those circumstances. As we proceed from planning to implementation, we will predict and evaluate the degree to which a particular project or plan is producing desired results from the perspective of environmental renovation and examine the details of the project or plan accordingly. During this process, we will communicate with various local stakeholders to cultivate mutual understanding (Figure 3).

Articles 1 and 2 present examples of this entire process. Article 1 concerns the process and methods being pursued by NIES in collaboration with local authorities and businesses in the town of Shinchi in Fukushima Prefecture, a municipality that was extensively damaged by the GEJE tsunami. Article 2 concerns the research on wood biomass utilization being pursued by NIES in the town of Mishima in cooperation with the local government, businesses and various other organizations. Articles 3 and 4 introduce our research on simulation and evaluation technologies being used in environmental renovation-based reconstruction community development. Article 3 concerns research to examine the future of local communities through simulations that use the regional integrated assessment model being developed by NIES. Article 4 presents the results of research on the feasibility of deploying distributed energy systems.

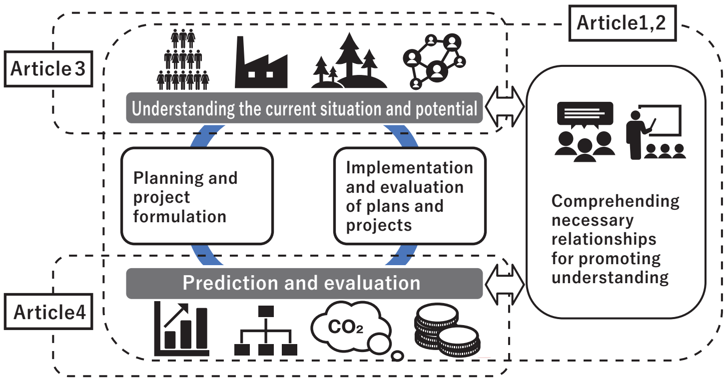

Figure 3. Fukushima Prefecture's location and regions

4. Conclusion

In this issue, we have focused on the outcomes of post-disaster reconstruction that utilizes local energy resources. Although not covered in this issue, NIES has also commenced research to support environmental renovation-based reconstruction community development in the Hamadori region of Fukushima Prefecture, particularly in the former evacuation order zones.

The evacuation of residents from this zone has caused serious population decline and de-industrialization, problems that can hopefully be addressed by establishing new industries that make use of local resources, especially local energy resources. We will continue to pursue research in close association with local communities based on the results of existing research on environmental renovation-based community development.

5. References

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Research on environmentally sustainable community energy supply in Fukushima Prefecture

Highlights of this research

1 We are leveraging knowledge regarding ICT and community energy systems to support environmentally sustainable reconstruction community development in the town of Shinchi.

2 We analyzed residential energy consumption using data collected by electricity consumption meters installed in homes in Shinchi.

3 We are providing planning assistance for the deployment of a community energy supply system in the environs of Shinchi Station and developing technologies for advanced energy supply and demand management.

1 History of reconstruction community development and research in collaboration with the local community in Shinchi

For rethinking energy supply and consumption, 2011 was an important year. Shinchi, a town with a population of about 8000 in the northern extremity of Fukushima Prefecture on the border with Miyagi Prefecture, suffered extensive damage when about 20% of its area was inundated by the tsunami caused by the GEJE. In the process of reconstruction, Shinchi was selected in December 2011 for the Cabinet Office's "Future City" initiative. The Future City initiative aims to connect local residents, local governments, research institutes, and private businesses through two-way information networks and build prototype work and domestic life community platforms for sharing information on the local environment and everyday life.

Soma LNG terminal has been constructed in the Soma Port No. 4 Pier district of the town, and a pipeline to transport LNG to Sendai is planned. Another issue is whether new industries established in conjunction with reconstruction are environmentally sustainable.

NIES has been conducting environmental emergency research in Shinchi since immediately after the GEJE, and opened discussions in June 2012 on cooperating with the town to support its environmentally sustainable reconstruction. In March 2013, Shinchi Town and NIES signed a basic agreement on cooperation, and NIES has since then continued to support environmentally sustainable local development in Shinchi. As part of this initiative, NIES has worked with Shinchi Town to install energy consumption monitoring systems in residents' homes, public facilities, commercial facilities and elsewhere.

This article presents the results of our research on energy consumption monitoring in households in Shinchi and explains our research on a community energy system that takes into account the nearby presence of an LNG terminal.

2 Analysis of residential energy consumption by electricity consumption monitoring

In this section, we present some of the results of our analysis of residential electricity consumption monitoring data obtained from the Living Assist System, an information system being developed by NIES, as basic information for examining community energy conservation measures and efficient energy supply. Since the individual data vary widely, we have aggregated it here by season (Figure 1). These results show clearly that no matter what the season, electricity consumption tends to rise in the morning and evening. This reflects the times of day in which residents are most active within their households. There is also a small peak around noon, which is thought to reflect the use of induction cookers and microwave ovens at lunch time. Comparing the average for all households by season (Figure 1a), electricity consumption shows a big peak in winter that is characteristic of households in cold regions. Comparing summer and intermediate seasons, during the daytime to evening when air conditioner use tends to rise, electricity consumption is higher in summer, but is much the same in summer as for intermediate seasons from late night to early morning. Looking at only all-electric homes (Figure 1b), results showed that electricity consumption was particularly high in the early morning in winter compared to the average for all households (Figure 1a). This is because early morning in winter is when electric water heaters and thermal storage heating systems are usually in operation. Comparing summer and intermediate seasons, power consumption in all-electric homes is, as could be expected, higher in summer during the daytime to evening owing to increased use of air conditioning but is higher in intermediate seasons from late night to early morning. This is because the temperature of the water before being heated affects electricity consumption during the hours in which electric water heaters normally operate.

Comparing weekdays and holidays (Figures 1c and 1d), electricity consumption on weekdays peaks prominently at around 6 am and then declines sharply until around 9 am, but on holidays, this tendency is on the whole less conspicuous. This too reflects the lifestyle of the residents. Going forward, we plan to analyze such differences in electricity consumption patterns according to household, equipment, season, and time of day in even greater detail, applying results to community energy project equipment design and operation planning, and assessment of renewable energy deployment potential.

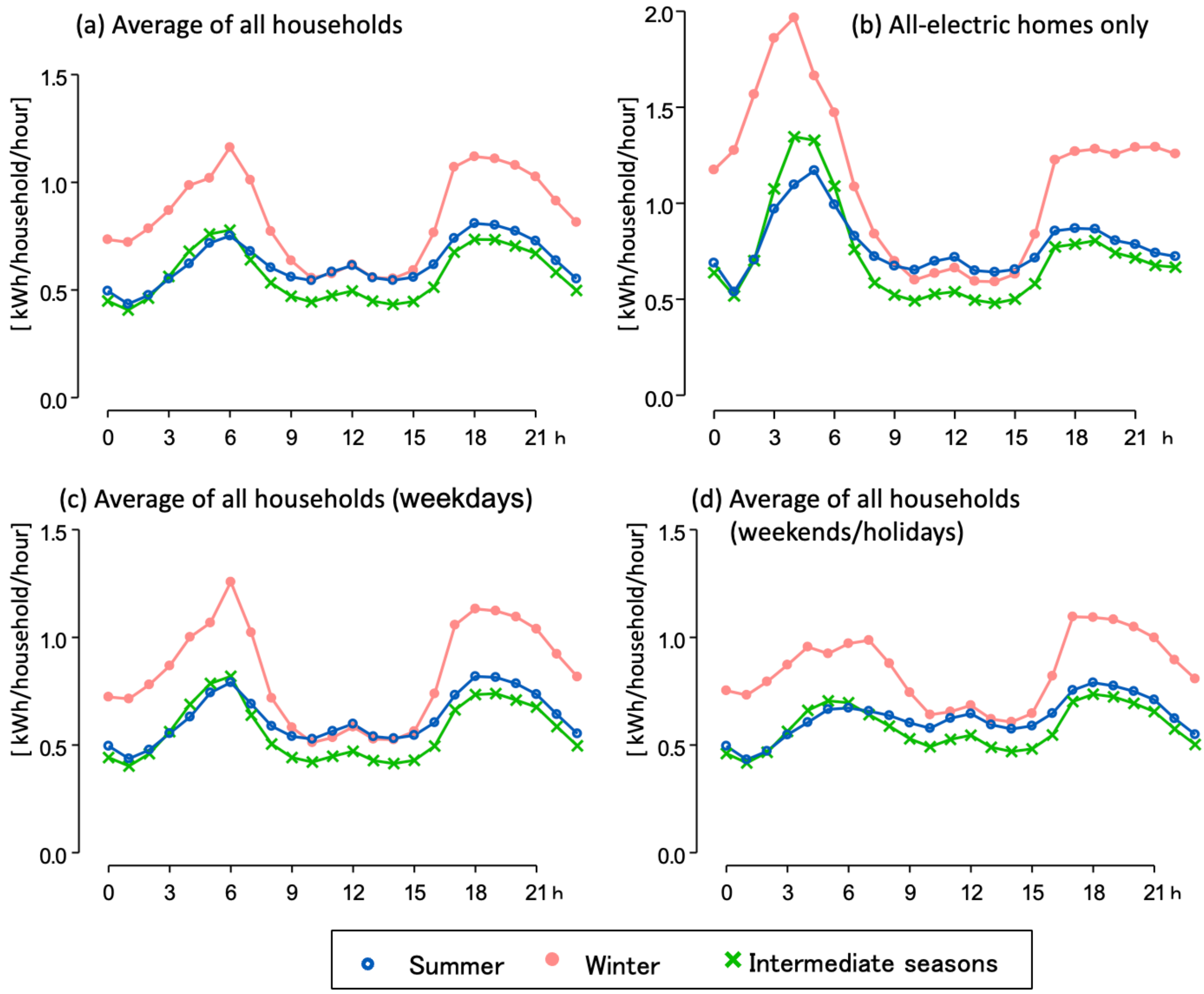
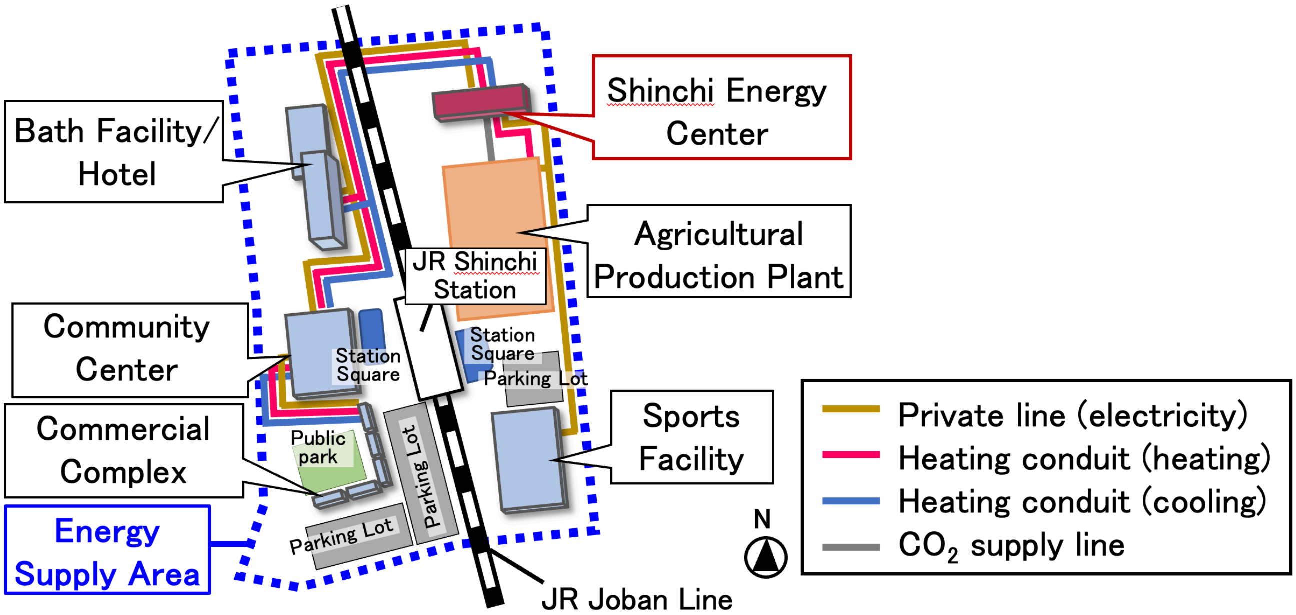


Figure 1.24-hour electricity consumption patterns according to season as revealed by electricity consumption monitoring

3 Establishing community energy supply projects

We have been working with Shinchi Town to analyze energy supply and demand and are finally ready to embark on implementation. As part of the reconstruction of the tsunami-damaged environs of JR Shinchi Station, preparations are currently underway for the launch of a high-efficiency community energy supply project for which NIES has provided planning assistance (Figure 2). Under this project, a Community Energy Center newly constructed northeast of JR Shinchi Station (Figure 3) will supply power and thermal energy to surrounding buildings. The Center, which will house a cogeneration system that uses waste heat from electricity generation as heat for heating and hot water supply (Figure 3b) and an absorption chiller (Genelink) that uses waste heat to chill water for air conditioning (Figure 3c), will enable high-efficiency energy management in response to demand for electricity and heat.

In conjunction with this project, we are working with Shinchi Smart Energy Corporation, which was established to manage this community energy supply system, to simultaneously develop further technologies. For example, we are carrying out new R&D to contribute to the local community, including research on measures for automatic control of equipment and deployment of renewable energy, and on trigeneration that uses CO2 generated by electricity generation in agricultural facilities.



(a) The exterior of Shinchi Energy Center

(b) LNG Cogeneration

(c) Aabsorption Chiller (Genelink)

Future challenges

- In Shinchi, we will help to further reduce CO_2 emissions by extending the supply range of the energy supply project and increasing the use of renewable energy.

- We will also develop general-purpose planning and assessment methods to enable the knowledge gained from R&D in Shinchi to be used in other regions too.

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Utilization of wood biomass in the Okuaizu region: Rethinking a local community to make it sustainable

Highlights of this research

1. The sustainable revitalization of rural regions requires the establishment of spheres of cooperation between stakeholders within a region to complement each other while utilizing local resources.

2. NIES is conducting basic research on the design and implementation of systems for achieving this sustainable revitalization through the regional circulation of local resources from production to distribution and consumption.

3. We are also supporting the creation of a consortium to work together to achieve multiple goals.

1 Introduction

The degradation of plantation forest in Japan has long been a cause for concern, but it has been exacerbated in recent years by an increasingly serious shortage of human resources and decline of local industries in rural regions. The government's establishment of a feed-in tariff (FIT) system for renewable energy generation sparked keen interest in power generation using unused timber and other wood biomass, so much so that it looked for a while as though the various problems faced by Japan's forestry industry would be quickly resolved. However, overheated competition for wood biomass for energy has become a cause for concern, and considering that regeneration with plantation forest is a much more daunting prospect than logging under the current forestry system, fears that the biomass industry will bring about a return to the bald mountains seen throughout Japan after WWII are by no means unfounded.

The Okuaizu region of Fukushima Prefecture faces the same forest degradation and depopulation issues as other regions. NIES signed an agreement with the town of Mishima in Okuaizu in 2017, and has since been conducting joint research with Mishima on wood biomass utilization. We have also actively provided research findings that were accordingly reflected in fiscal 2018 in Mishima's plans for wood biomass utilization.

This article synthesizes and presents research outcomes reported to date in various other places. The purpose of our environmental emergency research program in Mishima in the Okuaizu region is to deliver an example of the "Regional and Circular Ecological Sphere" (R-CES) put forward in Japan's Fifth Basic Environment Plan centered on a small-scale distributed energy plant. We believe that this initiative for Mishima Town will serve as a useful case study for other regions with similar issues.

2 Mishima Town and the Okuaizu region in Fukushima Prefecture

Mishima Town is part of Okuaizu, a snowy region located near the border of Niigata Prefecture in the southwest of the larger Aizu region of Fukushima Prefecture (Figure 1). According to AMeDAS meteorological data for Kaneyama Town next door to Mishima, annual average temperature is 10.4 ° C, annual precipitation 2020 mm, and maximum snow depth 177 cm. Blessed with abundant water from melting snow, the Tadami River was developed after WWII as a source of hydroelectricity, with the population of Mishima Town swelling to over 7000 as a result. The current population has, however, declined to under 1700, and the percentage of residents aged 65 or older is, at 53%, the highest in Fukushima Prefecture. Large-scale farming is difficult in such a mountainous region, and Mishima's small-scale part-time farmers have also increasingly given up tending their fields. However, 88% of Mishima Town is forested and most of that forest is privately owned cedar plantation forest.

Mishima is therefore very richly forested in terms of area, but much of the forest belongs to small-scale owners, many of whom can no longer be easily identified. Owing to decades of stagnating timber prices, Mishima's forests suffer from insufficient thinning and under-management. Even where the forests have been thinned, it has been done on an individual plot basis, resulting in timber of uneven quality. Aizu timber has always suffered from a reputation of being of low quality compared with timber from other regions owing to the prevalence of bent tree trunksused in construction. Forestry road networks also need to be developed for extraction and other operations, but little progress has been made. It is only recently that advanced forestry machinery has begun to be deployed.

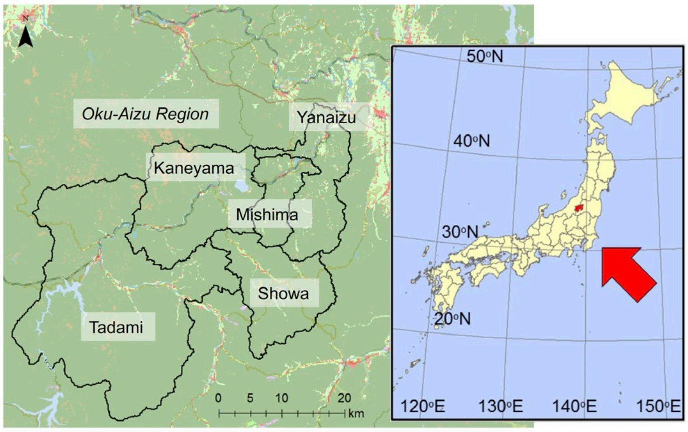

Figure 1. Okuaizu region, Fukushima Prefecture

To promote forest management and utilization of wood biomass, Mishima Town drew up the New Energy Vision inside Mishima Town in February 2006 and a more detailed version the following year. This Vision proposes the use of wood pellets, which are easy to handle, as an alternative to oil-based boilers and stoves as a means of exploiting its abundant forest resources. However, due in part to the impact of the Great East Japan Earthquake in 2011 and the extensive damage caused by the heavy rains in Niigata and Fukushima later in the same year, interest in biomass utilization waned.

In 2016, the chambers of commerce of the 13 municipalities of the Aizu region (including Mishima's) and other organizations joined forces to establish "Aizu The 13" project. The project's goal was to increase the production of timber from the Aizu region and manufacture high-performance plywood and fuel for energy. Various initiatives are being pursued by public-private partnerships such as the Aizu Regional Forest Resource Utilization Business Council and Aizu Forest Utilization Organization.

3 Joint research to date

NIES Fukushima Branch conducts research on local community development, also working as occasion demands with specialist researchers from other institutions on research topics of a more specialized nature.

In a study of the biomass potential of privately-owned forest in the Okuaizu region (Ooba et al., 2018), we analyzed the cost of chip production (including logging and transportation) for energy generation. This research showed that chip production for energy in very low-intensity forest operations (area-based annual operation ratio of 0.36%/y) would almost certainly be economically inviable. However, scenarios in which intensive thinning is carried out to increase yield showed that chip production of JPY 7000/m³ or less would be feasible, and that production could be increased in the future to about 10,000 m³ under well-managed forest in the future (e.g., 2060) (paper in preparation).

We examined the feasibility of deploying a biomass energy system in a representative public bathing facility already in operation in the target locality (Togawa et al., 2018). We conducted a survey jointly with Mishima Town to estimate seasonal and hourly energy demand and other parameters of the facility, which is located on the banks of the Tadami River. We estimated that a scenario in which a small-scale biomass cogeneration system was installed and operated around the clock in all seasons would require approximately 700 t/year of wood biomass. Our examination of economic feasibility, however, left room for concern.

NIES Fukushima Branch has installed home energy management systems (HEMS) in homes in Mishima to study residential energy consumption, including modeling for a cold region such as Okuaizu. Based on this research, we have prepared an energy chart for each village in Mishima Town (Togawa et al., 2019) and are estimating the potential for distributed energy systems in such regions from the demand perspective (Figure 2).

The above research projects also led to the award of a grant by Fukushima Prefecture to conduct joint research with Nippon Koei Co., Ltd. on the local production of energy for local consumption in Mishima using Mishima-sourced wood biomass and other local resources. A feasibility study (FS) was conducted in 2017. This survey was conducted at a different facility from that mentioned above, but it showed that if the electricity generated were sold using Japan's FIT system, the operation would be economically viable, and put estimated biomass consumption at approximately 800 t/year.

We conducted a field survey on forest environment awareness in Mishima Town in 2018 (Nakamura et al., 2018). Five hundred ninety-nine people aged 18 and over living in the town were randomly selected, and 264 responses (44.1% response rate) were obtained. Results showed that 76% of respondents knew the location of the forest land they owned, but only 58% knew the boundaries between their plot and adjacent plots, indicating a need to demarcate boundaries. However, many forest owners are not actively managing their plots, with "low timber prices" being cited most frequently in response to a question regarding management issues. Many also gave "old age" as a reason, while other responses chosen included "labor shortage", "lack of forest roads", and "unknown boundaries".

Figure 2.Village chart (Togawa et al., 2019)

We also sampled potential forest owners and asked them about the kind of support or subsidies they would need for ownership and management. While many selected economic factors (56 choosing timber prices and supply chain, 30 choosing logging and extraction assistance), boundary confirmation and forest road construction was 80 responses.

The above questionnaire survey also found keen public interest in the disaster prevention and mitigation functions of forests. Memories of the heavy rains of 2011 and associated flood damage have still not faded. The forests of Okuaizu have undergone almost no change in decades, and their full-scale utilization for biomass and its impact on the environment need with carefully consideration. From this fiscal year, we plan to conduct research on adaptation to climate change in the Okuaizu region, starting with a study aimed at eventually creating a hazard map indicating landslide and other risks.

4 Reflecting research findings in policies for Okuaizu

In addition to holding joint research meetings at least monthly with town hall employees of Mishima and the other four municipalities of Okuaizu involved in civil engineering, construction and regional policy under the auspices of Okuaizu Five-Municipality Revitalization Council, we have shared our research findings with the Mishima Town Forestry Policy Formulation Committee and through lectures in Mishima Town, meetings with stakeholders, and other gatherings.

In fiscal 2018, Mishima Town launched initiatives that constitute its first step in promoting the utilization of wood biomass. One is the collection of firewood from December using a "wood station" scheme. Under this scheme, every 1 m^3 of local timber brought in is exchanged for a 4500 yen voucher for use in local stores. The town also plans to convert the HVAC system of the Mishima Town Local Crafts Museum, a core facility that keeps the traditional basketwork crafts of the area alive, into a system that uses a wood-burning boiler. This boiler will use the firewood collected by the town's wood station mentioned above.

A new system for forest management can be available based on the newly started subsidy from the national government to the local government. Forest plot demarcation and consolidation was carried out in some parts of Mishima Town under the Fukushima Forest Regeneration Project implemented by Fukushima Prefecture after the GEJE, and we plan to use the knowledge gained through these operations as a model for planning policies that can be applied to a broader area. Since the full-scale use of wood biomass would constitute the foundation of a larger supply chain, we plan to further refine our forest research and share findings that contribute to this goal.

5 Conclusions

One of the key focuses of the Fifth Basic Environment Plan decided by the Cabinet in 2018 is the concept of "Regional and Circular Ecological Sphere" (R-CES). In line with this, Japan's Ministry of the Environment is supporting to many candidate the model projects or communities to achive the concept of the R-CES. R-CES could be seen as an integration of the long-established environmental goals of low-carbon society, recycling, climate stabilization, and coexistence with nature. We believe that the utilization of wood biomass in Mishima and the Okuaizu region as advocated in this project (Figure 3) has the potential to create a community that embodies the R-CES concept.

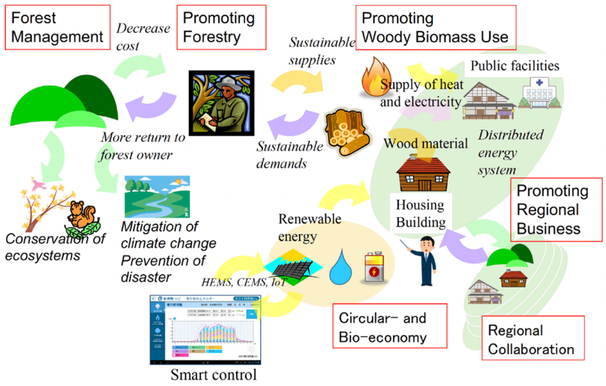

Figure 3. Regional and Circular Ecological Sphere (R-CES) initiative to generate various benefits by utilizing local resources (forests) and circulating them as energy etc.

Success requires public-private partnership as well as academic and technical support, but there are businesses and non-profit organizations in the town that are eager to use wood biomass and other renewable energy. Driving more effective and sustainable regional circulation of biomass and the economy requires a greater volume of logging than that envisaged in the energy site research and feasibility studies conducted so far. However, the amount that can be harvested is not infinite (and anticipated energy demand is not large). We are currently envisaging local businesses supplying locally sourced biomass for relatively small energy systems with service areas covering a specific district (village), Although small-scale, such energy businesses not only ensure that any profits are plowed back into the locality, but will also have positive ripple effects in the form of industrial development, human resource development, and stable local jobs. Small-scale energy businesses like this that handle a key segment of local services and are not overly dependent on investment and profits may well evolve into businesses that like Germany's Stadtwerke (municipal utilities) that handle a wide range of public services. This means that they have the potential to grow into substantial local industries in mountainous areas.

Under its Environmental Renovation Research Program, NIES will continue to further its understanding of local needs and make the most of its capabilities in integrated environmental research to study R-CES and other aspects of environmentally sustainable local community development.

Future challenges

- We need to refine our research, analysis and modeling methods for evaluating R-CES initiatives, and further broaden our range of understanding of local needs.
- Local circulation needs to be expanded and combined to build and maintain R-CES initiatives, but research on evaluating such initiatives has only just begun.

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Supporting regional reconstruction and sustainable development with a regional integrated assessment model

Highlights of this research

1. **A regional integrated assessment model that calculates balances between future population, economy, transportation, energy, and other variables is useful for planning long-term sustainable development in a region after post-quake reconstruction.**

2. **We used a regional integrated assessment model in the town of Shinchi in Fukushima Prefecture to identify required conditions and analyze the benefits of measures, applying the results of our analysis to plans for Shinchi.**

3. **By utilizing more detailed geographic information, the model can also be used to analyze how urban planning can reduce future building- and transportation-related energy consumption.**

1 Environmentally friendly reconstruction and sustainable local development

Eight years have gone by since the GEJE. In addition to the reconstruction and environmental recovery of areas affected by radioactive contamination, we need to think increasingly about the kind of local development that needs to be implemented to create better local communities over the long term. With the aim of aiding a new kind of community development that promises a better future for residents while protecting the local environment, we are using various simulation technologies to conduct research that supports the planning and implementation of the initiatives of local governments, residents and businesses as well as related projects from the perspective as the local population.

For example, the consideration of regional reconstruction from a long-term perspective requires analysis of the long-term outlook for industry and population of a region. Many of the GEJE-affected municipalities also face the issues of aging population and future population decline even if they manage to achieve reconstruction goals. To achieve their goals, municipalities need to achieve targets for sustaining population, stimulating industry, developing transportation infrastructure and so forth while simultaneously meeting environmental targets such as reducing carbon emissions and recycling resources. With the population of Japan as a whole in decline, local communities will also need to enhance their appeal to survive. Communities can, for example, be revitalized when job opportunities in surrounding industries or attendance/employment at surrounding educational facilities prompt an influx of new residents that has the effect of enhancing livability. Because of the complex interrelationship between many factors in society, simulations using computer models can be useful in analyzing initiatives to assess their effectiveness and plan policies accordingly.

2 Development of regional integrated assessment model

We have developed a computer model for simulating the way communities can achieve residential, industrial and other targets in addition to local environmental targets, including commuting to workplaces or schools outside the community. A model that uses equations to express the relationship between various fields and analyzes overall future development is called an “integrated assessment model”. Such models have been used mainly to study the future of the world as a whole, of the Asian continent, countries and such like, but we have refined the concept to create what we call a “regional integrated assessment model” that can be used even for individual municipalities.

Our regional integrated assessment model first looks at what kind of industries can be located in the region concerned. If, for example, we input the size of the industry that we want to attract or develop, the model will calculate the labor force required by the industry—in other words, the employment generated by the industry in the region. Since there is a strong correlation between the choice of place of residence and employment opportunities at the municipality level, this relationship can be used to estimate anticipated population for any particular locality. The percentage of people who will work in surrounding localities, and people who will commute from those localities also needs to be considered at this stage. Furthermore, if people living in the community shop and engage in other activities within the community, commercial activity and industrial production in the community will increase, giving rise to more jobs, and thereby population growth and concomitant growth in consumption. The model is therefore used to calculate this kind of effect too. The model will also analyze the age and gender of workers and residents to estimate the number of children likely to be born. Given a specific population maintenance target, such simulations can be used to determine the amount of employment required, the number of people commuting to surrounding localities, the amount of housing required as a result, the number of people in each age group likely to move in or move out of the community and so forth. These then become the levels that should be achieved and can be applied to the consideration of community policy targets. However, future uncertainties may well invalidate the estimates of models created from current data. AI and other IT may, for example, reduce the need for labor in various industries, so we simulate different outcomes for particularly important factors. This is called "sensitivity analysis". We may, for example, set several productivity improvement rates and run calculations accordingly to compare the results. This kind of sensitivity analysis enables us to assess the impact of future uncertainties on simulation results.

3 Support for town planning in Shinchi, Fukushima Prefecture

The town of Shinchi is a municipality with a population of about 8000 located at the northern edge of Fukushima Prefecture's Hamadori region. The town suffered extensive damage when about 20% of its area was inundated by the tsunami caused by the GEJE. Various reconstruction initiatives have since been launched and steady progress has been made, including the opening of the Joban Expressway, resumption of train services on the JR Joban Line, and the construction of a new LNG terminal at Soma Port. The challenge is now to leverage such new infrastructure and industry to promote further reconstruction. Against such a backdrop, Shinchi was selected in 2011 for the Cabinet Office's "Future City" initiative for its plan to leverage IT and install energy consumption monitoring systems in the homes of its residents as well as public and commercial facilities and elsewhere with the aim of creating an environmentally sustainable community. NIES signed an agreement with Shinchi and has since conducted various research with the town to support its environmentally sustainable reconstruction community development efforts. As part of this collaboration, we used our regional integrated assessment model to calculate future scenarios to help Shinchi formulate plans for maintaining its population. These scenarios were a "business as usual" (BaU) scenario in which Shinchi's population continues to decline as it was already doing before the GEJE, and a population maintenance scenario in which the population remains largely stable at its present level. With the population maintenance scenario, we examined necessary measures and their effects in various fields including housing supply, education and childrearing support, healthcare/welfare, industrial development, transportation planning, and energy supply based on long-term prospects. Since the model not only calculates population, but also considers the overall future form of the community, including industry, transportation, and other aspects, we met repeatedly with Shinchi Town officials to discuss concrete future assumptions and conditions for initiatives concerning industrial structure, housing policy, childcare support measures, commuting relations with surrounding municipalities and such like. Our calculations were based on the results of these discussions together with the opinions of residents gleaned through workshops and other channels, so as to align them as closely as possible with the vision for the town that its people aspired to achieve. As a result, we were able to calculate population maintenance targets, the conditions for initiatives required to achieve those targets, and the population maintenance effectiveness of different initiatives (Figure 1).

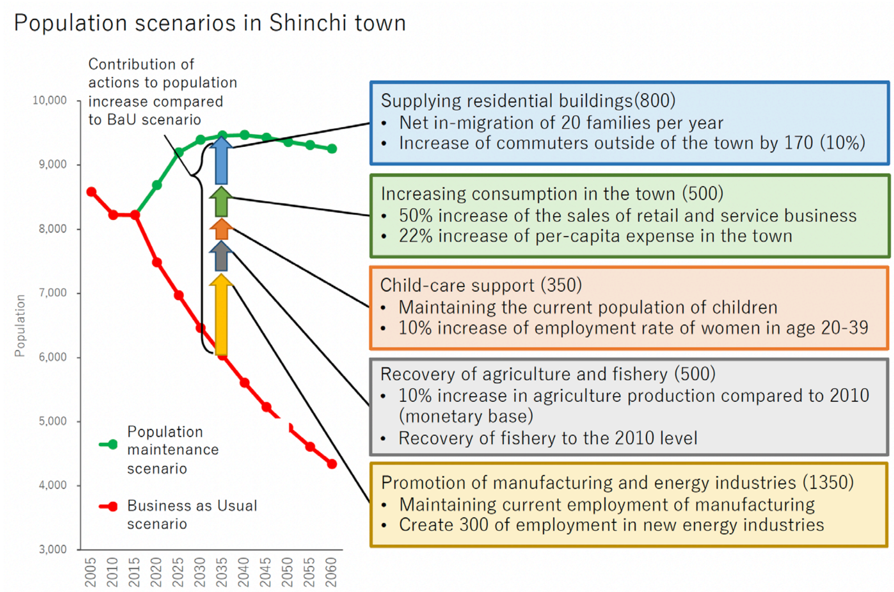

Figure 1. Initiatives required for population maintenance and their degree of contribution (Shinchi Town, Fukushima Prefecture, 2016)

4 Detailed analysis incorporating the locality's spatial information

More specific consideration of the sustainable future of a locality requires a more spatially granular perspective than that offered at the municipality level. For example, if the number of inhabitants who are unable to drive themselves is expected to increase as the population ages, the issue of whether the facilities required to meet the needs of such residents are within walking distance or can be accessed by bus or other mode of public transport needs to be considered. However, increasingly popular new services such as car sharing require a certain number of users within a certain area to be viable.

In the energy field, cogeneration (low-carbon energy supply technology with high overall energy efficiency owing to use of thermal enrgy generated when burning fuel to generate electricity) is a promising technology for using energy efficiently within a specific locality, but requires a certain concentration of homes and other facilities that use the electricity and heat. Land use and the placement of facilities also affect forest conservation and supply of renewable energy (since installation of solar or wind power generation plants depends on certain conditions).

We accordingly expanded the regional integrated assessment model to run simulations on 500 x 500 m grid in locations with concentrated populations and economic activity and developed a method for analyzing the deployability of low carbon technologies such as car sharing or community energy generation. We tested this model in the city of Koriyama and found that the locations in which these low-carbon technologies could be deployed would increase greatly were most people to move to the center of Koriyama when rebuilding their homes (Figure 2, Figure 3).

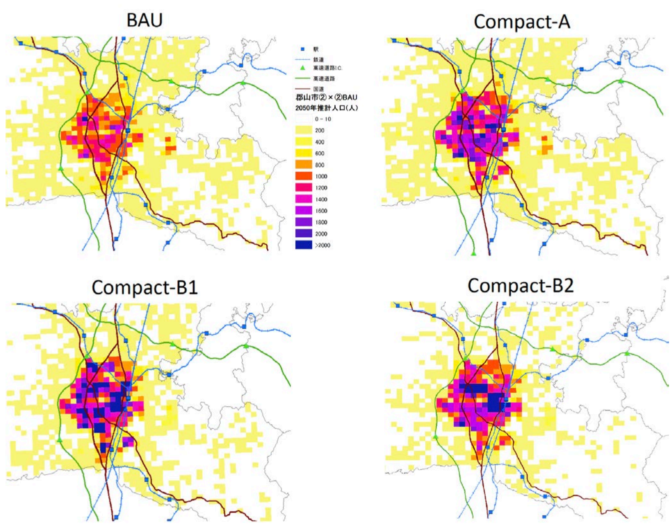

Figure 2. Estimation of spatial distribution dependence on population density in Koriyama City (2050) (Gomi et al., 2017)

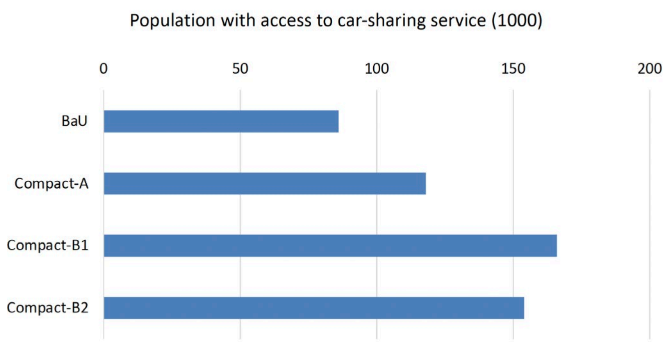

Figure 3. **(a)** Target local transportation businesses (Gomi et al., 2017)

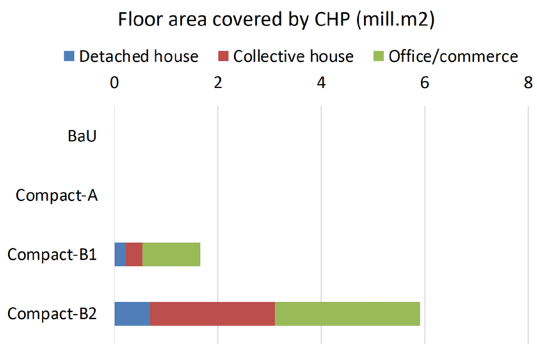

Figure 3. **(b)** Target local energy businesses (Gomi et al., 2017)

Future challenges

- We will develop calculation tools to enable the kind of simulations that we conducted in Shinchi and Koriyama to be carried out in other localities as well.
- Some of the issues being addressed by local communities such as education and healthcare equality are not currently directly covered by our regional integrated assessment model. Moving forward, we need to improve our model to cover a broader range of regional issues such as these. When we do so, we think that it would be useful also to refer to the Sustainable Development Goals (SDGs), aimed as they are at developing comprehensive solutions to economic, social, and environmental issues.
- Since evacuation orders issued following TEPCO's Fukushima Daiichi Nuclear Power Plant accident are being gradually lifted, we also need to analyze localities in which evacuees are returning after large-scale evacuation to support their restoration and reconstruction.

For more information

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Planning support for distributed energy systems that contribute to post-disaster reconstruction and sustainable community development

Highlights of this research

1 We have developed a framework to support the design of appropriate distributed energy systems according to the natural resources and energy demand characteristics of the locality concerned.

2 We conducted a case study in the Okuaizu region of Fukushima Prefecture to evaluate the benefits of deploying a distributed energy system and identified issues related to the commercialization of such systems.

1 Changes in approach to energy systems brought about by the GEJE

The GEJE and Fukushima Daiichi Nuclear Power Plant accident raised public awareness about the need to create a safe, secure and sustainable society, and various initiatives have been implemented to increase renewable energy generation as one measure for achieving this goal. In GEJE-affected areas, promoting renewable energy has been positioned as a key reconstruction strategy for the way it would contribute to the creation of a sustainable society as well as create jobs to replace those lost as a result of the disaster. Under the Fukushima Innovation Coast Framework, clusters of related industries and R&D sites are also being established and developed in the region.

As a result, renewable energy generation including nationwide construction of mega-solar power plants has grown rapidly, but renewable energy nevertheless accounted for only 7% of Japan's energy mix as of 2016. This means that the country still has a long way to go to meet the 2030 target of 22–24% for renewable energy set forth in the Ministry of Economy, Trade and Industry's Long-term Energy Supply and Demand Outlook (2015). One of the factors hampering the growth of renewable energy in Japan is the fact that the key players involved are big city-based companies that have very few ties to the local communities concerned. This has given rise to friction between local residents and the operators of renewable energy-related facilities in some localities. Also, such projects have tended to be structured so that energy charges paid by residents and businesses flow out of the region as in the past, rather than being fed back into the local economy. This means that they have not necessarily helped to develop local industries or breathe new life into the communities in which they are located. Remedying such issues requires building the right environment and accumulating basic information for enabling local communities to plan and operate their own energy systems. We therefore developed a framework to support the design of distributed energy systems appropriate to the energy supply and demand characteristics of the locality concerned. We also conducted a case study in the Okuaizu region of Fukushima Prefecture to evaluate its effectiveness and identify factors and issues critical to the design and commercialization of such systems.

2 Model for analyzing the benefits of deploying community energy systems

Energy systems could be thought of as systems to supply electricity or fuel (grid electricity, gas, kerosene, biomass resources, sunlight, etc.) to be converted by the demand side into usable electricity, heating, or cooling. The performance of energy systems is greatly affected not only by the design of their hardware, but also by operation plans adapted to season or time of day. This applies particularly to small distributed community energy systems because of the unique characteristics of their available energy sources and demand fluctuation patterns. We accordingly developed a methodology for planning community energy system hardware design and operation by using a planning process based on the hierarchical relationship between hardware design and operation. An overview of this planning process is shown in

Figure 1. Designing a distributed community energy system depends firstly on considering the energy supply conditions in the target area to determine the potential availability and cost of each type of energy. The next step is to estimate energy demand according to season or time of day separately for electricity, heating, and cooling. The third step is to set forth the framework for considering the community energy system. This framework shows the general structure including all candidate energy systems. Based on existing research (Yokoyama, 2014), we call this framework the "superstructure." The superstructure is composed of subsystems representing candidate devices and the potential flow of energy (input/output relationship) between them.

We then simultaneously identify the system configuration and operation plans according to season and time of day for minimizing (or in some cases maximizing) an objective function that combines flow values such as fuel consumption and stock values such as equipment capacity under various constraints that reflect local conditions and technical information. Depending on purpose, we select subsystems from the superstructure and determine the devices to be operated and their operation input/output levels according to season and time of day. As such, any device that needs to be operated at least once in any season or time of day must be selected at the design stage, and the capacity of the device must exceed the maximum annual output value.

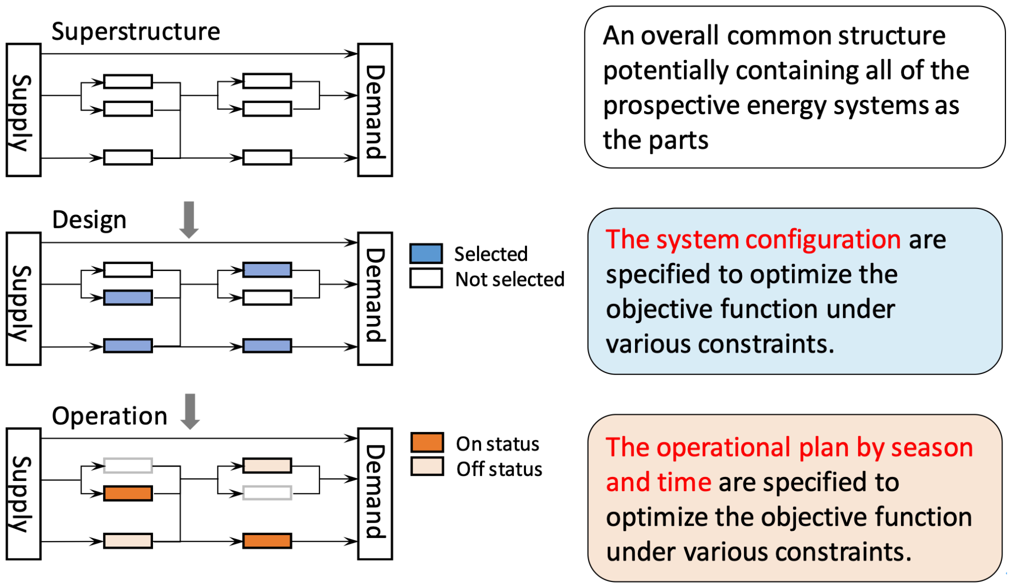

Figure 1. Community energy system planning process

3 Examination of the benefits of deploying community energy systems

Let us now introduce the results of our research on the feasibility of deploying distributed energy systems for which we used a public bathing facility in Okuaizu, a mountainous region in Fukushima Prefecture. We conducted a facility survey jointly with the local government and set energy demand by season and time of day based on the data obtained. The mountainous areas are characterized by abundant forest resources that can be converted into energy, and since small 10 kW biomass cogeneration systems (biomass combined heat and power (BCHP)) developed mainly in Europe were already being deployed in Japan, we examined the feasibility of deploying a distributed energy system with such a BCHP system at its core.

We first set the design conditions. We believe that decisions regarding the design of energy systems should be governed not purely by the pursuit of economic efficiency, but rather through consideration of a variety of factors including environmental and societal goals. For this study, we examined two system plans, one geared to cost minimization, the other to CO2 minimization. For the cost minimization plan, we further examined cases in which a FIT (FIT) or a 50% facility deployment subsidy was applied. Figure 2 shows the optimal system design results derived from our planning process model for cases 1 to 4. Case 1 features an all-electric system in which a heat pump powered by a mix of grid and solar power enables the supply of heat as well as electricity. The system also features a large-capacity heat storage tank for actively utilizing night-time power. Case 2 system also uses electricity supplied by grid and solar power as in Case 1, but uses a biomass boiler supply heat generation. Cases 3 and 4, which envisage subsidies of one kind or another, feature systems with BCHP at their core. However, whereas Case 3 assumes round-the-clock BCHP unit operation throughout the year, Case 4 assumes that the BCHP unit is not operated from midnight to early morning in all seasons.

We next evaluated societal benefit within quantifiable range. We define societal benefit here as the total value of cost reduction, CO2 reduction, and the cost to society of implementing the system. We set the benefit of CO2 reduction at JPY 5000 per ton-CO2 based on the carbon emissions trading price. Figure 3 shows our results. Case 1 proved to generate the greatest societal benefit. A comparison with Case 2 suggests that cost reductions are more meaningful than CO2 reductions in planning community energy systems of this scale. The societal benefits of Cases 3 and 4, which make use of subsidies, were lower than that of Case 1. This is due to the large burden imposed on the larger society (costs related to buying electricity at high FIT price and furnishing subsidies etc.) by deploying systems that generate economic benefits for the operator or CO2 reduction benefits. As such, although the utilization of biomass resources and BCHP deployment are likely to proceed under policies currently being implemented, our model suggests that the burden to larger society will exceed benefits.

Also, looking at biomass resource consumption in each case, 687 t/year is consumed in Case 3 in which the BCHP unit operates around the clock throughout the year. This means that this single facility would consume only about 2% of the 38,876 t/year of available biomass resources for the entire locality. This indicates that the locality is capable of supplying biomass resources as fuel for the facility on a sustainable basis.

Our results indicate that if FIT or capital investment subsidy systems are not applied, all-electric systems are more efficient for operators and therefore more likely to be adopted in practice. Such systems can be expected to reduce costs and CO2 emissions compared with current systems, but the catch is that they do not help to utilize local resources. With systems that depend on FIT or subsidies, on the other hand, the societal benefit diverges from the operator's benefit, and BCHP systems would probably be the ideal choice from the operator's viewpoint. However, because such systems place a large burden on society, their design and scope of application need to be carefully scrutinized, and any decision to use them should be based on a comprehensive evaluation of their benefits, including revitalization of forestry and other local industries, and technological innovation driven by their utilization.

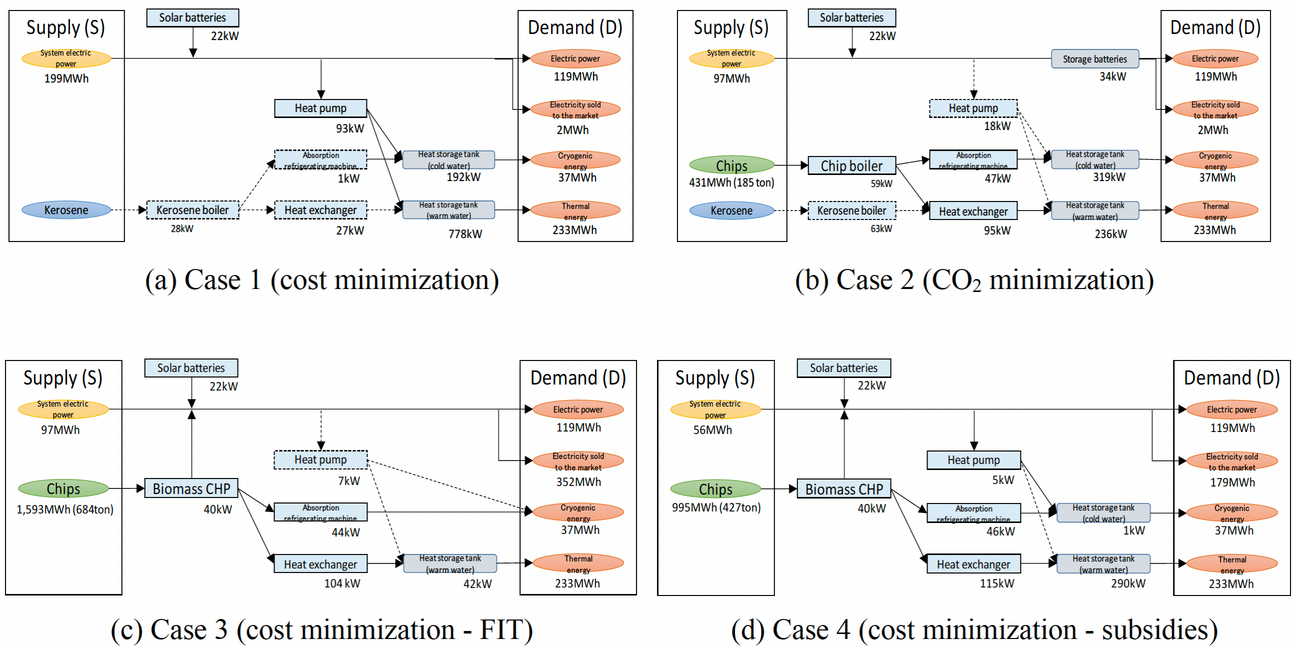

Figure 2. System design results

Figure 3. Estimation of societal benefits

Future challenges

- Utilization of local wood biomass resources would likely result in societal benefits such as wood chip manufacturing-related job creation that have not been fully accounted for in this study. Particularly in Case 3 with the large burden it imposes on society, resource consumption is also large, and there are societal benefits from using the local resources that are likely to offset the burden on society. We therefore see a need to expand our model to comprehensively evaluate benefits to the community as a whole, including the above benefits.

- We aim to generalize the results of our simulations and analysis and clarify the relationship between local communities and appropriate energy systems so as to provide regional stakeholders considering the deployment of distributed energy systems (local governments, private sector businesses, forestry cooperatives, etc.) with information that serve as a basis for such considerations.

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Addendum: Key laws and policies related to disaster recovery, reconstruction and regional development

After the GEJE, the Basic Act on Reconstruction in Response to the Great East Japan Earthquake came into effect on June 24, 2011, laying the legal groundwork for policies that constitute the foundation for post-GEJE reconstruction, including a system of special arrangements for deregulation and other measures for facilitating reconstruction (the "System of Special Zones for Reconstruction") as well as reconstruction grants and other measures for securing financial resources required by local governments for reconstruction. The Act on Special Measures concerning the Handling of Pollution by Radioactive Materials, which came into force later on August 30, 2011, lays down the Japanese government's basic policies on the handling of environmental pollution from radioactive materials discharged by the nuclear power plant accident, including measures for the disposal of waste contaminated with radioactive materials and decontamination of soil etc., and provides financial support for decontamination efforts being carried out in various parts of Fukushima Prefecture. With the decrease in radiation doses since fiscal 2013 as a result of the natural decay of radioactive materials and decontamination efforts, evacuation orders have been gradually lifted in the evacuation order zones surrounding the Fukushima Daiichi Nuclear Power Plant.[1] On May 19, 2017, the Act on Special Measures for the Reconstruction and Revitalization of Fukushima was amended to enable the establishment of special zones for reconstruction and revitalization within zones designated as "difficult for evacuees to return to."[2] Policies were established to drive environmental remediation, re-inhabitation and resumption of economic activities within these special zones.[3] In the town of Tomioka,

for example, a plan (Tomioka Town Special Reconstruction and Revitalization Zone Reconstruction and Revitalization Plan) has been drawn up for the implementation of reconstruction community development projects including forest regeneration, commercial revitalization, and resumption of agriculture in the town's special zone for reconstruction and revitalization while continuing with decontamination and house demolition activities within the same zone.

[1] The following 12 municipalities have been designated as evacuation order zones:
Tamura City, Minamisoma City, Kawamata Town, Hirono Town, Naraha Town, Tomioka Town, Kawauchi Village, Okuma Town, Futaba Town, Namie Town, Katsurao Village, Iitate Village

[2] The Japanese government reorganized the evacuation order zones on April 1, 2012, designating zones within the evacuation order zones in which radiation doses are so high that they pose health risks (zones in which total radiation dose for one year exceeds 50 mSv and accumulated radiation dose will likely not fall below 20 mSv even after 6 years have passed since the accident) as zones that are difficult for evacuees to return to.

[3] Reconstruction Agency website: Special Reconstruction and Revitalization Zone Reconstruction and Revitalization Plans (http://www.reconstruction.go.jp/topics/main-cat1/sub-cat1-4/saiseikyoten/20170913162153.html, as of February 26, 2019 (Japanese only))

Laws concerning the principle and purpose of regional development such as the Special Zones for Structural Reform Act and Local Revitalization Act were already in place before the GEJE. After the Great East Japan Earthquake, the government launched a “Future City” initiative as an environmental policy aimed at building sustainable socio-economic systems that address issues such as the environment and aging populations. Eleven municipalities received Future City designation on December 22, 2011.[4] Six of these are in areas affected by the GEJE, including Shinchi Town and Minamisoma City in Fukushima Prefecture. The Future City initiative was positioned as a key reconstruction measure in both Shinchi Town and Minamisoma City. Following the coming into force in fiscal 2014 of the Act on Overcoming Population Decline and Vitalizing Local Economy, in December 2015 Fukushima Prefecture drew up its Fukushima Revitalization Strategy to drive regional revitalization efforts. This strategy sets the goal of stabilizing the population of Fukushima Prefecture at about 1.6 million by 2040, and supports the efforts of local governments and residents to develop sustainable and attractive communities through such measures as creating jobs, attracting permanent residents, supporting childrearing, and promoting tourism.

Laws and policies related to Fukushima Prefecture’s reconstruction and regional development have in this way been established since fiscal 2015 with the goal of creating a sustainable region both within and outside the evacuation order zones from the economic, social, and environmental perspectives. The laws and policies of reconstruction and regional revitalization were originally drawn up from different policy contexts, but they now increasingly overlap to provide institutional and financial support to the initiatives of local stakeholders with the goal of creating sustainable communities in disaster-stricken areas.

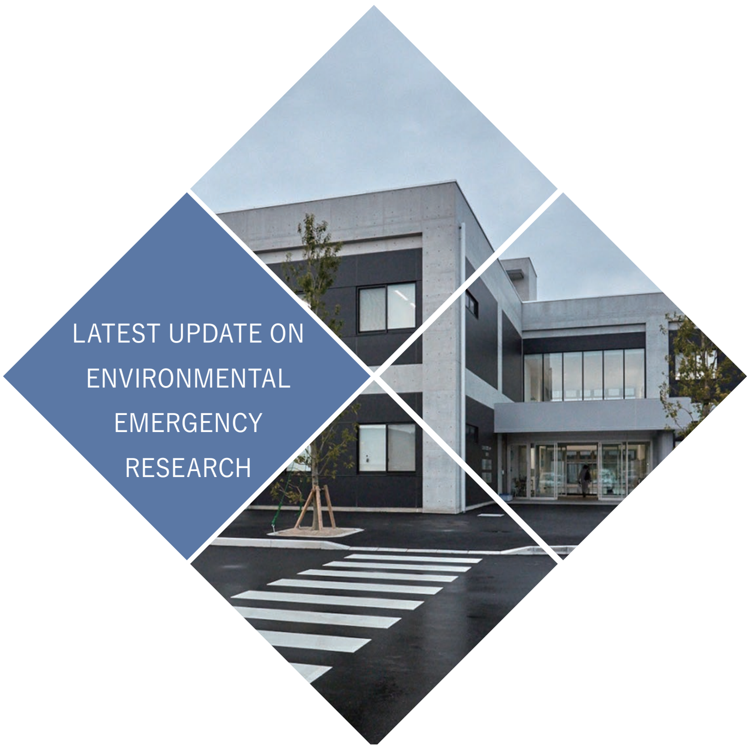
[4] Shimokawa Town, Kamaishi City, Kesen Area, Shinchi Town, Iwanuma City, Higashimatsushima City, Minamisoma City, Kashiwa City, Yokohama City, Toyama City, Kitakyushu City

Cover photos

① Conducting research in Mishima
② Shinchi’s Community Energy Center
③ NIES Senior Researcher Kei Gomi giving a lecture in Koriyama
④ Shinchi Community Center under construction
⑤ Living Assist Tablet System
⑥ The No.1 Tadami River Bridge in autumn (Mishima) Photo: Kaori Shiga

About "LATEST UPDATE ON ENVIRONMENTAL EMERGENCY RESEARCH"

LATEST UPDATE ON ENVIRONMENTAL EMERGENCY RESEARCH is a publication aimed at presenting the latest outcomes of the environmental emergency research being pursued at NIES Fukushima Branch to people working on the front lines of efforts to resolve the many different problems caused by disasters. We endeavor to outline the structure of the issues we are tackling, and present leading related research outcomes in an easily digestible format. This publication will hopefully contribute to the resolution of frontline issues related to disasters and the environment, and to the restoration of a safe and stress-free living environment.



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