# Smart Community Recovering from the Tsunami-Disaster: Case Study of the Community Energy Supply Project in Shinchi Town, Fukushima

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## Abstract

The present study was aimed at investigating urban reconstruction development in Shinchi Town, which is located on the northeastern coastal edge of Fukushima Prefecture. Shinchi Town experienced major damage from the Great East Japan Earthquake in 2011. Thereafter, an environmentally friendly community energy supply system was planned and introduced as a core project for reconstruction of the town. The National Institute for Environmental Studies, Japan, provided academic support for designing and planning of systems, determining energy conservation and $CO_2$ emission reduction, and feasibility studies. As a part of the project, a community-based energy organization, named Shinchi Smart Energy, was newly established near the town's rebuilt railway station. This organization supplies electric power and heat energy in the area undergoing redevelopment around the station. Shinchi Smart Energy employs a cogeneration system that uses waste heat from electricity generation for heating and hot water provision and an absorption chiller (Genelink), which uses waste heat to chill water for air conditioning, enabling high-efficiency energy management. Evaluation of the project reveals that it is being properly operated at this stage, although the facilities on the demand side have not been fully completed since the arrival of COVID-19 and the resulting socioeconomic impacts. Future studies will focus on furthering the introduction of renewable energy and expanding the area receiving the power supply in Shinchi Town, as well as spreading the knowledge gained from this town to other areas.

**Key words :** $CO_2$ emission reduction, cogeneration, community energy management,
distributed power source, district heating and cooling, reconstruction town development

## 1. Introduction

The Great East Japan Earthquake (GEJE), which occurred in 2011, was the first major disaster experienced by Japan since its population began declining. After previous similar disasters, urban reconstruction plans were made, aimed at extensive urban expansion with the goal of providing substitutive town functions to the damaged districts. The GEJE, however, accelerated the depopulation trend, especially outmigration, from disaster areas that were already scarcely populated even before the GEJE, resulting in further population decline in the region. It has already been argued that in Japan, population decline is causing deterioration of central districts and sprawling decentralization of towns and cities, which increases their $CO_2$ emissions per capita and makes them less carbon efficient; these observations have been confirmed in the case of municipalities in disaster-prevalent areas. Hence, municipalities undergoing reconstruction focus on developing compact cities characterized by higher traffic efficiency and higher housing density, thereby increasing efficiency in terms of reducing air conditioning load and optimizing the heat supply. Furthermore, $CO_2$ reduction is also attained via efficient local energy systems employed for cooling and heating buildings. A number of disaster-affected municipal governments have created a basis for residential and commercial activities in the reconstruction process by redeveloping into compact cities with more efficient energy supply and demand in the local system (Hayashi, 2014; Kitakaze, 2016).

The situation regarding energy use has changed significantly since the GEJE (Komiyama & Fujii, 2012; Benjamin, 2014; Zhang and Mclellan, 2014). Before the GEJE, reducing $CO_2$ emissions was an important policy issue for medium-to-long-term global warming countermeasures. After the event, however, not only have global warming countermeasures been considered, but also policy issues on energy. The government has implemented several power-saving measures to mitigate peak loading of the power system; these include: addressing issues associated with nuclear power generation, imposing a renewable energy feed-in tariff, liberalizing power retailers, and separating power production from power distribution and transmission. This is because the large-scale energy supply network, which previously served the entire nation, was obviously vulnerable. The supply network for power and gas was disrupted during the GEJE and the energy supply was interrupted in several areas, even in the areas that were relatively less affected. This led to a keen interest in renewable energy as an emergency power source during disasters, in addition to its contribution toward a decarbonized future. The Fukushima Daiichi Nuclear Power Station accident (Hall, 2011; Yamane et al., 2013; Suzuki, 2014) further complicated the perspective. To mitigate peak loading of the power system, in a situation where a nuclear power plant lost function, it was found that rolling blackouts and legally binding power usage restrictions needed to be implemented. Radioactive contamination led to a large-scale evacuation order for residents in various localities that had social and economic impacts, leading a large number of citizens to reconsider their perceptions regarding energy supply issues. From the perspective of both disaster prevention and environmental re-creation, coordinated management of energy supply and demand has become more efficient at the local scale through the introduction of distributed power supplies and construction of autonomous energy networks (Iwamura, 2015).

Against this backdrop, efforts to develop towns in which distributed community energy management was introduced have been promoted in the process of disaster recovery in Shinchi Town, Fukushima Prefecture. In the districts around the JR Shinchi Station, reconstruction from severe damage by the tsunami following the GEJE has been progressing, and various facilities have been constructed thus far (Fig. 1). A high-efficiency community energy system has started to supply electricity and heat energy to facilities built in the vicinity of JR Shinchi Station.

In this study, the planning and evaluation process of the community energy supply project were evaluated via collaboration among the local government of the town of Shinchi, private companies and research professionals. This paper is organized as follows: Chapter 2 gives an overview of Shinchi Town, and the process of reconstruction after the GEJE in conjunction with cooperation from the National Institute for Environmental Studies (NIES). Chapter 3 outlines the community energy supply project. As this community energy supply project cannot be evaluated using full-year data, Chapter 4 introduces the results of evaluating environmental performance at the planning stage. Chapter 5 reports the results of an evaluation using the actual data currently available. Lastly, Chapter 6 provides a summary of the findings and introduces future perspectives.

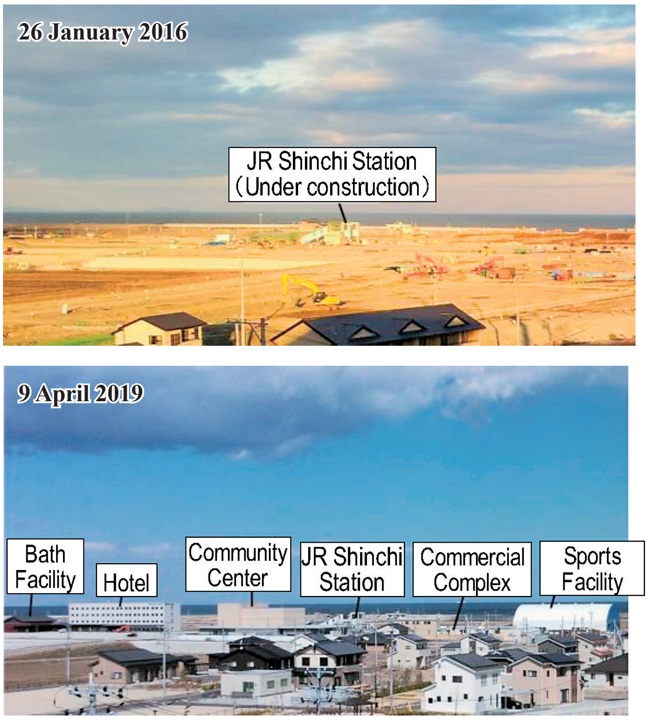


**Fig. 1** Reconstruction around JR Shinchi Station.
(photograph taken from Shinchi Town Hall)

## 2. Post-Disaster Reconstruction Process in Shinchi Town

Shinchi Town is a small municipality with a population of about 8,000 and a total area of 46.53 $km^2$, located near the border between Miyagi and Fukushima Prefectures, at the northern end of Fukushima Prefecture on the Pacific Ocean side (Fig. 2). It is approximately 300 km north of Tokyo. The temperature is low as compared to that in Tokyo, and the winters are especially cold (Fig. 3). The population of this town peaked in 1995 and has declined since, owing to reduced birthrate and ageing of the remaining population; this is the case for most Fukushima localities.

In Shinchi Town, the number of casualties was approximately 120 in the GEJE and subsequent tsunami. The tsunami inundated a large land area below the elevation of 10 m, with the flooded area encompassing about 20% of the town. As a result of the tsunami, 516 houses were damaged, and JR Joban Line Shinchi Station was destroyed, while 40% of the agricultural land (420 ha) was inundated.

For the post-disaster reconstruction of Shinchi Town, the town's government presented "a smart hybrid town concept" to increase the values of the environment, economy and society. The aim of this concept was to reconstruct the area by combining information and communication technology (ICT) with the social mechanisms that support the community. This concept proposes a new community information infrastructure for local residents networked with the municipal government, research facilities and business sectors and involves a bidirectional information system of sharing information on the local environment and lifestyle. Based on this concept, Shinchi Town, as a disaster-affected site, was selected as a "future city" by the Prime Minister's Cabinet Office in December 2011. With its selection as a "future city", discussion on cooperation with NIES toward the reconstruction of the town started, and in March 2013, a basic agreement on cooperation was drawn up between the Shinchi Town government and NIES. Based on research knowledge resources such as social communication, NIES has supported the planning of future visions of the town, and aided in investigations and formulation of the local comprehensive plan and local reconstruction plan (Fujita & Hirano, 2016; Hirano et al., 2017a). We developed an information system that serves as a residential interface for the information infrastructure, and it is presently in the phase of social demonstration experiments (Hirano et al., 2018). Various functions of this information system such as visualization of energy use on the demand side are already available. Community energy conservation campaigns have already been implemented using this information system, contributing to improved awareness regarding energy conservation and a more active community (Otsuka et al., 2019). The energy-saving campaign was a demonstration experiment, involving implementation of energy conservation activities; meaningful results were obtained on provision of energy conservation information and added economic incentives for residents.

As part of this reconstruction and community development support, we have put forth proposals and planning support for regional energy management linked to community development (Togawa et al., 2013; Togawa et al., 2014). This effort has progressed, and the social implementation of the regional energy supply in the reconstructed community has been achieved. As a core project of the urban reconstruction project around JR Shinchi Station, a community energy center, i.e., Shinchi Energy Center, was constructed, with local heat conduits, a community power grid, and $CO_2$ supply pipes being installed (Fig. 4). Details on the project are provided in the next chapter.

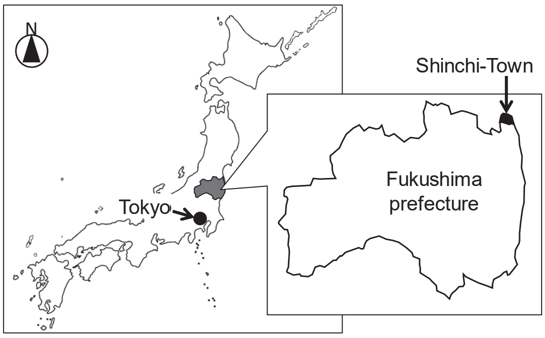


**Fig. 2** Location of Shinchi Town.

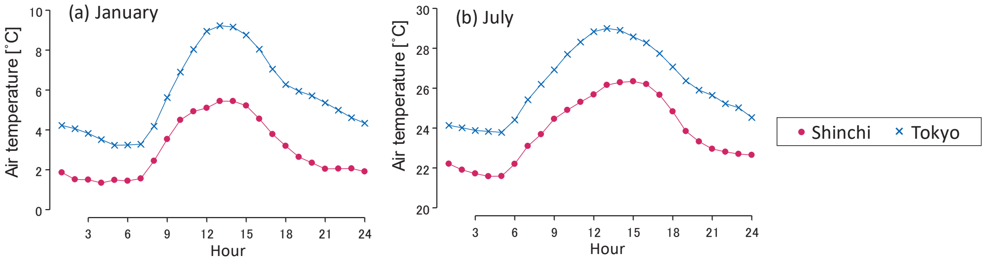


**Fig 3** Variations in air temperature in Shinchi and Tokyo in January and July.

Shinchi Energy Center: Main building

Heat supply conduits on the north side of the building

Site area: 7,606.36 m² / Building area: 714.48 m² / Total floor area: 687.96 m² / Structure: Steel frame (1 story) / Completion: November 2018

**Fig. 4** Shinchi Energy Center.

## 3. Outline of the Community Energy Project

In February 2018, a community-based energy organization, named Shinchi Smart Energy, was newly established by 12 entities comprising the local government of Shinchi Town and multiple companies and organizations. In November 2018, the Shinchi Energy Center, which provides a highly efficient energy supply, was completed. The Shinchi Energy Center is a community energy supply facility that supplies electricity and heat to facilities around JR Shinchi Station by utilizing cogeneration systems, solar panels, storage batteries and a heat source equipment system. Figure 5 shows an energy flow chart of the system, and Fig. 6 shows photographs of the main equipment. The Shinchi Energy Center has five gas engine cogeneration systems with a power output of 35 kW (175 kW in total) that utilize liquefied natural gas (LNG); the systems are regulated by the number of units in operation depending on energy demand. The cogeneration system utilizes waste heat from power generation to increase the total energy efficiency. LNG, an energy source, is supplied to the center via an LNG pipeline that branches off from the Soma LNG terminal. In addition to utilizing LNG, the center also has solar panels with a rated output of 50 kW installed, providing effective use of renewable energy. Electricity and heat are supplied from the Shinchi Energy Center to facilities in the area through private lines and heat supply conduits. In the energy supply area (the area supplied with electricity and heat), a hotel and hot bath facility with relatively high heat demand have been constructed for commercial use, and hot water supplied by the cogeneration systems is effectively utilized in these facilities. In addition, cooling during summers by operating the cogeneration system is also a feature of this project. In Japan, power peaks occur during summer when air conditioners are in use; thus, to reduce peak loads, cooling technology using gas with absorption chiller heaters has come into widespread use. What is called “Genelink,” is a set of waste heat recovery absorption chiller heaters that produce cold and hot water using waste heat from power generation, such as from gas engines. Some cogeneration systems obtain steam using gas turbines. Because the scale of this project is small, however, it uses gas engines, and the waste heat provides only hot water. Therefore, in the Shinchi Energy Center, cooling and heating are performed with hot wastewater from power generation using Genelink.

Energy began being supplied to consumers in March 2019 (Fig. 7). All the facilities in the supply area shown in Fig. 7 were newly constructed after the tsunami disaster. In addition, the Shinchi Energy Center functions as a regional base for energy distribution. For example, in the event of a power outage during a large-scale disaster, it will be possible to provide an uninterrupted power supply to the energy supply area of the center.

A community energy management system (CEMS) provides integral management of these facilities as well as energy utilization. One of the functions of CEMS is to provide the information necessary for community energy center management. Management is required for when the cogeneration equipment is combined with multiple auxiliary heat sources and power purchased from existing power companies (grid power), thus reducing excess heat while not exceeding the contract power from the grid. In this case, the prediction of demands and power generation via solar power, which depends on climate conditions, becomes essential. Under such complex conditions, information necessary for energy management personnel to make appropriate decisions is provided, contributing to more efficient operations.

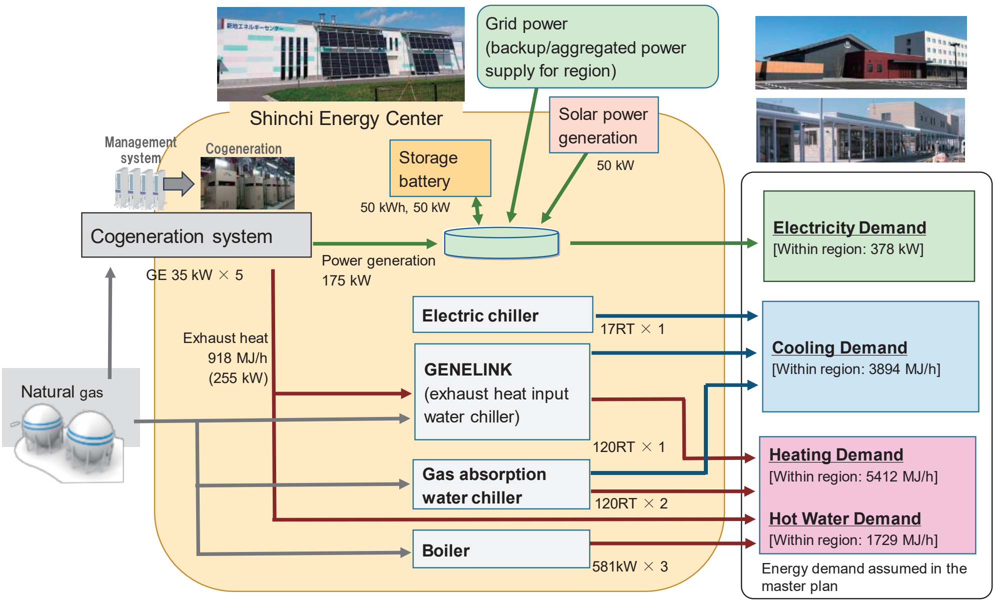


**Fig. 5** Electricity/heat supply system and energy flows in the Shinchi Energy Center.

Gas engine co-generation system

Waste heat recovery absorption type chiller/heater (Genelink)

Solar panels

Control room

**Fig. 6** Main equipment at the Shinchi Energy Center.

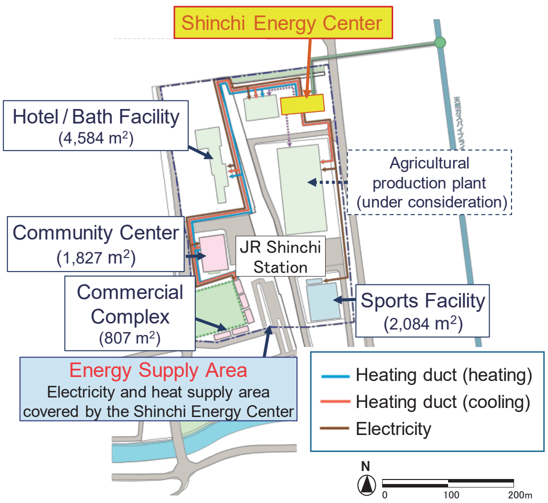


**Fig. 7** Energy supply area covered by the Shinchi Energy Center in the JR Shinchi Station Development Area. Floor areas are shown in parentheses.

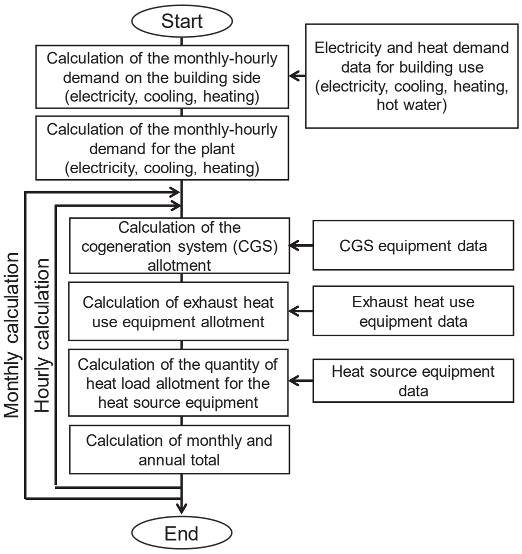


**Fig. 8** Flow chart of stimulation evaluation calculations.

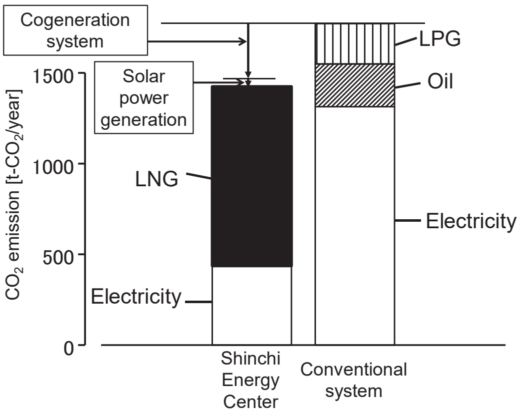


**Fig. 9** Calculation results of the $CO_2$ emissions.

## 4. Evaluation of Environmental Performance

We are conducting research on evaluating and improving the efficiency of community energy supply and demand management around JR Shinchi Station. We aim to improve energy efficiency and reduce $CO_2$ emissions in this region and generalize knowledge about efficient operation methods for applications in other regions. However, due to delays in the construction of community centers and agricultural facilities, as well as the socioeconomic impact of COVID-19, the energy supply record at Shinchi Energy Center is currently inadequate, and investigations using available data are incomplete. For this reason, we first present the results of a study based on the master plan (Shinchi Town et al., 2016). In this case study, although the data and calculation conditions are primarily based on the master plan, the capacity of the solar panels has been modified to correspond to practical conditions and recalculated accordingly.

Energy simulations were used to calculate electricity and gas consumption. In the simulations, input data were provided, and calculations were conducted for the load allotment of various heat sources based on input data and operational priority settings. Subsequently, city gas and electricity consumption were calculated based on the coefficient of performance (COP) of the heat source equipment, efficiency data and other factors. Based on these results, the energy savings, $CO_2$ reduction, and costs of this system were calculated. The various facilities shown in Fig. 7 were considered in the energy demand, and the demand pattern was set based on the existing energy consumption intensity data. (The supply system for the energy center and the assumed energy demand are shown in Fig. 5.) Then, the operating conditions of each item of equipment for supply were evaluated, as shown in Fig. 8.

Based on the above conditions, we calculated the total yearly $CO_2$ emissions when all facilities were in operation (Fig. 9). We also calculated the $CO_2$ emissions in the case of a conventional system being installed in each building for comparison. The results show that a $CO_2$ reduction of approximately 20% can be expected by modifying the community energy system based on the highly efficient community energy supply provided by the Shinchi Energy Center. In addition, the seasonal and time-dependent operation patterns of each device were also comprehensively examined. For example, various improvements have been made: approximately 10% of power consumption can be supplied by solar power generation during daytime peak hours and approximately 30% of cold heat consumption can be supplied by a Genelink using cogeneration exhaust heat (figures omitted).

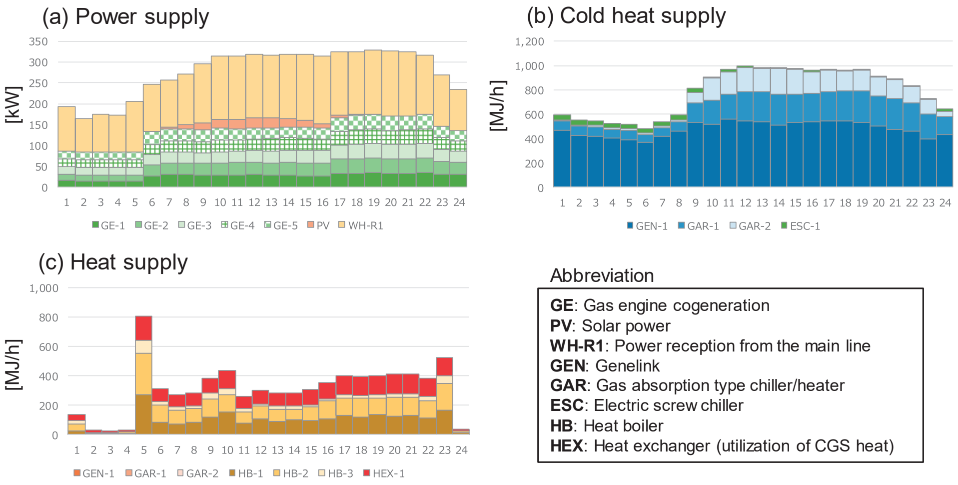
## 5. Energy Evaluation Based on Available Data

We are conducting energy conservation diagnosis at the Shinchi Energy Center as part of developing technology for planning and evaluating community energy utilization. This is a tentative evaluation result, however, because the expected number of consumers assumed during the planning stage has not yet been achieved.

As an example of the midsummer season, Fig. 10 shows the recorded electricity, cold heat and warm heat supplies for August. In August, cold water was supplied to consumers at 381 GJ and hot water at 222 GJ; although mainly cold water was supplied, one-third of the total demand was for hot water. The number of operational cogeneration units was reduced during the night, but the overall cogeneration system operated 24 hours a day. For the power supply, along with solar power generation, distributed power sources provided approximately half of the local power demand. Energy for cooling was supplied by Genelink, which used exhaust heat from cogeneration, for more than 60% of the total demand. Owing to the demand for hot water in the public bath facilities and hotels, there was some heat demand in summer. Cogeneration exhaust heat and a boiler were used to meet this heat demand.

Fig. 11 shows the energy supply in December as an example of winter conditions. Because there was almost no demand for cold water in December, this aspect was not included in Fig. 11. On the other hand, the demand for hot water increased to 877 GJ owing to its use in both water and space heating. Based on the results of our energy conservation diagnosis, the operation of the cogeneration system was modified in November, and the cogeneration system was stopped during the midnight power time zone of the grid power system. This operation contributed to cost reduction and grid power load smoothing. Correspondingly, heat was supplied from the cogeneration exhaust heat and boiler during day and from the boiler during night.

Fig. 12 shows the cogeneration operation results based on the practical supply and demand data for the seven months from June to December 2019. Since the



Abbreviation

**GE**: Gas engine cogeneration
**PV**: Solar power
**WH-R1**: Power reception from the main line
**GEN**: Genelink
**GAR**: Gas absorption type chiller/heater
**ESC**: Electric screw chiller
**HB**: Heat boiler
**HEX**: Heat exchanger (utilization of CGS heat)

**Fig. 10** Hourly energy supply in August.

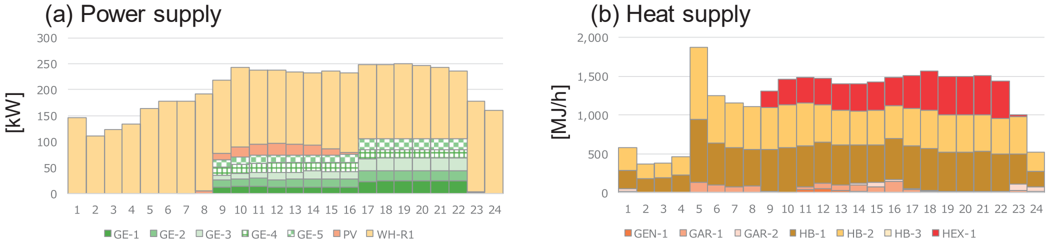
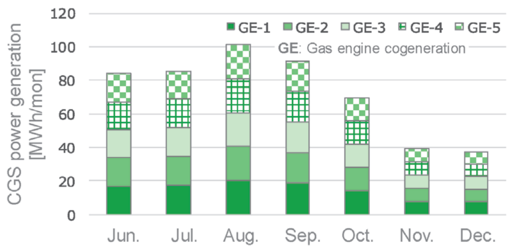
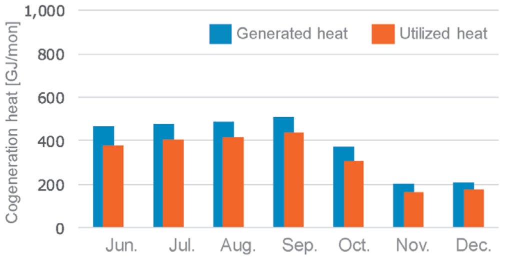


**Fig. 11** Hourly energy supply in December. The abbreviations in the legends are the same as in Fig. 10.

(a) Power generation by the cogeneration system



(b) Generation and utilization of cogeneration heat



(c) Overall efficiency of cogeneration system

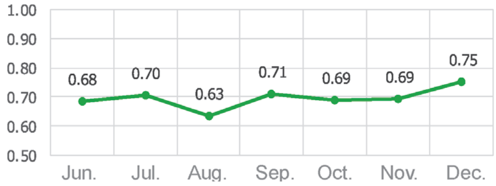


**Fig. 12** Operational status of the cogeneration system from June to December 2019.

impact of COVID-19 is currently unclear, this paper only presents data for the period before the impact of COVID-19. However, the community center was still under construction during this period. In addition, the planning of agricultural facilities was delayed owing to the effects of a massive typhoon in 2019. Therefore, Fig. 12 shows the results under the condition of insufficient energy consumers as compared to the number assumed at the planning stage.

For these seven months, Fig. 12(a) shows that the five cogeneration units generated approximately 80–100 MWh/month during summer. After November, the cogeneration operation method was modified and the amount of power generation shifted to approximately 40 MWh/month, which is approximately half of that in summer. Five cogeneration units were operating at almost equal operating time. The output was adjusted by controlling the number of operating units; hence, they were not always under simultaneous operation. However, to match maintenance timings, five units were controlled to have the same cumulative operating time. Fig. 12(b) shows that the utilization rate of cogeneration exhaust heat was approximately 80%–90% each month; the power generation exhaust heat was confirmed to be effectively used for heat supply. As shown in Fig. 12(c), the overall efficiency of cogeneration was stable at approximately 70%. In December, the overall efficiency was 75%, confirming good operating conditions.

## 6. Summary and Future Perspective

This paper describes a case study on the planning and evaluation of an environmentally friendly energy supply project that is being developed in the central area of Shinchi Town. This project is being carried out as part of reconstruction of the town after considerable damage caused by the tsunami following the GEJE. In this project, the Shinchi Energy Center was constructed to supply energy to the facilities around JR Shinchi Station. Although the current evaluation is tentative, the overall efficiency of cogeneration is approximately 70%, and the utilization efficiency of exhaust heat is approximately 80–90%, confirming that it is in good operating condition. In the future, we plan to evaluate its environmental performance using practical data as the surrounding facilities on the demand side are completed and the supply records are collected.

Our subsequent goal is to apply the knowledge obtained in Shinchi Town to other regions. Therefore, we are currently working on developing a general-purpose evaluation system for evaluating the feasibility of a community energy supply system in accordance with various regional conditions. In this system, in addition to the data on energy supply and demand management realized at the current Shinchi Energy Center, various models for energy demand forecasting and optimal operation forecasting will be incorporated to evaluate efficient energy management. For the residential sector, we have constructed an energy demand forecast model using energy monitoring data in Shinchi Town (Lubashevskiy & Hirano, 2018) and estimated the electricity demand distribution to calculate the potential for introducing a community energy supply. For the commercial sector, because the data available on facilities in Shinchi Town are insufficient for obtaining generalized knowledge, we are investigating forecasting methods based on regional climate conditions using existing databases (Hirano et al, 2017b). Based on these results, we aim to conduct data analysis and evaluation for horizontal expansion in other regions, and study methods for evaluating renewable energy as well as the potential for introducing cogeneration by incorporating demand forecasting.

### Acknowledgements

The project introduced in this paper is being carried out under the smart community adoption promotion project with NIES acting as the academic advisor, based on the Basic Cooperation Agreement, for supervising Shinchi Town with the cooperation of related companies.

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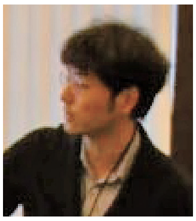

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(Received 7 September 2020, Accepted 21 December 2020)