Issues and Potentials of Local PPS in Realizing a Japanese Version of Stadtwerke

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Abstract—**This paper presented an overview of local power producers and suppliers (local PPS) that were established in Japan since the general liberalization of the retail electricity market, with particular focus on the current situation and issues of the local PPSs in terms of their operations and their renewable energy-related efforts. Further, this paper analyzed relevant cases in Ishikari city in Hokkaido, Karatsu city in Saga prefecture, and Sakura city in Chiba prefecture, to discuss and inform future efforts towards realizing a Japanese version of Stadtwerke.**

Index Terms—**Japan, Local PPS, renewable energy, Stadtwerke.**

I. Introduction

According to data provided by the Agency for Natural Resources and Energy, a part of the Ministry of Economy, Trade, and Industry (METI), a total of 662 power producers and suppliers (PPS) have been established in Japan as of 2020 [1]. The primary cause of this increase is the acceleration of the competition in the retail electricity market since its general liberalization. The general liberalization of the retail electricity market in Japan was undertaken in three stages. The general liberalization was first established in March 2000, and the "special high-voltage" class, which included large factories, department stores, and office buildings; was allowed to freely choose from a range of power suppliers that included the newly introduced "local power producers and suppliers" (local PPS). This liberalization was then expanded in April 2004 and April 2005, by granting the same freedom of choice to the "high-voltage" class, which included small-to-midsize factories and small-to-midsize buildings. Finally, general liberalization began on April 1, 2016, allowing the "low-voltage" class, which included households and small stores, to choose their power suppliers [1]. The national average supply rate by PPSs, to the consolidated national demand, has since increased from 5.3% in April 2016 to 16.1% in 2020. Presently, the rate of supply by PPSs in the "special high-voltage," "high-voltage," and "low-voltage, lighting/general household" classes is 5.6%, 23.2%, and 17.3%, respectively [2]. PPSs are now regional companies responsible for primarily providing electricity to public facilities, private companies, and households in specific regions, thus making the use of locally-generated power. These companies are called local PPSs, and as of 2017, approximately 162 existed [3]. This calculation was based on the 290 enterprises that supplied power out of the 372 that were registered at the time. Aside from these, there were 62 national-scale enterprises (four or more regions) and 56 enterprises operating primarily in urban centers (2 to 3 regions).

Since the Great East Japan Earthquake, unsuccessful anti-global-warming scenarios and energy policies have forced Japan to deviate from using large-scale, centralized power sources and adopt standalone, decentralized energy systems that use renewable energy. Since they are local, standalone, and decentralized energy systems, local PPSs can promote the local production of energy for local consumption and create local jobs, thereby providing solutions to social issues associated with low birth rate, aging society, and regional depopulation. Further development of the local PPSs is expected, and the local PPSs are viewed as having the potential to function like the Stadtwerke of Germany.

Stadtwerke are business entities scattered across Germany that maintain and operate regional energy sources and infrastructures, working closely with their respective communities, managing electricity, gas, heat, waterworks, transportation, telecommunication, and a range of public facilities. Recently, the Stadtwerke have been re-publicized. Currently, approximately 1,000 exist across Germany [4], and their rates of supply to the national demands in Germany are 86.4% for waterworks, 70.2% for heat, 66.7% for gas, 61% for electric power, and 43.8% for sewerage, respectively [5]. As standalone, decentralized energy systems contributing to the public interest, Stadtwerke have gained the trust of many Germans and are strongly supported by residents in regional communities [6]. Meanwhile, local governments in Japan lack both the know-how to operate energy enterprises and the market necessary to effectively reproduce Stadtwerke in Japan using a similar approach as that used in Germany. Therefore, to realize a Japanese version of Stadtwerke, it is necessary to seek for an original approach that conforms to the prospective development of Japan's local PPSs and the experiences they have gained thus far.

This paper provides an overview of existing cases of local PPSs in Japan. Then, we examine the current situation of local PPSs, with a focus on their operators and the compositions of power-source (i.e., efforts related to renewable energy). Furthermore, case studies based on field research conducted in Ishikari city in Hokkaido, Karatsu city in Saga prefecture, and Sakura city in Chiba prefecture, are

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presented with suggestions for the development of a Japanese version of a Stadtwerke. Finally, this paper presents a course of action, informed by the research results, toward a Japanese version of Stadtwerke.

II. Methodologies

To obtain an overview of the nationwide situation of local PPSs, we collected information from a total of 44 cases. Furthermore, prior studies on activities of local PPSs were examined to guide the discussion concerning Stadtwerke and their issues in Japan. Finally, case studies of Ishikari in Hokkaido, Karatsu in Saga, and Sakura in Chiba were examined and discussed with the results of the above research.

Data necessary for analysis were collected from official websites, various reports and minutes of city councils, and interviews.

III. Discussions in Japan Regarding Stadtwerke

A. The Operators of Local PPSs

Local PPSs are categorized by the following three patterns in Japan, based on their operators.

Pattern A: Participation by a regional government as an investor

Sometimes called the "regional government PPSs," these local PPSs, funded by regional governments, are gaining attention as local PPS models that consider the role of local governments like Stadtwerke. As of 2020, there were 44 regional government PPSs in Japan, such as Nakanojo Electric Power. Established in 2013, Nakanojo Electric Power was the first local PPS in Japan to be primarily owned by a regional government with funding (i.e., 60%) from Nakanojo Town in Gunma prefecture and V-Power Co., Ltd. (i.e., 40%) [7]. Regional government PPSs are run by regional governments with communities of different sizes, ranging from a population of <10,000 to over a million. About half of the regional government PPSs currently belong to communities with a population range of 100,000 to 200,000 (Fig. 1).

Table I is a list of details of regional government PPSs in Japan. The proportion of funding by regional governments varies from <1% to 100%. However, only a few companies are funded entirely by their regional governments and operate in the form of public corporations like in Germany. In contrast, the majority of regional government PPSs have been established as "third sector" companies—a term for public-private partnerships in Japan—with regional government funding proportions of slightly over 50% [8]. Unlike in Germany, regional governments in Japan have not accumulated much knowledge (such as that required for self-sufficiency in supply-demand adjustments) to operate companies.

Consequently, there are many cases in which the regional government forms a balancing group in a large PPS and subcontracts business. Moreover, many regional government PPSs involve other entities such as regional banks and Shinkin banks for funding procurement, regional gas companies for the energy business, and chambers of commerce and industry for the revitalization of local enterprises. The vast majority of regional government PPSs primarily supply electricity to public facilities. However, some PPSs also supply electricity to households through partnerships with regional gas companies. Many regional government PPSs are also engaged in the introduction of at least one type of renewable energy. This aspect is discussed in detail in the next section.

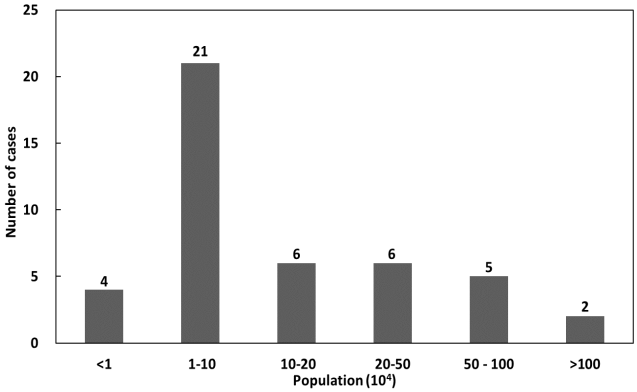


Fig. 1. Number of regional government PPSs by a community population.

Specifically, regional government PPSs have four administrative objectives: 1) reduction of electricity costs for public facilities; 2) local production of energy for local consumption; 3) regional economic circulation; and 4) regional decarbonization [9]. In particular, PPSs that have been established under the primary leadership of regional governments have led active and leading roles in the process of planning measures to contribute to the regional community while also solving administrative issues. This type of a PPS is not as profit-driven as private corporations but prioritizes the improvement of the living standards of residents, thus contribute to the regional public interest.

Pattern B: Indirect involvement by regional governments

In Pattern B, the regional government is involved in the establishment of the local PPS by signing a regional coordination agreement and providing various forms of support, excluding direct funding. Local PPSs of this type can make use of the knowledge possessed by private corporations while still maintaining public-interest-oriented characteristics through cooperation with local administrations. Therefore, these local PPSs are becoming popular, as a new model for public-private coordination. An example of this pattern is Sango Himawari Energy in Sango Town, Ikoma-gun, Nara prefecture, which is funded 100% by Kokusai Kogyo Co., Ltd. [10]. This PPS was established in April 2017 under an "agreement concerning the promotion of a local PPS enterprise in Sango Town, Ikoma-gun" signed between Sango Town and Kokusai Kogyo Co., Ltd. This has allowed Sango Himawari Energy to develop its business as a private enterprise while following the general community development strategies led by the regional government. It is still critical to build appropriate stakeholder management

systems for local PPSs of this type since the efficiency of operations and the contribution to public interest directly depend on the roles that the private corporations and the regional government play, respectively.

Pattern C: Primary leadership by private corporations.

TABLE I: LIST OF NEW LOCAL POWER PRODUCERS AND SUPPLIERS FUNDED BY REGIONAL GOVERNMENTS

Prefecture	Company Name	Renewable Energy Sources	Sales Destination	Capital Stock (yen) / Regional Governments investment ratio (%)
Hokkaido	Karch	Biomass	Public facility	8.4 million / 59.5
Iwate	Kuji Regional Energy, Inc.	Megasolar, Hydropower	Public facility, Households	10 million / 5
Miyagi	Kamiden Satoyama Public Corporation	Megasolar	Public facility, Private facility	6 million / 66.7
Miyagi	Higashimatsushima Organization for Progress and Economy, Education, Energy	Megasolar	Public facility, Private facility	Subsidy for operation from the community
Akita	Kazuno Power, Inc.	Hydropower	Public facility	9.9 million / 49
Yamagata	Yamagata Power Supply, Inc.	Megasolar	Public facility, Private facility	70 million / 33.4
Fukushima	Soma I Grid Co. Ltd.	Megasolar, Small Hydropower	Public facility, Private facility	9.9 million / 10.1
Fukushima	Katsurao Electric Power, Inc.	Megasolar	Private facility, Households	42 million / 52.4
Gunma	Nakanojo Power Co. Ltd.	Megasolar	Public facility, Households	3 million / 60
Gunma	Oota Power, Inc.	Unpublished	Private enterprise (high voltage power)	7 million / 60
Saitama	Tokorozawa Mirai Power , Inc.	Megasolar, Biomass	Public facility	10 million / 51
Saitama	Hukaya e Power, Inc.	Megasolar	Private facility, Households	20 million / 55.6
Saitama	Chichibu Power Supply, Inc.	Megasolar, Hydropower, Waste to energy	Public facility, Private facility	20 million / 95
Chiba	Chiba Mutsuzawa Energy, Inc.	Megasolar, Cogeneration system	Public facility, Households	9 million / 55.6
Chiba	Narita Katori Energy, Inc.	Megasolar, Waste to energy	Public facility	9.5 million / 80
Chiba	Choshi Power, Inc.	Megasolar	Private facility, Households	9.99 million / 50
Niigata	Niigata Swan Energy, Inc.	Megasolar, Biomass, Waste to energy	Public facility	50 million / 10
Ishikawa	Kaga General Services, Inc.	Unpublished	Public facility	50 million / 100
Nagano	Marubeni Ina Power, Inc.	Waste to energy	Public facility	50 million / 10
Shizuoka	Smart Energy Iwata, Inc.	Wind Power, Gas engine power generation	Public facility, Private facility	100 million / 5
Shizuoka	Hamamatsu Power Supply, Inc.	Megasolar, Waste to energy	Public facility, Private facility	60 million / 8.3
Mie	Matsusaka Power Supply, Inc.	Small Hydropower	Public facility	8.8 million / 51.1
Shiga	Konan Ultra Power, Inc.	Megasolar	Public facility, Private facility	11.60 million / 51
Kyoto	Kameoka hurusato Energy, Inc.	Megasolar	Private facility, Households	8 million / 50
Osaka	IZUMISANO-PPS.PR.JP	Megasolar	Public facility, Private facility	6 million / 83
Nara	Ikoma Civic Power, Inc.	Megasolar, Small Hydropower	Public facility, Private facility, Households	15 million / 51
Tottori	Tottori Civic Power, Inc.	Megasolar, Small Hydropower, Biomass	Public facility, Private facility, Households	20 million / 10
Tottori	Local Energy, Inc.	Megasolar, Biomass, Hydropower, Geothermal power generation	Public facility, Private facility	90 million / 10
Tottori	Nanbu Dan-Dan Energy, Inc.	Hydropower	Public facility, Private facility	9.7 million / 41.2
Shimane	Okuizumo Electric Power, Inc.	Small Hydropower	Public facility, Private facility	23 million / 87
Hiroshima	Fukuyama Mirai Energy, Inc.	Megasolar, Biomass, Hydropower, Waste to energy	Public facility	100 million / 10
Tokushima	Miyoshi Energy, Inc.	Procurement of megasolar, Biomass	Public facility, Private facility	25 million / 8
Fukuoka	Miyama Smart Energy, Inc.	Megasolar	Public facility, Private facility, Households	20 million / 55
Fukuoka	Kitakyushu Power, Inc.	Waste to energy	Public facility, Private enterprise (high voltage power)	60 million / 24.2
Fukuoka	Coco Terrace Tagawa, Inc.	Unpublished	Public facility, Private facility	8.7 million / 28.8
Nagasaki	Minasapo, Inc.	Unpublished	Public facility	5 million / 50
Nagasaki	Nishikyushu Sasebo Powers	Unpublished	Public facility	30 million / 90
Kumamoto	Nature Energy Oguni, Inc.	Megasolar, Hot spring heat binary	Public facility, Private facility	9 million / 37.8
Kumamoto	Smart Energy Kumamoto, Inc.	Waste to energy	Public facility	100 million/ 5
Oita	Power Supply Oita, Inc.	Megasolar	Private facility, Households	20 million / 0.25
Oita	Bungoono Energy, Inc.	Megasolar	Private facility, Households	20 million / 30
Kagoshima	Hioki Regional Energy, Inc.	Megasolar	Public facility, Private facility, Households	2.4 million / 4.2

Kagoshima	Ichikikushikino Power, Inc.	Megasolar	Public facility, Private facility, Households	10 million / 51
Kagoshima	Osumi Peninsula Smart Energy, Inc.	Small Hydropower	Public facility, Private facility	5 million / 67

Source: Prepared by the author based on various materials.

In this pattern, the local PPSs are funded entirely by private corporations that assume primary leadership over the operations. These have been considered a highly efficient model for local PPSs due to the extensive business knowledge of private corporations. In many cases, these local PPSs are operated by private corporations with extensive experience in the electricity retail business and financial capacity to launch new business projects. Additionally, many incorporate the names of the regions in their company names. For example, Shizuoka Gas and Power, funded 100% by Shizuoka Gas Co., Ltd. [11], is a local PPS owned by a regional gas company, while Miyako Shindenryoku, funded 100% by NTT DATA Corporation [12], is owned by a telecommunications company. Moreover, there are cases in which local PPSs are funded by private companies that are involved in industries related to the primary power sources used by those PPSs. For example, in 2022, Kai City plans to establish a local PPS that will handle woody biomass power generation, expected to be funded by Hitachi Zosen (80%) and a local forestry organization (20%). There is also a high chance that industrial waste management enterprises or companies operating waste incineration facilities will become operators of local PPSs involving waste-power generation.

B. Renewable Energy-Related Efforts

The Paris Agreement was signed as a result of negotiations at the United Nations Climate Change Conference (COP 21) held in December 2015. The Paris Agreement sets a long-term goal of reducing the amount of greenhouse gases emissions down to zero by the second half of this century. The Great East Japan Earthquake, unsuccessful energy policies, and application of measures to prevent global warming have forced Japan to reconstruct its energy system. Japan has since been actively engaged in the introduction of renewable energy to realize a low-carbon society. Low-carbon society is a goal that has been upheld in the "Long-Term Growth Strategies Based on the Paris Agreement" (Cabinet decision of June 11, 2019) and has a target of reducing greenhouse gas emission in 2030 by 26% compared to the value in 2013. Renewable energy development and operations have since accelerated in tandem with the rapid development of local PPSs, due to the introduction of the feed-in tariff (FIT) system in 2012 that fixes the price of renewable energy-based electricity.

Fig. 2 shows the total capacity of renewable energy introduced each year since the introduction of FIT (i.e., 2012). The seven years from 2012 to 2018 had a total increase of 47.8 million kW in FIT-applied renewable energy, mostly (i.e., 44.57 million kW) from solar power for residential and non-residential use. This highlights the overwhelming predominance of solar power generation. The current status of renewable energy introduction by prefecture (Fig. 3) shows that Ibaraki, Chiba, and Aichi are the top three prefectures, and there is a general predominance of solar power generation across Japan. In contrast, wind power generation accounts for a relatively large portion of energy introduction in prefectures such as Akita and Hokkaido, while biomass power generation dominates in Ibaraki and Aichi. Therefore, these power-source compositions reflect regional characteristics. Cases of local PPSs funded by regional governments exhibit similar trends (TABLE I). In the order of the most to the least numerous, the types of power sources used in a total of 39 cases were: solar (29 cases; 74.4%), hydropower (12 cases; 30.8%), waste (8 cases; 20.5%), biomass (7 cases; 17.9%), geothermal (2 cases; 5.1%), and wind (1 case; 2.6%). While the use of solar power is overwhelmingly predominant, there are also plans to increase wind power for local PPSs in regions such as Hokkaido and Tohoku, which have abundant wind resources. Thus, additional energy use by harnessing regional resources is anticipated.

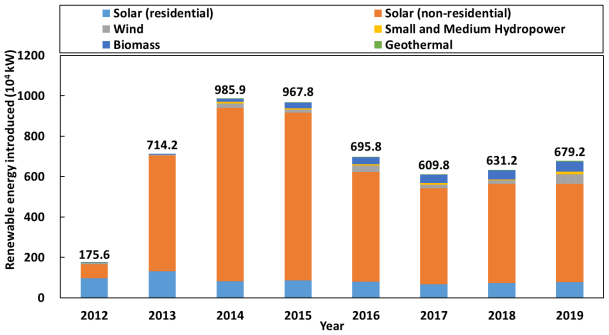


Fig. 2. Changes in the introduction of renewable energy in Japan. Data obtained from [1].

The amount that can be practically introduced, based on policies and technological limitations, is called the "introduction potential" for a specific type of energy resource. From the highest to the lowest, the total introduction potentials in Japan for the various types of renewable energy are 2.74595 billion kW for solar power, 1.40478 billion kW for wind power (on-shore potential of 284.56 million kW and offshore potential of 1.12022 billion kW), 8.9 million kW for small and midsize hydropower, and 8.15 million kW for geothermal power. The total introduction potential is 4.16778 billion kW [13], which is about 76 times the amount of the currently introduced capacity. Therefore, Japan has a high introduction potential for these types of renewable energy, allowing their use in the future. It is expected that they will be used as energy sources for local PPSs in symbiotic relationships with other fields such as enhancement of regional resilience and regional revitalization. Here, we discuss the issues and specific potentials of renewable energy use by local PPSs for the top-three renewable energy sources in terms of introduction potential, i.e., solar power, wind power, and

small-to-midsize hydropower.

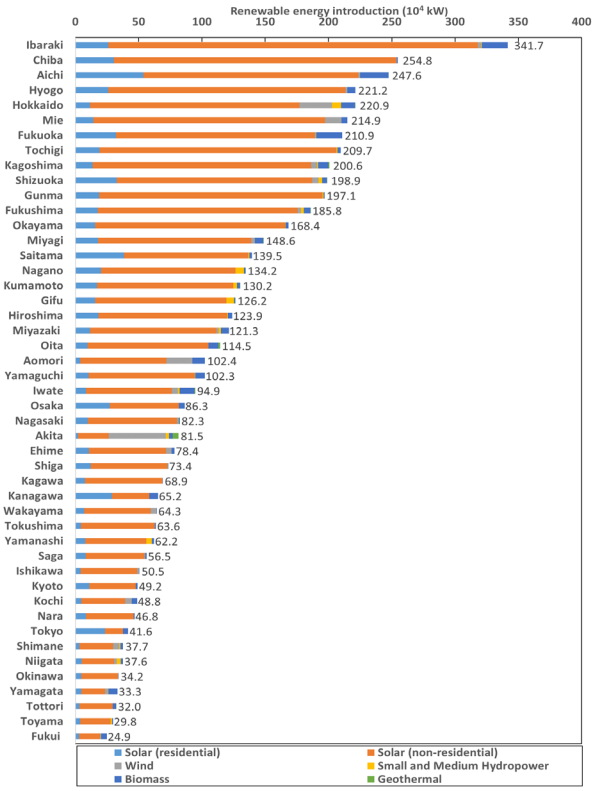


Fig. 3. Renewable energy introduction capacity by prefecture (as of March 31, 2020). Data obtained from [1].

1) Solar power generation

Solar power generation has been the most rapidly increasing renewable energy source since the introduction of FIT. This is due to factors such as high buying price (¥24/kWh for residential use and ¥14/kWh for non-residential use in the financial year (FY) 2019), low business risk, lack of limitations in terms of geographical suitability, relatively lenient regulations, and accessibility to permits [14].

Consequently, there have been cases of environmentally destructive construction of large-scale solar power stations that have caused controversies. As a result, some regional governments are regulating the establishment of solar power stations. Additionally, a law concerning waste disposal and cleaning of solar power generation equipment requires the "disposers," such as the enterprises that operate the facilities, to be held responsible for waste disposal. However, the relative absence of barriers to enter the solar power generation business not only attracts various enterprises but also creates a situation in which the entities that operate the facilities can adapt quickly. This is concerning for regional communities since it entails the possibility that solar panels and other equipment, some of which include harmful substances (such as lead and selenium), could be abandoned or unlawfully dumped once power generation operations are discontinued [15].

Therefore, while the introduction potential of solar power is immense, it is still necessary to ameliorate its pre-existing, disproportionate predominance by engaging in concurrent development and use of other types of renewable energy.

2) Wind power generation

The total introduction potential of wind power is significant in Japan. However, most of this is concentrated in certain areas in Hokkaido and Tohoku regions. Thus, wind power in Japan is extremely limited by geographical suitability.

Wind power generation involves universal issues such as bird strikes and low-frequency noise pollution. Additionally, rising power-generation costs have become an issue. According to data provided by the Agency for Natural Resources and Energy, the power generation cost in 2018 was ¥13.9/kWh, i.e., 160% of the global average (¥8.8/kWh). This is due to factors such as the lack of domestic wind turbine manufacturers, downscaling of wind farms due to geographical limitations, and lack of thorough improvement of maintenance efficiency.

Moreover, the use of wind power as the primary power source for local PPSs is hindered by long construction periods, relatively higher costs, and the necessity to develop mechanisms for the use of renewable energy during construction.

3) Hydropower generation

The introduction potential of small-to-midsize hydropower generation is smaller than that of solar and wind power. However, it is a renewable energy source that is introducible in most regions and also holds symbiotic potential with flood control and agriculture; thus, it is suitable for local PPSs. However, it requires its operators to be watchful of changes in water levels depending on rainfall, as these could impact the volume of power generation.

Most hydropower plants attached to dams and owned by regional governments (i.e., "publicly run hydropower") currently have long-term power sale contracts with electricity retailers. Currently, this limits its adoption as a power source by most local PPSs. However, once the contract periods have lapsed, hydropower may potentially become a primary power source of PPSs [16].

4) Other types of renewable energy

Waste-to-energy: General waste management has been the responsibility of municipal governments in Japan. Incineration facilities have, therefore, been generally established and maintained in each municipality, resulting in a larger number of smaller facilities than those in Europe and the United States. Meanwhile, progress has been made, in recent years, in the joint establishment of waste management facilities by multiple local governments. As such, facility sizes are increasing, while the amount of waste production is decreasing. Both the number of waste-to-energy facilities and their power-generation capabilities are increasing, thus suggesting that waste-to-energy has the potential to become a power source owned by regional governments [16]. In addition, industrial waste management performed by private corporations is expected to incorporate power generation. Nevertheless, given the frequent occurrence of opposition movements that view industrial waste management plants as "NIMBY (not in my backyard) facilities," it is necessary to design a system for holding a dialogue with residents, to obtain local consent.

C. Issues Faced by Local PPSs in Aspiring Stadtwerke

In the context above, it is clear that the establishment of local PPSs comparable to Stadtwerke will require the establishment of public-private coordination to maintain project continuity and ensure contribution to the regional public interest. The discussion above also noted the importance of expanding the usage of regional renewable energy to achieve a low-carbon society.

Regarding the "public interest," local PPSs in Japan are often described as a sociological approach, i.e., as "social enterprises." Social enterprises refer to "various energy enterprises whereof the principal objective is to serve public interest" [8], with the essence of the "maximization of regional public interest" [17]. Moreover, regional governments are powerful actors in the process of realizing the "maximization of regional public interest" [18]. However, there are many cases in Japan, in which local PPSs deviate from this fundamental objective. Below, we introduce some issues of concern and provide an overview of the critical issues for local PPSs in Japan.

1) Excessive focus on electric power

a) A case in which a regional government switched to a local PPS despite high electricity prices

In November 2018, upon their regional government's signing of a negotiated contract with local PPS Ikoma Civic Power (funded by Ikoma City in Nara prefecture), residents of Ikoma City submitted an audit request to inquire a case of wastage by procuring electricity at a higher rate than neighboring cities. The residents demanded that the mayor pay-back to the city about ¥250 million that was spent on electricity [19].

b) A case in which a local PPS focused on profits

In February 2020, a "transaction involving conflict of interest" took place between two companies: "Miyama Smart Energy" (Miyama SE) and "Miyama Power Holdings" (Miyama HD). Miyama SE was a "third-sector," local PPS funded by Miyama City in Fukuoka prefecture, while Miyama HD was a private corporation in charge of managing supply and demand for electricity provided by Miyama SE [20]. Since one person was the president of both companies, the transaction between the two companies counted as a "transaction involving conflict of interest" in corporate law, thus requiring approval by the board of directors. However, the transaction was conducted without approval. This stirred criticism that based on the possibility that Miyama SE had been bearing expenses for Miyama HD's partnership with enterprises that are unrelated to projects by the city, i.e., expenses Miyama HD should have incurred without taking advantage of Miyama SE's status as a regional government PPS [21].

There has been a growing concern that such focus on electric power can cause local PPSs to deviate from the goal of "maximizing regional public interest," becoming self-serving, engendering little price competition, and contributing to new regional monopolies.

In contrast, Germany uses Stadtwerke to galvanize its regional public sectors. The Stadtwerke operates energy businesses as secure sources of income that they return to society by investing in regional public services. By realizing this cycle of contribution to the regional public interest, Stadtwerke have gained the trust of residents, thus sustaining themselves as enterprises. Therefore, Stadtwerke work closely with their respective local communities.

Meanwhile, Kitakyushu City in Fukuoka prefecture returns a portion of the earnings of Kitakyushu Power—a local PPS which it funds—to the community in the form of scholarships through a regional education support service, thereby supporting local human resource development [22]. Similarly, Shonan Power, a local PPS led by a private corporation, invests profits in its local community. Specifically, the local PPS donates a portion of its business earnings to the professional soccer club Shonan Bellmare, thereby supporting local contribution activities by the soccer club (such as the construction of sports schools and healthcare for the elderly) [23]. As such, local PPSs across Japan have been experimenting with methods to return profits for the regional public interest, thus creating an added value, i.e., regional contribution, and ensuring their sustainability as enterprises to some extent. However, it is still necessary to further expand the vision for the future maximization of regional public interest.

2) Appropriate distribution of roles between the public and private sectors

Conventionally, operations of local PPSs have taken a top-down form in which the private and public sectors separately strive only for partial optimization and individual efficiency. Implementation of a Stadtwerke-inspired diversity of operations will require a shift from this top-down form to a network-type, the bottom-up form of operations allowing general optimization and synergy through close coordination with regional governments. For this purpose, it is necessary to seek and redefine the distribution of roles between regional governments and private corporations entering the local PPS business, to create a new model for public-private coordination.

3) Coordination with renewable energy

The improvement of the rate of local consumption of regional renewable energy and the reduction of CO_2 emission through renewable energy-related efforts by local PPSs is encouraged. It is also necessary to design a model connecting such efforts with regional public services. In other words, it is necessary to design various combinations between the regional infrastructure of renewable energy and public services. For example, Utsunomiya City in Tochigi prefecture plans to establish a local PPS aimed at the production of local energy (such as solar, biomass, and waste-to-energy) for local consumption in 2021. Furthermore, the city plans to use this energy project for introducing a light rail system scheduled for commencement of operations in March 2022 [24]. Moreover, while the use of regional energy for electricity production is widespread in Japan, very little is used for heat; therefore, more active efforts on this aspect are expected in the future.

It was the concept of "regional circular and ecological sphere" (regional CES) that defined the course of action towards realizing a Japanese version of Stadtwerke.

IV. Regional Circular and Ecological Sphere as a Concept for a Japanese Version of Stadtwerke

In April 2018, when the implementation of measures following Sustainable Development Goals (SDGs) and the Paris Agreement was widespread in the world, the 5th "Environmental Basic Plan," adopted by the Cabinet of Japan, proposed a regional CES. The regional CES is an approach that aims for "the maximal use of the resources within each region including the natural scenery, to form independent and decentralized societies that engage in mutual support by supplementing resources to one another as necessary, depending on regional characteristics" [25]. Therefore, the concept of regional CESs is gaining attention as an approach to deal with multiple issues with consolidated solutions, thereby realizing: 1) "local energy production for local consumption" and "promotion of industries" through the use of standalone and decentralized energy systems whereof regional energy companies (local PPS) are central; 2) "regional public interest," such as enhancement of public services and disaster prevention or response; and 3) "low-carbon societies" through the introduction of renewable energy [26].

This chapter analyzes the efforts towards the inception of a regional CESs. Such projects were led by the administrations of Ishikari city in Hokkaido and Karatsu city in Saga prefecture. Therefore, this chapter discusses the potential of these projects, as a Japanese version of Stadtwerke, regarding the roles played by the public and private sectors in the local PPS and its renewable energy-related efforts. Additionally, this chapter examines the case of Yukarigaoka, a community development project that has been implemented following the concept of "maximization of regional public interest."

A. Concepts for Ishikari's Regional Circular and Ecological Sphere

Ishikari city located in western Hokkaido, adjacent to the northern part of Sapporo city, and faces Ishikari Bay to the west (Fig. 4). TABLE II shows the overall statistics of the society and economy of this city. The top-ten industries of this city, according to the ratios of production value are: manufacturing (32%), wholesale/retail (13%), transportation (12%), services (11%), producers of government services (10%), construction (6%), electricity/gas/water (2%), real estate (2%), information and communications (2%), and finance/insurance (1%) [27].

In 2018 FY, Ishikari city used METI's "FY 2018 Subsidy for Projects Promoting Local Production of Energy for Local Consumption, Making Use of Regional Characteristics: Projects Supporting Diffusion of Concept." Kyocera Communication Systems Co., Ltd. (KCCS) as an applicant and proposed a project aimed to create a zone in the Ishikari Bay New Port Area that will use only 100% renewable energy-derived electricity. Moreover, a feasibility study was conducted on projects, including the proposed project in 2019. The development of a 100% renewable energy zone started in 2020. To realize its vision of achieving a regional CES by 2040, Ishikari city has been attracting enterprises, establishing a renewable energy business entity, and planning the use of mobility services (Table III). Fig. 5 shows a schematization of the concepts, elements, and critical mechanisms of this project.

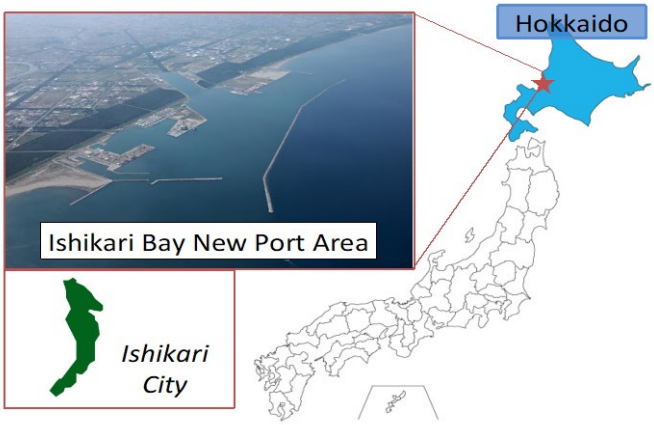


Fig. 4. Geographical location of Ishikari city.

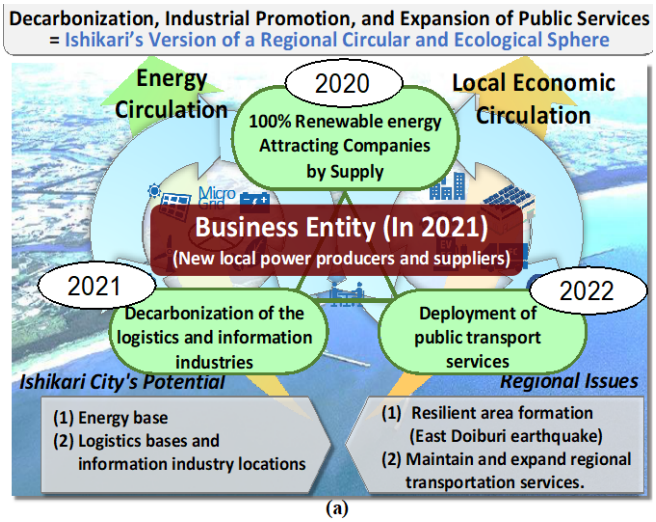
TABLE II: Socioeconomic Overview of Ishikari City (2019)

Population/number of households	58,258/27,855
Area (km^2)	721.9
Government revenue/expenditure	27.4 billion yen
Total production*	312.3 billion yen
Industrial composition (primary industries: secondary industries: tertiary industries)	1:24.3:74.7

*Data from 2013 [27]

TABLE III: Key Steps towards Realizing Ishikari's Version of a Regional Circular and Ecological Sphere

Year	Schedule
2019	Feasibility study
2020-	Development of the 100% renewable energy zone starts.
2020-	Attraction of enterprises starts.
2021	Establishment of a renewable energy business entity
2022-	Use of mobility services using renewable energy starts.
2040	Realization of Ishikari's version of a regional CES by supplying 100% renewable energy-derived electricity, decarbonizing the logistics and information industries, and deploying public transport services.



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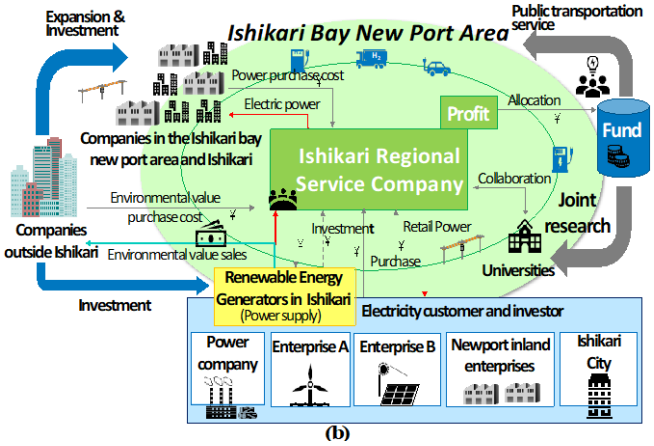


Fig. 5. Overview of Ishikari's version of a regional circular and ecological sphere.
(a) Schematization of the regional circular and ecological sphere
(b) Project and business map

Energy circulation and regional economic circulation are considered the two vital aspects to compose Ishikari's version of a regional CES. The plan is to allow mutual impact and synergy, within these aspects, among three engagements: attraction of enterprises by supplying 100% renewable energy-derived electricity, thorough decarbonization of the logistics and information industries, and deployment of public transport services.

Moreover, a local PPS provisionally called "Ishikari Regional Service Company" will become the main body for promoting this project. This company will procure renewable energy-derived wholesale electricity from power companies and other enterprises within Ishikari city. Then, it will sell this electricity to the market within the Ishikari Bay New Port Area, including public facilities and households with individual demands for electricity and enterprises. Furthermore, using its earnings in the form of a fund, the company will solve regional issues through contributions to public transport services, the development of energy ventures, deployment of electric vehicles, joint research with universities, and the establishment of various infrastructures including hydrogen energy facilities. As such, the company's mission will be to generate circulations desirable for realizing Ishikari's version of a regional CES.

1) The proposed operators of a local PPS and their roles

There is a plan to establish a public-private local PPS incorporating not only efforts by the administration but also the knowledge possessed by private enterprises. This local PPS will be funded by power generators/suppliers, within Ishikari city, that can supply renewable energy and other enterprises located within the Ishikari Bay New Port Area. The current primary stakeholders and their roles in this project are given below.

KCCS: In March 2019, KCCS signed an agreement with Ishikari City to collaborate in the construction of a corporate housing area that will use 100% renewable energy-derived electricity. KCCS will be responsible for attracting environment-conscious IT companies to build a data center near the Ishigaki Bay New Port. Moreover, electric vehicles will be introduced, and the company is developing an automatic delivery robot for a shared delivery service within the region that will use electricity supplied by the local PPS. Moreover, the design of this compact mobility system will be applied to the collection of waste, and other additional mobility services are also expected to be created.

Hokkaido Electric Power Co., Inc.: Hokkaido Electric Power signed an agreement for regional collaboration with Ishikari City to 1) build a system for cooperation aimed for the promotion of the development of renewable energy (such as offshore wind power generation and biomass power generation) 2) concretize methods to realize the renewable energy zone in Ishikari Bay New Port Area, 3) plan development of industries rooted in the use of renewable energy, and 4) plan new development of businesses that will work closely with the regional community. The company plans to apply knowledge related to the management of supply and demand to the operations of the local PPS, and to other areas of business, that it has accumulated as a private corporation.

Ishikari city: The city is expected to play a role in consolidating the opinions and results of the various actors involved in the local PPS, allowing smooth cooperation among multiple enterprises, regardless of their investment amount. Thus, the city is expected to lead the construction of a mechanism that will promote the work of private-sector players, clarifying the relationship between the public and private sectors, and exploring new forms of public-private collaboration.

2) Proposed Renewable energy-related efforts

There is a plan to achieve a renewable energy usage (electricity) of 26.6 GWh/year (i.e., the electricity requirement for approximately 7,650 households) by 2040, raising the rate of local consumption of renewable energy of the region to 97%. The power sources proposed for this plan include solar power (2,000 kW), offshore wind power (2,000 kW), woody biomass power (2,000 kW), and small solar power generation equipment installed on detached houses in the city as post-FIT power sources (500 kW). Such use of the abundant renewable-energy potential of the region is expected to reduce CO_2 emissions by 17,862 T/year (i.e., the emission of approximately 650 households). However, the regional potential of renewable energy cannot be exploited immediately. Therefore, it is necessary to devise concrete measures to enlighten the actions of corporations to support renewable energy.

B. Concepts for Karatsu's Regional Circular and Ecological Sphere

Karatsu city is located in northwestern Saga prefecture (Fig. 6), with a population of ~120,000 and an area of 487.6 km², accounting for ~20% of Saga prefecture (Table IV). The top-ten industries within this city, in terms of production value, are: manufacturing (20.4%), services (11.7%), wholesale/retail (10.5%), real estate (10.2%), construction (6.2%), producers of government services (5.1%), transportation (4%), information and communications (2.9%), finance/insurance (2.9%), and electricity/gas/water (2.7%) [28].

A feasibility study on the overall design for an area surrounding Karatsu City's water purification center was conducted in 2019 as a part of a project to construct a "Karatsu Smart Resilience Base" in Karatsu city. In July 2019, regional energy companies, such as Karatsu Power Holdings, Inc., were established as local PPSs. Karatsu city plans to establish a system for local production of energy for

local consumption and realize its version of a regional CES by 2030, using these companies as the core of the project, launching diverse businesses including electricity retailing and mobility services (Table V). Fig. 7 shows the visual schematizations of the concepts and key elements of this project.

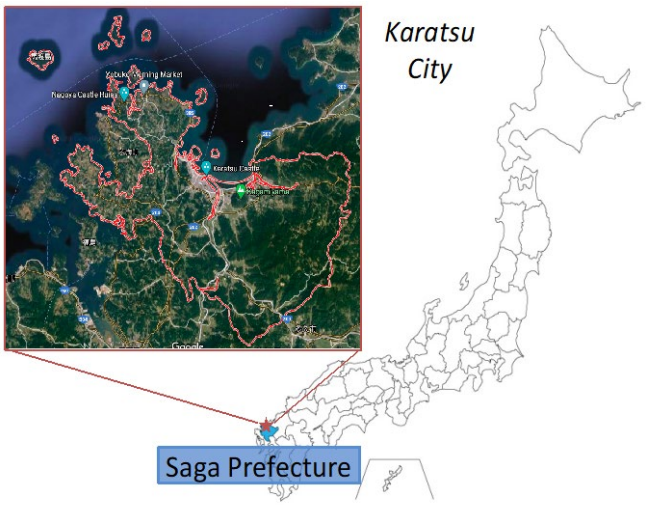


Fig. 6. Geographical location of Karatsu city.

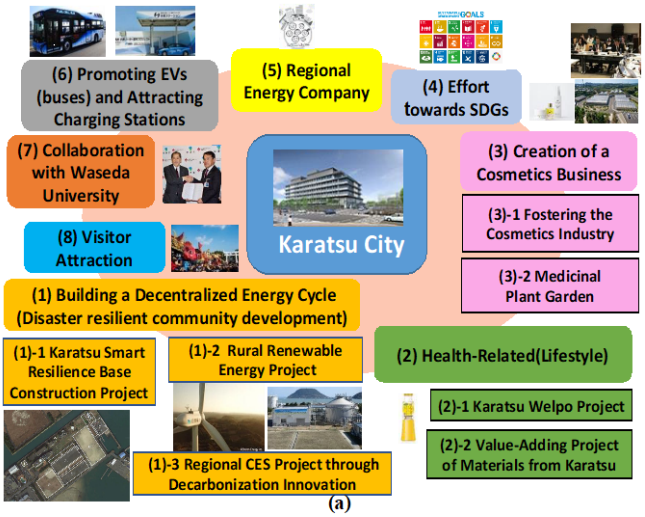
TABLE IV: SOCIOECONOMIC OVERVIEW OF KARATSU CITY (2019)

Population/number of households	121,278 /50,876
Area (km^2)	487.6
Government revenue/expenditure	67.7 million yen
Total production*	346 million yen
Industrial composition (primary industries: secondary industries: tertiary industries)	12.2:22.1:65.7

*Data from 2016 [28]

TABLE V: KEY STEPS TOWARD REALIZING KARATSU'S REGIONAL CIRCULAR AND ECOLOGICAL SPHERE

Year	Schedule
2019	Feasibility study Establishment of regional energy companies (July)
2020	Introduction of equipment and facilities
2030	Establishment of a system for local production of energy for local consumption with regional energy companies at its core



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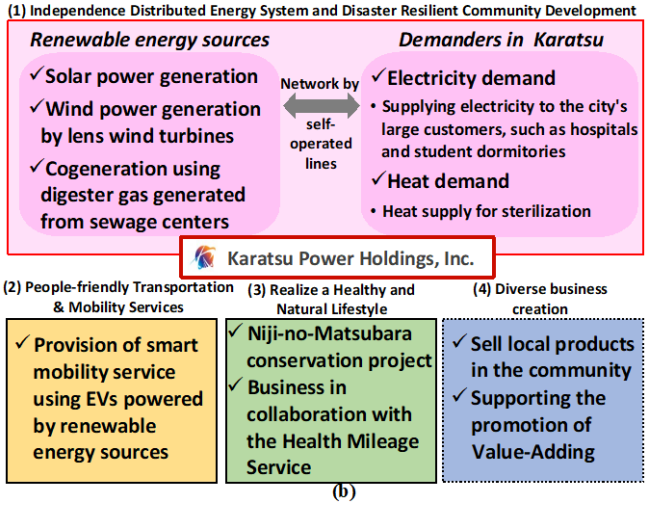

(b)

Fig. 7. Overview of Karatsu's version of a regional CES.
(a) Schematization of the project for the regional CES
(b) Project and business map.

1) The operators of local PPSs and their roles

The local PPS Karatsu Power Holdings, Inc. has a total capital of ¥10 million. Below is a list of its investors and their funding ratios.

- Karatsu Gas Co., Ltd. (65%)
- Shizen Energy Inc. (15%)
- Bizen Wind Power Energy Development (5%)
- Karatsu Shinkin Bank (5%)
- The Bank of Saga Ltd. (5%)
- Asutasuku (5%)

Among these companies, Karatsu Gas, as a regional city gas company, has assumed the role of leading the business. The local financial institution Karatsu Shinkin Bank has assumed the role of leading business management support and making use of public funds.

While Karatsu city has not been funding the local PPS directly, its involvement has been indirect through efforts such as leading the exploration of measures to maximize the regional ripple effects while considering the regional characteristics.

2) Renewable energy-related efforts

The plan in Karatsu city is to achieve a renewable energy usage (electricity) of 17,021 MWh/year (i.e., electric power for approximately 3,871 households) by 2030, thus increasing the rate of local consumption of regional renewable energy to 22%. This is expected to reduce CO_2 emissions by 2,325 T/year (i.e., emissions of ~726 households). Furthermore, for heat utility, the introduction of cogeneration is underway in Karatsu City from the perspective of disaster prevention after the city suffered from both the Kumamoto earthquake in 2016 and the Western Japan heavy rain disaster in July 2018. In this regard, it is necessary to consider both the demand for heat and the value of independent heat generation.

So far, from the two viewpoints, i.e., the operators of a local PPS and their roles and renewable energy-related efforts, we have discussed the potential of regional CES concepts being embodied in Ishikari, Hokkaido and Karatsu, Saga as Japanese versions of Stadtwerke. Next, we discuss the embodiment of "maximization of regional public

interest" —an essential concept in the context of designing a Japanese version of Stadtwerke—in relation to the Community Development Project in Yukarigaoka that has been implemented in Sakura city in Chiba prefecture.

C. Community Development Project in Yukarigaoka

Yukarigaoka is located in Sakura city in Chiba prefecture, within a 38 km radius of and a 45-minute commute to central Tokyo (Fig. 8). The community development project was undertaken by Yamaman Co., Ltd., with a capital of ¥3 billion [29], which specializes in real estate, property development, and railroad construction. The development started in 1971, and it has since involved the introduction of a housing unit sale system and mobility services (Table VI). Today, the total developed area is approximately 245 ha, the total planned number of housing units approximately 8,400 (7,600 households as of April 2020), and the total planned population approximately 30,000 (at present, 18,697) [30]. The private corporation Yamaman Co., Ltd. has been managing the development of this town from various aspects, including the sale of housing units, commercial zone development, healthcare/welfare services, and transport systems (Fig. 9).

Fig. 8. Geographical location of Yukarigaoka.

TABLE VI: HISTORY OF YUKARIGAOKA [30]

Year	Events
1971	Yukarigaoka's town development starts.
1979	Sale of housing units begins (200 units/year).
1983	Yamaman Yukarigaoka Line commences full operation (total length: 5.2 km).
1987	Introduction of urban-type cable television (CATV)
1992	Sky Plaza commercial facility (presently Aeon) opens.
2004	Crime and disaster prevention "Patrol Center" opens.
2012	Miraia district opens.

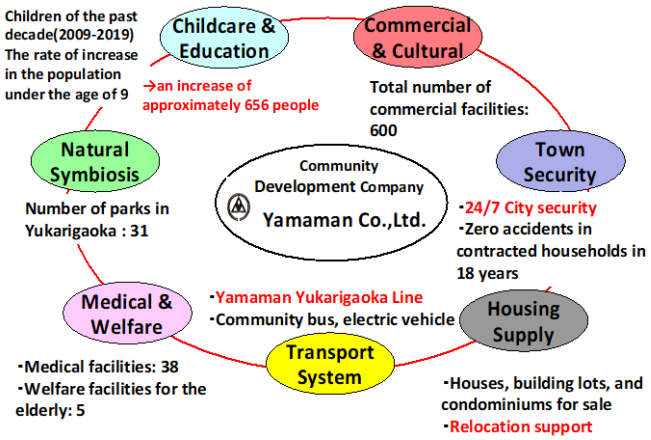

Fig. 9. Community development project in Yukarigaoka [30].

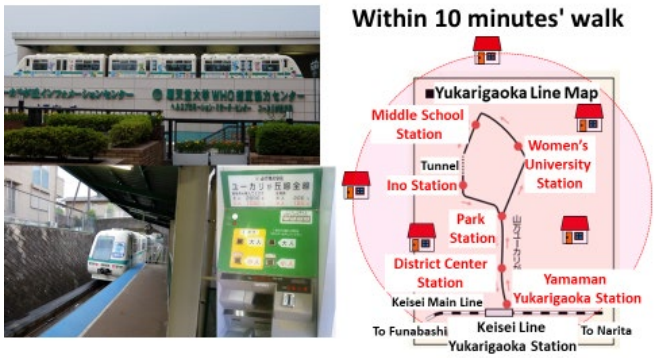

Fig. 10. Photograph and line map of the mobility system Yukarigaoka Line.

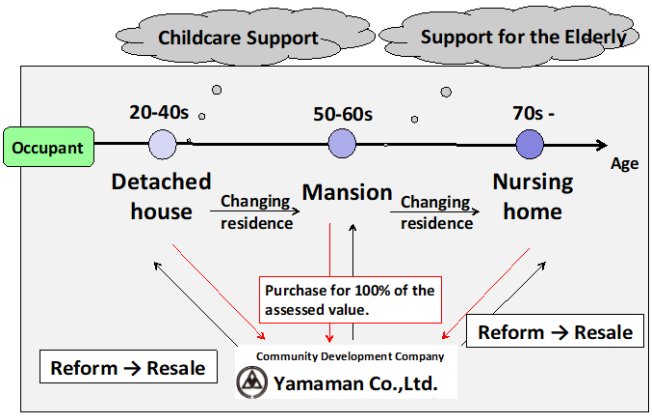

Fig. 11. Mechanism of the "Happy Circle System" of Yukarigaoka.

Additionally, the Community Development Project in Yukarigaoka has two unique systems.

1) Yamaman yukarigaoka line

The Yamaman Yukarigaoka Line commenced full operation in 1983 as a unique transport system using noiseless, pollution-free electric trains. The total length of the line is 5.2 km, and the trains travel between six stations within the town in 14 minutes. From any housing unit, the closest station is accessible within 10 minutes by foot (Fig. 10). Additionally, as a response to societal aging, electric buses have been introduced as a mobility system to facilitate access from homes to the stations.

2) Yukarigaoka happy circle system

The "Happy Circle System" is a unique system used to promote the circulation of the generations of residents in Yukarigaoka by supporting their relocation. The system allows residents to relocate within Yukarigaoka by selling their old homes at 100% of the assessed values. Then, the homes are reformed and resold to younger generations (Fig. 11). The system is designed to create a generationally diverse community, improve town management, and raise property value.

V. TOWARD A JAPANESE VERSION OF STADTWERKE

Conventional approaches in the designs of Stadtwerke-inspired local PPSs in Japan include the distribution of roles among operators aimed at business sustainability and the introduction of renewable energy aimed at achieve a low-carbon society. However, these

approaches, by themselves, are insufficient to complete a Japanese version of Stadtwerke. The essence of Stadtwerke is the "maximization of regional public interest." This is unattainable without approaches where the introduction of renewable energy and the "maximization of regional public interest" major aims of the distribution of roles among operators. Failure to attain these creates the risk of developing self-serving local PPSs, which could bring about new regional monopolies.

Moreover, Japan's current electric power system has not been developed to introduce a "decentralized energy system." Approaches aimed at bridging the gaps of the existing system will only yield non-general solutions [17]. Concurrently (with technological development and demonstration projects), it is necessary to design a system that departs from the pre-existing framework, to seriously picture a society in which a Japanese version of Stadtwerke is complete.

Additionally, it is essential to understand that the value of local PPSs, as a potential Japanese version of Stadtwerke, lies in their potential function as local platforms that can provide various services aimed at resolving social issues. Such functions should be combined and intertwined with the primary, energy-based business of local PPSs. Overall, strides need to be made to develop a blueprint of a Japanese version of Stadtwerke, that incorporates diverse and concrete approaches for the maximization of regional public interest, considering social demands and departing from the current excessive focus on electricity. Instead, energy provision should be considered as only one of multiple sources of income for local PPSs.

VI. Conclusion

Below is a conclusion of issues and courses of action needed for the development of a Japanese version of Stadtwerke, based on the cases in Karatsu, Ishikari, and Yukarigaoka.

1) Operators of a Japanese version of Stadtwerke

It is necessary to design a sustainable business entity, adopting a public-private collaboration model in which the regional government assumes leadership, involves diverse regional enterprises to ensure the progress and effectiveness of the business, and makes an effort to gain the trust of the residents through enhancement of public services.

2) Renewable energy-related efforts

It is necessary to design a mechanism that will allow regional renewable energy resources (electricity and heat) to be used as the basis for regional public services while ameliorating the pre-existing imbalance of renewable energy power sources by reducing the disproportionate predominance of solar power.

3) Concrete plans for the maximization of regional public interest

It is necessary to consider the local needs sufficiently and then to design original public services tailored to the needs. In particular, local mobility is directly related to regional issues in Japan. Considerations for not only infrastructure but also specific regional situations are necessary.

For future work, it is necessary to study and compare the case studies of local PPSs not only in Japan but also overseas, such as those in Europe and developing countries.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Shuheng Zhao conducted the literature review, analyzed data, and wrote the paper; Hiroshi Onoda designed and supervised the research; all authors had approved the final version.

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