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Making Renewable Energy a Mainstay Power Source through Local Production for Local Consumption

—The key is to transform consumer behavior with electricity rates that reflect costs—

Michinori Naruse*

naruse.michinori@jri.co.jp

<Summary>

◆ The government has set an ambitious goal of achieving carbon neutrality by 2050. To realize this goal, renewable energy must become the main source of electricity. In the case of power systems that mainly use renewable energy, (1) the cost of adjustment of supply and demand, such as investment in storage batteries and demand response (DR, Adjust Power Consumption on the Demand Side), and (2) the cost of investment in the transmission network from the new power plant to the place of demand will additionally arise. Therefore, even if the cost of generating electricity from renewable energy is reduced, the total cost is expected to increase compared to the current electricity system centered on thermal power generation. These costs must be kept as low as possible and the benefits must outweigh the costs.

◆ The share of renewable energy in Japan's power generation is just under 20%, lagging behind Europe. While wind power generation using westerlies has been the driving force in Europe, solar power generation has been the driving force for the expansion of renewable energy in Japan. In the case of solar power generation, there are frequent occurrences of power surpluses during the daytime, and strengthening supply-demand adjustment is an urgent issue in Japan. In this situation, large users are promoting the use of DR, but among small users such as housing, DR has barely spread at all because electricity rates are on a pay-per-use basis and incentives are scarce.

◆ Conventional electric power systems, mainly thermal power generation, can be said to be

* Vice Senior Economist(Economics Department, JRI).

large-scale centralized, but considering the following four points, it would be more efficient to switch to a local production for local consumption type electric power system in Japan in order to make it a main source of renewable energy.

The first point is an increase in the burden of grid maintenance. The cost of maintaining the transmission network can be reduced by promoting local production for local consumption, while the cost effectiveness of maintaining the transmission network is expected to deteriorate due to depopulation in many regions.

The second point is underinvestment in interconnections due to regional monopolies. In Japan, transmission networks have been established within the jurisdiction of major electric power companies, and investment in interconnection lines connecting regions has been kept to a minimum. If large-scale concentrated renewable energy sources such as offshore wind power are to be used as a main source of electricity, it will be necessary to invest heavily in the construction of a new power transmission network that will link supply areas such as Hokkaido with major consumption areas such as Tokyo.

The third point is that there is a shortage of suitable sites for large-scale centralized renewable energy. In Japan, where wind conditions are poor, offshore wind power is more expensive than other renewable energy sources. In addition, there are fewer shallow beaches, limiting the locations where ground-based offshore wind systems can be installed. Mega solar plants also have limited room for additional installation due to the small flatland area.

The fourth point is the existence of ECHONET Lite, a standard for the consumer electronics IoT. In order to promote local production for local consumption type renewable energy, it is essential for small consumers such as houses to participate in DR. For this purpose, Japan has already developed a standard that can collectively control home appliances. Globally, there is no standard that allows unified control of home appliances from different manufacturers other than ECHONET Lite.

◆ The measures taken by the preceding regions will be useful for studying specific aspects of local production and local consumption of electricity and measures to promote them. Fujisawa SST, a smart city centered on low-rise houses, has installed solar power generation facilities and household storage batteries in all of its households, and has established a system that allows each household to consume its own electricity. At Kashiwa-no-ha Smart City, which consists of mid-to-high-rise buildings, solar power generation facilities have been installed on the rooftops of the buildings, and supply and demand have been adjusted among users in the area using large shared storage batteries and private lines. In Iida City, Nagano Prefecture, which is blessed with a rich natural environment, in addition to photovoltaic power generation for residential use, various renewable energy sources, such as mega solar power, small and medium hydroelectric power, and biomass, are being introduced to promote local production and local consumption of electricity.

◆ From these examples, the following issues emerge. The first is the installation of a distributed power source. Residential photovoltaic power generation, which can make effective use of roofs, is one of the most promising distributed power sources in the limited area of flat lands, but some kind of device is required to promote its introduction nationwide. The next issue is the adjustment of supply and demand within the region. Under the current system, it is necessary to establish a self-employed line in order to obtain economic benefits through adjustment of supply and demand among users in the region. In order to promote local production for local consumption nationwide, it is necessary to make use of existing power distribution networks to adjust supply and demand within the region.

◆ In the case of electric power systems that mainly use renewable energy for local production and local consumption, the role of users will be significantly expanded, such as installation of power generation facilities and implementation of DR. In order to encourage consumers to change their behavior, it is effective to reflect costs in electricity rates and make the most of market mechanisms. Specifically, the following three points are required.

The first point is the introduction of carbon pricing such as a carbon tax. If the introduction of a carbon tax could raise electricity rates, it would be economically reasonable for consumers to consume their own electricity by installing solar power generation facilities.

The second point is the spread of dynamic pricing. Because electricity rates fluctuate according to supply and demand conditions, consumers can benefit from DR. In order to promote dynamic pricing, it is essential to mature the wholesale market, which is an index of electricity rates.

The third point is reform of the consignment fee. At present, the wheeling fee, which is the cost of transmission and distribution, is fixed regardless of the distance of wheeling, and this hinders incentives to adjust supply and demand in neighboring areas. Transportation fees should take into account actual costs such as distance.

◆ The main objective of promoting the use of renewable energy sources for local production and local consumption is to achieve carbon neutrality efficiently, but at the same time, it is expected to achieve other benefits. Specifically, (1) creation of local jobs and revitalization of local communities through installation and maintenance of power generation facilities,

(2) realization of smart homes through integrated management of home appliances, and (3) utilization of power data in other fields such as business area analysis and advertising.

- **This is a English version of "地産地消による再生可能エネルギーの主力電源化を — コストを反映した電気料金による需要家行動の変容が鍵 —" in JRI Review (The original version is available at https://www.jri.co.jp/MediaLibrary/file/report/jrireview/pdf/12984.pdf)**

1. Introduction

The Japanese government has set an ambitious goal of achieving carbon neutrality by 2050. In order to achieve this, it is necessary to thoroughly replace fossil fuels such as gas and gasoline with electricity, and to gradually reduce or eliminate thermal power generation, which currently accounts for about 3/4 of the total, and replace it with decarbonized power sources[1]. Even if the restart of nuclear power plants, whose operations have declined significantly since the Great East Japan Earthquake, is pushed forward to a certain extent, public opinion is not in a position to approve the large-scale expansion of nuclear power plants[2]. To achieve carbon neutrality, renewable energy must become the main source of electricity.

The largest problem for the main power source of renewable energy is its high cost. In recent years, due to technological innovation and mass production, the cost of power generation from some renewable energy sources, such as solar power generation, has fallen to the level of thermal power generation. However, in order to turn renewable energy into a mainstay power source, in addition to power generation cost, the following two additional costs will arise, so the total cost is expected to greatly exceed that of the current power generation system centered on thermal power[3].

The first additional cost is the cost of adjusting power supply and demand. Power must always match supply to demand. If thermal power generation was the main source of power, as in the past, it would have been better to adjust the amount of power generated at the supply-side thermal power plant to meet demand. On the other hand, since power generation from renewable energy is subject to natural conditions such as the weather and it is difficult to adjust the output, it is necessary to store surplus power in storage batteries and take measures such as discharging when the amount of power generation becomes insufficient. Since storage batteries are expensive, in order to control supply and demand at low cost, it is necessary to use digital technology such as the EMS (Energy Management System)[4] and to adjust as much as possible on the demand side (known as demand response (DR)[5]), which has not been fully utilized so far.

The second additional cost is the cost of the transmission network. Currently, power transmission networks are in place from thermal power plants to demand areas. However, since the optimal location for renewable energy is generally different from the location of existing power plants, it is necessary to build new power transmission networks to demand areas. In particular, while Hokkaido and Kyushu are suitable places for renewable energy, the Tokyo metropolitan area and the Kansai region have a large demand for electricity, and an enormous amount of investment is required to connect these regions. However, the use of renewable energy sources for local production and local consumption will reduce investment in new power grids.

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1 There is also the idea that thermal power generation can be maintained through combining it with the storage of carbon dioxide such as CCS (Carbon dioxide Capture and Storage) and CCUS (Carbon dioxide Capture, Utilization and Storage). However, a drastic reduction in thermal power generation is still necessary because storage technology has yet to be established and it is difficult to secure storage sites.

2 The share of nuclear power accounting for Japan's power generation fell from 25.1% in fiscal 2010 to 0.0% in fiscal 2014. Although the reactors have gradually been restarted since then, the ratio stood at 6.2% in fiscal 2019, far below the level before the Great East Japan Earthquake.

3 The cost of accepting power into a power system, which is separate from the cost of generating individual power sources, is sometimes referred to as the "integration cost." However, the specific scope and content of the integration cost varies depending on the situation in which it is used.

4 A system to visualize energy such as electricity, gas, and heat, and to optimize the operation of equipment for energy-saving.

5 In some cases, DR is limited to a mechanism for adjusting demand through market transactions, which has been observed in recent years. In this paper, however, we will broadly refer to the adjustment of power consumption by the demand side as DR.

In making renewable energy a mainstay power source, it is necessary to minimize such costs as much as possible and to realize benefits that exceed the costs. To achieve this, what kind of power system should we aim for and how can we realize it? These are the questions considered herein.

First, what kind of power system should we aim for? The current power system can be said to be a "large-scale centralized power system," but if renewable energy is to be used as a mainstay power source, it would be more efficient to use a "local production for local consumption" system, in which investment in the power transmission network is restrained. In thermal power generation, the larger the power plant, the more efficient it becomes, but this does not necessarily apply to renewable energy[6]. Rather than simply following the conventional "large-scale centralization" approach, a comprehensive review should be conducted with a focus on costs.

Next, what are the means by which the desired power system can be realized? In the case of renewable energy, the role of users in the power system will be significantly greater than in the past, including the installation of power generation facilities by users and the implementation of DR. This is especially true in the case of local production for local consumption. However, the Sixth Basic Energy Plan, which was decided on by the Cabinet in October 2021, contains many small measures, and the government has failed to present any fundamental measures to encourage consumers to change their behavior.

The structure of this paper is as follows. First, Chapter 2 summarizes basic information on the introduction of renewable energy and the use of DR in Japan. Chapter 3 shows that promotion of local production for local consumption is efficient in Japan, taking into account differences in the environment compared to Europe. Chapter 4 summarizes cases and issues in regions where local production and local consumption are being promoted in advance. Chapter 5 proposes measures required to promote local production and local consumption nationwide. And Chapter 6 shows the merits, other than decarbonization, that should be pursued at the same time as promoting the conversion of renewable energy into mainstay power sources and local production for local consumption.

2. Introduction of renewable energy and DR in Japan

(1) Status of introduction of renewable energy

According to the International Energy Agency (IEA), renewable energy accounted for only 19.0% of Japan's total power generation in 2019, which is low compared to other countries (Figure 1). In general, the power generation potential of renewable energy is proportional to the area, while the power demand is proportional to the population. Therefore, countries with a low population density have an advantage in expanding the use of renewable energy. Japan, with its high population density, is somewhat at a disadvantage, but even taking this into account does not explain the significant gap between Japan and Germany or the United Kingdom, indicating that Japan is behind in its efforts[7].

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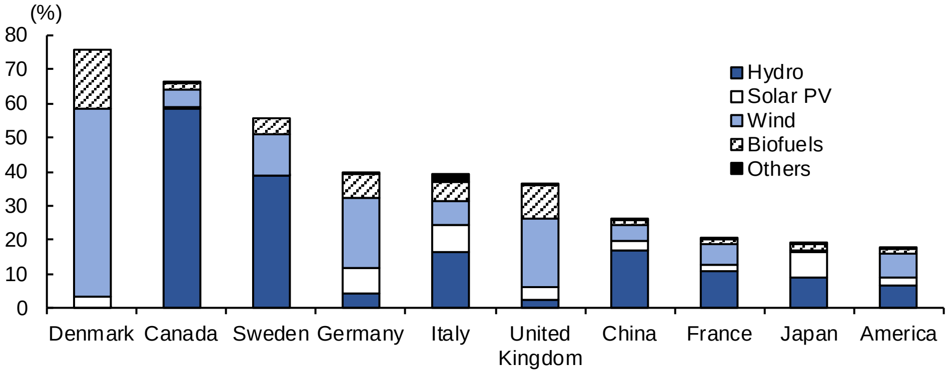
6 In general, the larger a heat engine is, the more efficient it becomes. This is mainly because the ratio of the surface area (proportional to the heat loss) to the volume (proportional to the output) decreases as the size increases.

7 France and the United States are on par with Japan, but France's main energy source is nuclear power, and the United States has been reluctant to promote decarbonization under the Trump administration.

Figure 1 Ratio of Renewable Energy to Total Power Generation (2019)

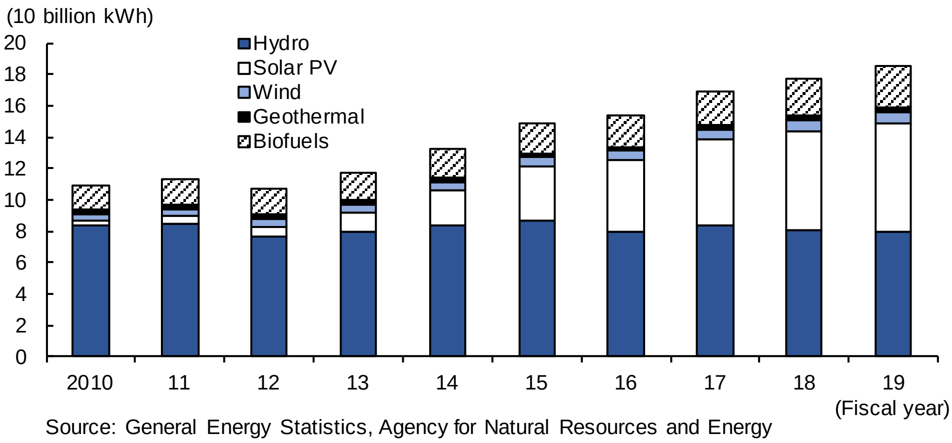


Source: Data and statistics, IEA, Japan Research Institute
Note 1: Others are geothermal and tidal power.
Note 2: In China, 2018.

The breakdown of renewable energy types varies greatly depending on the environment of each country. In Sweden and Canada, both large countries with many steep mountains, the share of hydropower is high. On the other hand, many European countries, especially Denmark, the UK, and Germany, have high rates of wind power generation because they can utilize westerlies throughout the year. Of all the renewable energy sources, the output of photovoltaic power generation and wind power generation is greatly influenced by natural conditions, which is called variable renewable energy (VRE). The higher the ratio of VRE, the greater the need for batteries and DR.

Looking at the trends in renewable energy for Japan's power generation, hydroelectric power and photovoltaic power are the two main sources, but only photovoltaic power generation has expanded since the beginning of the 2010s (Figure 2). In Japan, the development of hydroelectric power has been actively pursued since the Meiji period, and during the period from the 1900s to the 1950s, when the demand for electric power was lower than it is now, hydroelectric power was the mainstay of power generation, known as "suishu kaju." Historically, most suitable sites for large-scale hydropower generation had already been developed, and it is currently not easy to expand further, with the ratio of hydropower generation remaining unchanged in recent years.

Figure 2 Renewable Energy Power Generation in Japan



Source: General Energy Statistics, Agency for Natural Resources and Energy

On the other hand, in the case of solar power generation, although Japanese companies have been leading its technological development on a global scale, backed by the Sunshine Project[8], which was formulated in response to the first oil crisis in 1973, the introduction of solar power was limited for a time due to its high cost. The situation changed drastically when the government of the Democratic Party of Japan established the Feed-in Tariff (FIT) scheme for renewable energy in July 2012 following the Great East Japan Earthquake. With FIT, electric power companies would purchase the power generated by photovoltaic power generation at a fixed price (the purchase price at the time of establishment of the system was 42 yen/kWh) for 20 years so that the profitability of the power generation business would be sufficiently ensured. This resulted in rapid expansion of the introduction of photovoltaic power generation, mainly by mega solar[9]. Although renewable energy sources other than solar power, such as wind power and geothermal power, are also subject to FIT, they are not growing as much as solar power generation, partly because development takes time.

For the time being, the expansion of renewable energy will be largely dependent on solar power generation capability, which can be installed in a short period of time. In fact, the 6th Basic Energy Plan states that Japan will aim to increase the share of renewable energy in total power generation by 2030 to around 36-38%, but most of this will continue to depend on the expansion of solar power generation (Figure 3). The Japanese government has no specific outlook for the future after 2030, and although the power mix for 2050 is only shown for reference, the government is considering significantly increasing offshore wind power to achieve carbon neutrality. In any case, solar power generation and wind power generation, which are VRE forms, are expected to be the main sources of renewable energy.

Figure 3 Composition of Power Sources in the Basic Energy Plan

(%)

	FY 2019 Achievements	2030 Planning	2050 Reference Value
Solar PV	6.7	14~16	
Wind	0.7	5	
Geothermal	0.3	1	
Hydro	7.8	11	
Biofuels	2.6	5	
Renewable Energy	18.1	36~38	50~60
Thermal	75.7	41	30~40
Nuclear	6.2	20~22	
Hydrogen and Ammonia	0.0	1	10
Total	100.0	100	100

Source: Agency for Natural Resources and Energy, Japan Research Institute

(2) DR Usage

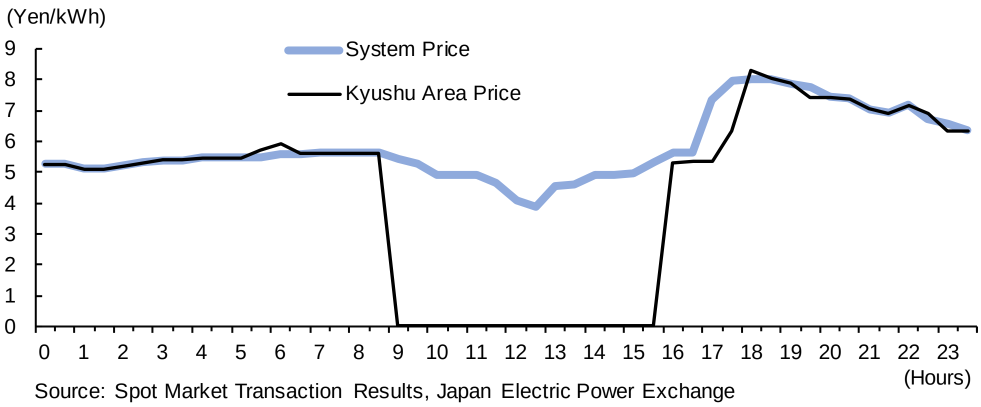
As mentioned above, if the ratio of solar power generation and wind power generation increases, the need to adjust supply and demand through storage batteries and DR will increase. In Kyushu, where the proportion of solar power generation is large in Japan, there are many situations in which electricity generated by solar power

8 Plans to develop new energy technologies, including solar energy. Before it was integrated into the New Sunshine Project in 1993, a total of 532.2 billion yen was spent on 14 projects.

9 As of December 2019, of the cumulative installed capacity of 53.3 GW for solar power generation, 41.8 GW was more than 10 kW (mainly mega solar), and 11.5 GW was less than 10 kW (mainly residential), mainly mega solar. On the other hand, in FY 2012, of a total of 6.7 GW, more than 10 kW accounted for 1.0 GW, and less than 10 kW accounted for 5.7 GW. This suggests that the majority of photovoltaic power generation before the introduction of FIT was for residential use.

during the daytime on sunny days is not used up. In fact, from 9 a.m. to 3 p.m., the wholesale price of electricity in the Kyushu area peaked at the lowest price of 0.01 yen/kWh (Figure 4). In such a state of surplus electric power, the output control is applied to the photovoltaic power generation business or the like, and during that time, the capacity of the power generation facility is underutilized. Even if the amount of installed solar power generation facilities is increased further, the operation rate will further decrease due to output control unless surplus power is stored or demand is shifted during peak power generation. Since storage batteries are expensive, for example, at around 2 million yen for household use, maximum use of DR is required in order to control supply and demand at low cost. The need for DR is expected to increase nationwide as solar power generation expands in the future.

Figure 4 System Price and Kyushu Area Price (April 5, 2021)



Source: Spot Market Transaction Results, Japan Electric Power Exchange
Note: The system price is a price that combines the bidding information of buyers and sellers all over Japan and matches supply and demand. In fact, between areas, as transmission capacity is limited, the price in each area deviates from the system price when there is a bias in the supply-demand situation among regions.

Even before the spread of solar power generation, a DR framework was in place for large users such as large factories. However, in the past, the main purpose of DR was not to respond to fluctuations on the supply side, but rather to peak cuts on the demand side, that is, to equalize demand. Even if the amount of power generated at a thermal power plant can be adjusted on the supply side, it is inefficient to prepare a power plant that is not normally in operation for only a short period of peak demand[10]. Therefore, by reducing the peak on the demand side, the balance between supply and demand can be equalized.

DR can broadly be divided into two types: the electricity rate type and the incentive type. The charge type DR is designed to suppress demand in times of tight supply by setting the charge high when the supply is tight and low when there is room. In the past, supply and demand for electricity was tight during the daytime on weekdays, when economic activity was brisk, so many electric power companies set their electricity rates at lower rates at night and on holidays. For this reason, companies in industries such as electric furnaces, where electricity rates account for a high percentage of their sales costs, have contributed to cutting peak electricity demand during the daytime on weekdays by shifting factory operations to nighttime or holidays and producing when electricity is at lower rates.

Incentive-based DR is a system in which a customer receives compensation in exchange for adjusting demand

[10] The Demand Response Council website states, "About 10% of power system costs are typically spent on peak demand, which is less than 1% of the time."

based on a request from an electric power company. In the past, electric power companies have concluded contracts with some large users to pay compensation when they cooperate in curbing demand during an emergency. However, these contracts were infrequently activated, as they were for emergencies only. In recent years, with the expansion of solar power generation, there has been a growing need to flexibly adjust the demand side in response to supply fluctuations. For example, the negawatt market[11] (March 2016), the capacity market [12](March 2020), and the supply-demand adjustment market[13] (April 2021) were established one after another, and institutional arrangements are being made so that supply and demand can be flexibly adjusted by utilizing the market. Large-Volume customers are required by investors and business partners to take steps to decarbonize, and FEMS[14] and BEMS[15] are already widespread, so it is expected that the utilization of DR will be strengthened to a certain extent in the future while utilizing these markets.

On the other hand, small consumers, such as those who live in houses, do not use DR at all, whether the electricity rate type or the incentive type. Because liberalization of the retail sales of low-voltage power was delayed in April 2016 compared to special high-voltage (March 2000) and high-voltage (April 2004 and April 2005), most users are still applying the conventional metered rate system[16]. In the first place, before the current smart meter was installed, the meter reader used an analog meter to read the meter once a month, so it was not even possible to grasp the state of power consumption by time zone. In addition, since the effect of DR per case is small for small consumers, the cost-effectiveness would be considered to be poor even if an incentive type DR were to be implemented by negotiating individually and entering into a contract.

3. Effectiveness of Local Power Production for Local Consumption in Japan

In promoting the use of renewable energy as a main source of power in Japan, there are two major approaches: large-scale centralization, and local production for local consumption. In reality, choosing one or the other is not necessary, as the most practical approach is considered to be in the middle, but it is necessary to plan a strategy considering which power system will be closer in the future. Design of the system and operation of supply and demand adjustment will differ accordingly.

It can be said that conventional electric power systems centered on thermal power generation and nuclear power generation are large-scale centralized systems in which power is generated at large-scale power plants and transmitted to demand areas. Even if the main power source is shifted to renewable energy, the idea is that large-scale concentrated power generation would be maintained by offshore wind power and mega solar power. On the other hand, another idea is to shift the emphasis to local production for local consumption by generating

[11] A market for trading the value of electricity savings.

[12] A market to trade power for the future (four years later). The Organization for Cross-regional Coordination of Transmission Operators secured the contract through bidding. Bidding is mainly done from the supply side, such as thermal power generation, but it is also possible for the demand side to bid through DR.

[13] A market for adjusting the supply and demand of electricity. There are 5 product categories, of which the third-order adjustment force (2) with the longest response time of 45 minutes started trading in April 2021. Deals in the remaining four product categories will also begin.

[14] Factory Energy Management System

[15] Building Energy Management System

[16] There are three types of contracts for customers to purchase electricity: low-voltage, high-voltage and extra-high-voltage. Of these, low voltage is less than 50 kW for small customers such as houses and shops, high voltage is 50 kW or more but less than 2,000 kW for companies and small and medium sized factories, and special high voltage is 2,000 kW or more (and 20,000 V or more) for large customers such as large factories and railway companies.

electricity in demand areas as much as possible, including residential solar power generation.

A power system based on local production for local consumption has many advantages such as low cost of investment in the transmission network, low transmission loss, and effective use of heat during power generation (Figure 5). On the other hand, many challenges need to be overcome, such as the need for a large number of entities, including small consumers, to install power generation facilities and participate in DR. If the balance of supply and demand is consistent throughout Japan, it would be possible to respond to this situation to a certain extent by strengthening DR by large consumers. However, when promoting local production for local consumption, in principle, it is necessary to aim for a supply and demand balance in each region, and DR by small consumers is also essential. This is because in addition to the fact that there are areas, such as residential areas, with no large-volume users, electricity needs to be prevented, in principle, from reverse tides from low pressure to high pressure, and it is difficult for large-volume users, such as extra-high pressure users, to use excess electricity generated at low pressure (see the column for details).

Figure 5 Characteristics of Large-scale Centralized Power Generation and Local Production for Local Consumption of Renewable Energy

	Large-scale Centralization	Local Production for Local Consumption (Distributed Type)
Typical Power Generation Facilities	Offshore Wind, Mega Solar, etc.	Residential Photovoltaic Power Generation, etc.
Power Generation per Facility	Large	Small
Number of Power Supplies Required	Few	Abounding
Location of Power Generation Facilities	All of Japan Possible	Installation in the Vicinity of Demand Areas
Investment in Transmission Facilities	Large Burden	Small Burden
Supply-demand Adjustment	Coordinated over a Wide Area	Adjust Locally
DR Participants	Mainly Large Customers	Small Consumers also Need to Participate
Investment In batteries	Need	Need
Transmission Loss	Large	Small
Heat Utilization of Cogeneration, etc.	Difficult	Easy

Source: Japan Research Institute

Under these circumstances, Europe, which is leading the way in the spread of renewable energy, is promoting the use of renewable energy as a main power source while maintaining large-scale centralized power systems. In Europe, which is blessed with westerlies, offshore wind power, which is a typical large-scale concentrated renewable energy, is active, and the cross-border power transmission line grid is developed across the whole of Europe. Therefore, the need to balance supply and demand in each region is not high[17]. On the other hand, considering Japan's environment, which is elaborated in the following four points, it would be more efficient to

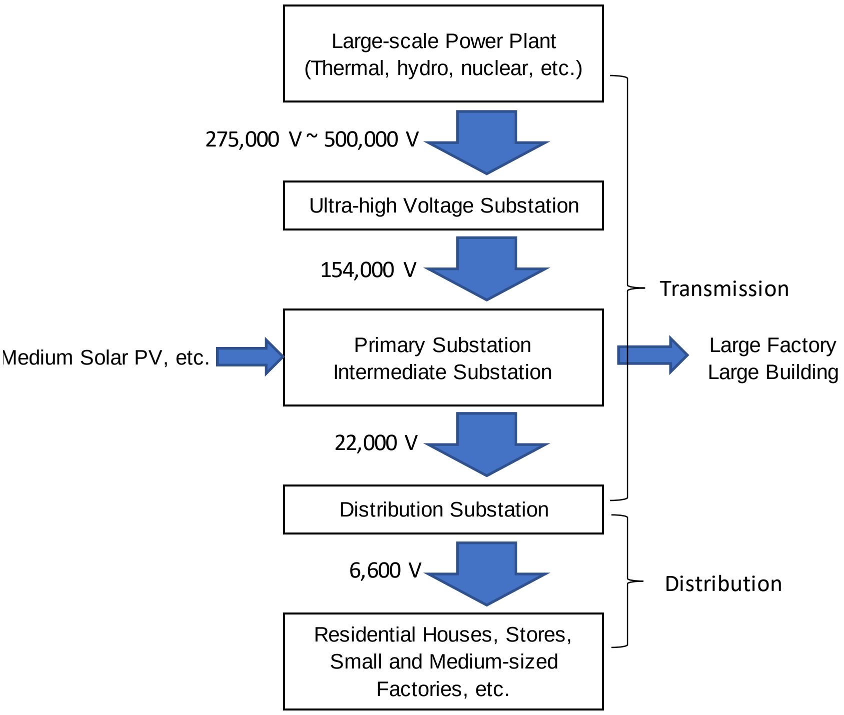
[17] In 1951, the Union for the Coordination of Production and Transmission of Electricity (UCPTE) was founded. European Coal and Steel Community (ECSC), regarded as the origin of the EU. It was established in 1952, and the integration of Europe began with the integration of energy markets. One of the reasons was with the energy security perspective with Russia (former Soviet Union) in mind. UCPTE is currently an organization called ENTSO-E, which manages the European Wide Area Transmission Network.

shift to a power system that focuses on local production for local consumption rather than following Europe's path.

[Column] Structure of Transmission and Distribution

Since the higher the voltage, the smaller the loss is during power transmission, power is transmitted at higher voltage from large-scale thermal, nuclear, and hydroelectric power plants to the vicinity of the demand area, and the voltage is lowered to 6,600 V at the distribution substation and delivered to the customer[18] (Figure 6). In transmission and distribution, the section from a large-scale power plant to a distribution substation is called "transmission," and the section from a distribution substation to a customer is called "distribution."

Figure 6 Transmission and Distribution Routes from Power Stations to Customers



Source: Prepared by the Japan Research Institute from the Federation of Electric Power Companies, etc.

Facilities such as substations are designed based on the assumption that the current flows from the higher voltage side to the lower voltage side, and when the current flows back (reverse tide), a large load is imposed on the facilities, while the loss of electric power also increases. Many distributed power sources, such as residential photovoltaic power generation, are connected to a 6,600 V distribution network. So, if supply exceeds demand in the distribution network, a reverse tide will occur from the distribution network to the transmission network. To avoid this, it is therefore necessary to adjust supply and demand in the distribution network.

18 The voltage is further reduced from 6,600 V to 100 V or 200 V by a pole transformer on a utility pole just before being drawn into a house.

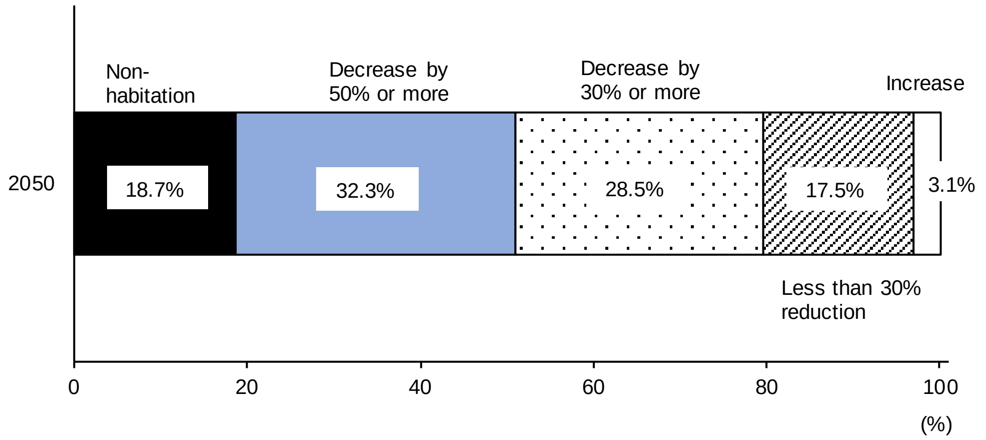
Large-Volume customers, such as large factories, cannot participate in adjusting supply and demand in the distribution network because they receive high-voltage power directly from the transmission network without using the distribution network. On the other hand, surplus electricity generated by medium-scale solar power generation directly supplied to the power grid can be effectively utilized even by large users in DR.

In addition, about 30% to 40% of the electricity rate is covered by the "wheeling fee," which is the cost of transmission and distribution.

(1) Increased burden of grid maintenance due to depopulation

The first point is that the cost of maintaining the transmission and distribution network can be reduced by promoting local production for local consumption as the population declines and the cost-effectiveness of maintaining the transmission and distribution network deteriorates. Japan's population peaked in 2008 and is expected to decline to about 100 million by 2050. The population decline will not be uniform across the country, but will remain relatively moderate in urban areas and be rapid in rural areas. According to an estimate by the Ministry of Land, Infrastructure, Transport and Tourism, about half of residential areas in Japan will experience a population decline of more than 50% by 2050 (Figure 7). If the current grid is maintained as is in the future, by simple calculation, the cost of transmitting electricity to these areas per person would more than double.

Figure 7 Number of Sites by Rate of Population Change in 2050
(1 km mesh base compared to 2015)

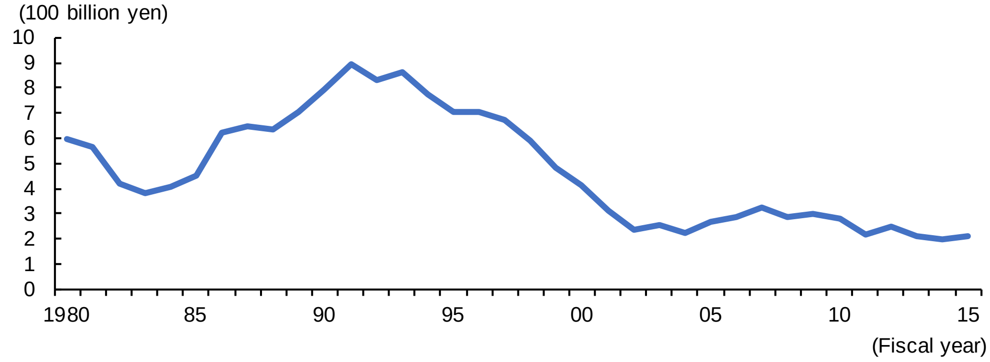


Source: Ministry of Land, Infrastructure, Transport and Tourism
Note: The number of sites is calculated by dividing each site by the rate of population change in each square kilometer of residential area in the country.

Furthermore, investment in Japan's power transmission networks peaked during the bubble period and then began to decline, and since 2000, investment has been held to a low level (Figure 8). When it is time to renew the transmission network facilities, it will be necessary to consider downsizing them and abolishing the transmission network to some areas, taking into account the prospects of population decline and local production and consumption of electricity, rather than maintaining the status mechanically.

In sparsely populated areas, the cost of transmitting electricity from large-scale power plants located far away is high per capita, but because of the low population density of the areas, it is relatively easy to meet electricity demand with renewable energy. In these areas, it may be more efficient to achieve complete local production and local consumption of electricity independent of the national grid.

Figure 8 Investment in Distribution Facilities of the Former Tokyo Electric Power



Source: Tokyo Electric Power Company Holdings
Note: Distribution facilities refer to transmission, transformation and distribution facilities.

(2) Underinvestment in interconnection lines through regional monopolies

Second, promoting local production for local consumption can reduce the cost of establishing new transmission networks from new large-scale renewable power plants to demand areas. In Japan, although liberalization of electric power has gradually been promoted since 2000, the regional monopoly system that comprised 9 major electric power companies[19] continued for a long time after the war, and each electric power company developed its own power transmission and distribution network within its own jurisdiction. Investment in interconnection lines connecting regions is kept to a minimum, and the amount of power that can be exchanged across regions is still limited. In Chapter 2, we introduced that there is surplus power in the daytime on a clear day in Kyushu, but because the capacity of interconnection lines is small, it is not possible to transmit all surplus power to areas such as the Kansai region, which is a major demand area.

Large-scale renewable energy power plants, such as those using offshore wind power and mega solar power, are suitable in Kyushu, Hokkaido and the Tohoku region, while electricity consumption is concentrated in the Tokyo metropolitan area and the Kansai region. Connecting these sources of electricity will require significant investment in new transmission networks. The Organization for Cross-regional Coordination of Transmission Operators estimates that if the ratio of renewable energy sources is increased to 42% by introducing 45 GW of offshore wind power, it will cost around 3.8 to 4.8 trillion yen to strengthen the power transmission network (Figure 9). While this estimate includes cost reductions due to economies of scale and technological innovation, it does not take into account increased costs due to route changes based on fisheries compensation costs and water depth, and there is concern that costs may increase.

In addition, copper prices, which have been rising rapidly since the latter half of 2020, pose a risk of cost

[19] The nine companies are: Hokkaido Electric Power, Tohoku Electric Power, Tokyo Electric Power, Hokuriku Electric Power, Chubu Electric Power, Kansai Electric Power, Chugoku Electric Power, Shikoku Electric Power and Kyushu Electric Power. Okinawa Electric Power is sometimes referred to as the 10th major Electric Power Company.

fluctuations (Figure 10). While the recovery of the global economy is helping to boost copper prices, some point to structural factors to realize a decarbonized society, such as the expected long-term expansion of demand for copper in power transmission lines and electric vehicles[20].

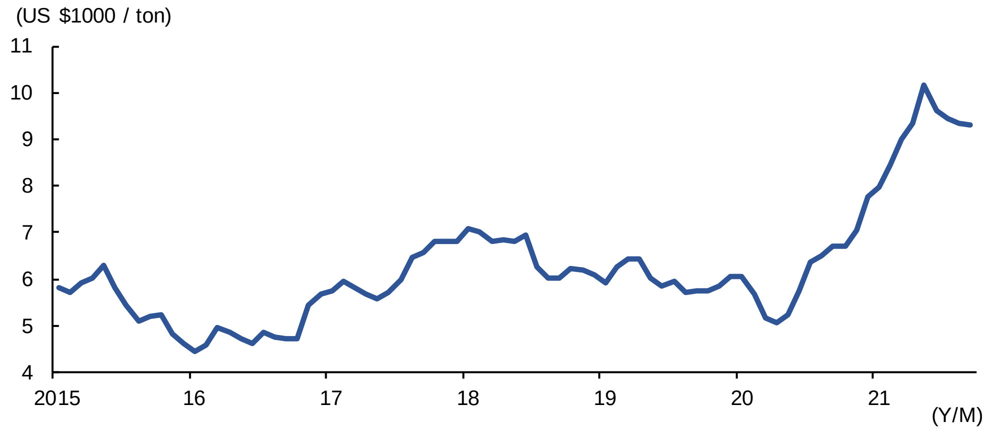
Considering the cost of investment in the power transmission network, if the cost of power generation is not significantly different between a large-scale centralized power generation system and a local production for local consumption system, the total cost of the local production for local consumption system will be smaller. In some densely populated areas, such as the three major metropolitan areas, it is difficult to cover all power consumption with renewable energy within the region. However, even in such cases, it is still possible to reduce the cost of investment in the power transmission network by installing power sources that consume as much power as possible from local sources, and reducing the amount of power that depends on areas outside the region.

Figure 9 Cost of Transmission Network Expansion when 45 GW of Offshore Wind Power is Introduced

Expansion Facility	Interconnect Capacity (GW)	Construction Cost (Billion Yen)
The Hokkaido-Tokyo Route (Undersea Cable) Newly Established	8	1,470~2,190
Measures for Operational Capacity between Tohoku and Tokyo	-	700~810
Reinforcement in Tokyo	-	380~530
Kyushu - Chugoku Route Reinforced	2.8 to 5.6	360
Kyushu - Shikoku Route Newly Established	2.8	580~640
Increased Routes between Shikoku and Kansai	1.4 to 2.8	130
Reinforcement in Chugoku	-	100
Middle Region (Chubu, Hokuriku, Kansai) Expansion	-	50
Total	-	3,800~4,800

Source: Organization for Cross-regional Coordination of Transmission Operators
Note 1: The unit price was adopted in anticipation of economies of scale and cost reduction of technological innovation.
Note 2: Submarine cable works do not include the cost of fishery compensation and route changes in consideration of water depth.
Note 3: Figures may not add up due to rounding.

Figure 10 Copper Price (LME Monthly Average)



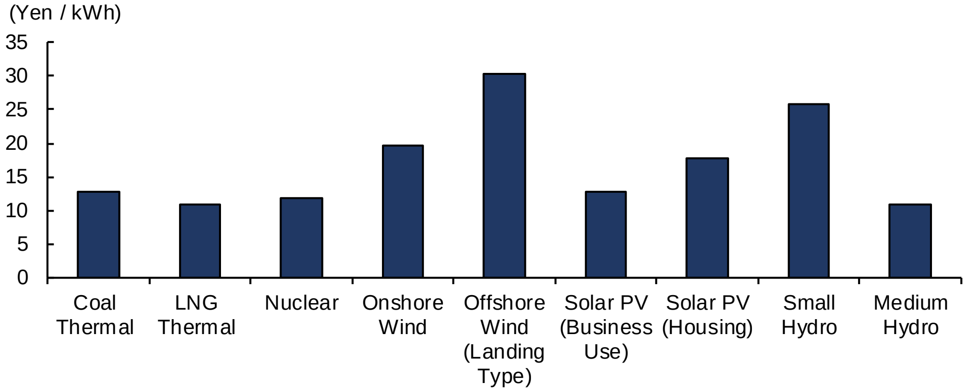
Source: Nikkei NEEDS

[20] On the other hand, reserves of copper are limited and it will gradually become necessary to use low-grade copper ore. In this case, the amount of energy required to supply copper increases, which is not only a cost increase but also contradicts decarbonization. By 2080, it is estimated that energy consumption for copper supply will be 16 times the current level.

(3) Lack of suitable sites for large-scale centralized renewable energy

Third, there is a shortage of suitable sites for large-scale concentrated renewable energy such as offshore wind power and mega solar power. Offshore wind power in Japan has a high cost relative to other renewable energy sources, partly because the country is not blessed with favorable wind conditions and has low power generation efficiency (Figure 11). In addition, although Japan is surrounded by oceans, there is little room for the introduction of offshore wind power with landings because there are few shallow shores. If a large amount of offshore wind is to be introduced, it will have to rely on floating wind turbines, which cost twice as much as landing-type wind turbines.

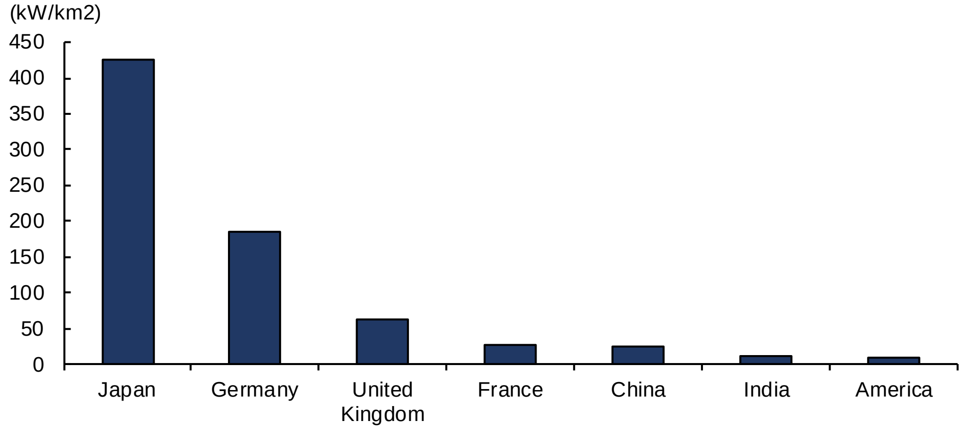
Figure 11 Power Generation Costs by Power Source in Japan (2020)



Source: Ministry of Economy, Trade and Industry, Japan Research Institute

Mega solar power generation has been leading the expansion of renewable energy with low generation costs, but it is becoming difficult to find additional installation space in Japan, which has few flatlands. Japan has the world's largest installed solar PV capacity per square foot (Figure 12), far ahead of Germany. Environmental problems and issues with local residents have already been seen sporadically, and it will not be easy to greatly expand mega solar power generation in the future.

Figure 12 Solar PV Capacity per Square Meter(2018)



Source: Agency for Natural Resources and Energy

(4) Presence of the standard ECHONET Lite

Fourth, the existence of ECHONET Lite, Japan's IoT standard for home appliances, is a strength for promoting local production and local consumption of electricity. As mentioned above, in order to promote the local production and local consumption of electric power, participation of small consumers such as houses in DR is essential. In this case, it is possible for residents to adjust electricity demand by manually operating household appliances in response to fluctuations in electricity rates and requests from electric power companies. It would be efficient if a computer could automatically judge and control home appliances in a unified manner using commands based on electronic data. Standardization is indispensable for this purpose. Conventional HEMS[21] has focused on visualizing power consumption, but in recent years, ECHONET Lite has made it possible to centrally control home appliances from different manufacturers and perform DR.

ECHONET Lite is a standard established by the ECHONET Consortium, which consists of more than 200 members, mainly electrical machinery manufacturers. Over the years, it has worked steadily to define control commands for more than 100 devices in the home. As home appliances often have their own functions, it is difficult to control other companies' products with standards, and they may not operate as expected. Accordingly, in 2016, the ECHONET Lite AIF certification system was established for the most important HEMS equipment, such as photovoltaic power generation, air conditioners, lighting equipment, storage batteries, fuel cells, water heaters, smart meters, and charge-discharge units for EVs. This certification is a specification that further improves interoperability by providing more specific usage at the application level. For AIF certification, a third party tests and certifies that the product can be controlled reliably[22].

There is no other international standard that can precisely control the behavior of a wide range of home appliances from multiple manufacturers. The existence of ECHONET Lite standards, including the AIF, is Japan's strength in implementing DR for small customers such as housing. In addition, all smart meters that are scheduled to be installed in all households by the end of fiscal 2024 have adopted the ECHONET Lite standard. Adoption to other equipment is optional for manufacturers. For air conditioners, 7.94 million units (including 4.3 million units certified by AIF) were shipped in fiscal 2020 using the ECHONET Lite standard. Thus, adoption is expanding mainly in equipment important to HEMS. The diffusion rate of HEMS itself was only 1.1% in FY 2019, but wide dissemination of HEMS is considered possible if there is an incentive to perform DR in houses.

4. Precedent examples and suggestions for local production and local consumption of electricity

(1) Case precedent

In the previous chapter, we argued that it would be more efficient for Japan to promote the use of renewable energy as a mainstay power source with emphasis on local production for local consumption. It would be useful

[21] Home Energy Management System
[22] In contrast, the standard ECHONET Lite standard is in principle self-certified.

to refer to cases of regions where local production for local consumption was promoted in advance when considering specific ways and measures to promote local production for local consumption. Here are three examples of smart city and rural city initiatives.

A. Fujisawa SST

Fujisawa SST (Fujisawa Sustainable Smart Town) is a smart city opened in 2014 on the site of a former Panasonic factory in the southern part of Fujisawa City, Kanagawa Prefecture. About 600 detached houses in the region have a target of ± 0 CO_2 emissions. All of the detached houses are equipped with solar power generation, storage batteries, Enefarm (fuel cell using city gas) or Eco Cute (heat pump water heater), and HEMS. By using HEMS to visualize and control the state of power generation and consumption, and by using storage batteries and EneFarm, a system has been established to enable maximum private consumption of photovoltaic power generation with large fluctuations in output.

However, each house is not independent of the distribution network of the electric power company (Tokyo Electric Power Company) and can use the system's electric power at any time, while the surplus electricity generated by solar power generation is sold. In the future, CEMS[23] of the whole town will also be considered, but at present, there is no interchange of electric power among users.

B. Kashiwa-no-ha Smart City

Kashiwa-no-ha Smart City is a smart city situated around Kashiwa-no-ha Campus Station of the Tsukuba Express in Kashiwa City, Chiba Prefecture. Neighboring areas were developed as a land readjustment project of the former site of the United States Air Force Communication Base and Kashiwa Golf Club, and Tsukuba Express was opened in 2005, with 'Gate Square,' the core area, opening in 2014. The city is centered around commercial buildings, offices and high-rise residential buildings, and each building has solar panels installed on its roof and a BEMS, while each house has a HEMS.

The most distinctive feature of Kashiwa-no-ha Smart City is the ability to adjust the supply and demand of electricity throughout the city by using a self-employed line[24] and a facility called a smart center as a control tower. Storage batteries are not placed in each house, but industrial storage batteries such as NAS batteries are used to adjust overall supply and demand. Electric power consumption tends to be high on weekdays in office buildings and on holidays in commercial facilities. By sharing electricity in urban areas, the city was able to cut its peak electricity demand by 26%.

C. Iida-city, Nagano

Iida City, Nagano Prefecture, is a regional city in southern Nagano Prefecture with a population of about 100,000. Since 1997, Iida has been providing support for the installation of photovoltaic power generation

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[23] Community Energy Management System
[24] Wires owned and managed by companies other than general power distributors (such as users and smart city operators).

facilities, taking advantage of the long hours of sunlight per year[25]. As of the end of March 2019, residential solar power generation had reached about 10.5%[26] of the total number of households. In addition to housing, under a scheme in which the roofs of public facilities are leased to a power company funded by citizens for 20 years and electricity is purchased at a fixed price, solar power is installed in many public facilities[27] such as city halls and schools. In addition, the mega sola Iida (Output 1 MW, 4,704 panels) jointly installed by Iida City and Chubu Electric Power Co., Inc., has been in operation since 2011[28]. As a result of these efforts, as of fiscal 2019, the amount of solar power generation in Iida City reached 33.32% of the annual power consumption of ordinary households.

Iida City, which includes about 84% of the total forest area, is also working hard to utilize biomass. In Iida City, the Nanshin Biomass Cooperative, which was established with the cooperation of five private companies, manufactures and sells wood pellets that are used as fuel for pellet stoves and pellet boilers in homes, offices, and public facilities. Iida City is also encouraging the introduction of pellet stoves and boilers with subsidies[29]. In 2016, the city's first biomass power generation was started at the Kabuchan Village theme park, and electricity was sold to Chubu Electric Power Company in addition to private consumption[30].

A number of small and medium sized hydroelectric power plants are also progressing, and the scale of the Seinaiji Hydroelectric Power Plant, which is located on the border of Achi-village and is scheduled to start operation in June 2022, is large, with an estimated annual power generation of about 29 million kWh (equivalent to the annual power consumption of about 8,800 households). The power from the plant will also be supplied to Seiko Epson Corporation, which since April 2021 has been using 100% renewable energy from Nagano Prefecture to cover the power consumption of all its business sites in Nagano Prefecture.

Although Iida City is actively promoting the expansion of renewable energy, no specific measures have been taken so far, as the mechanism for adjusting supply and demand within the region remains a subject for future study.

(2) Suggestions from previous cases

To realize local production for local consumption, it is necessary to install a sufficient number of distributed power sources in the region and adjust supply and demand within the region. How have these issues been addressed in previous examples?

First, the installation of distributed power sources. In urban areas with a relatively high population density, such as Fujisawa and Kashiwa, rooftop solar power generation, which makes effective use of rooftop space, is currently the most promising decentralized power source[31]. According to a survey commissioned by the

[25] The subsidy for FY 2021 is 10,000 yen per kW of maximum output, and 80,000 yen at a maximum.
[26] In Japan, the household penetration rate of solar power generation is estimated at about 5%. The percentage of detached houses is about 9%.
[27] Although the information is somewhat outdated, according to the Iida City website (updated May 31, 2011), solar power generation facilities have been installed at 38 public facilities under this scheme. It appears that the introduction of the system has been progressing gradually since then.
[28] This is the first commercial solar power generation project for Chubu Electric Power Co., Inc.
[29] In fiscal 2021, the subsidy program covered up to 100,000 yen, or 1/2 of equipment costs.
[30] However, Kabuchan Village was closed in 2018 due to bankruptcy of the management body, and operation of the power generation facilities was also terminated.
[31] On the other hand, it is effective to consider distributed power sources other than solar power for houses in the future. For example, Dandelion Energy is providing geothermal heating and cooling systems to homeowners, and the expansion of these technologies and services will be of interest.

Ministry of the Environment, the potential of residential photovoltaic power generation in Japan is approximately 210 GW, which exceeds the peak power generation in Japan (approximately 150 GW)[32]. In regional cities such as Iida, where the choice of power sources such as mega solar, biomass, and small- and medium-sized hydropower is expanding, these power sources can also be used by large users, but residential solar power still plays an important role. The basic strategy is to install solar power generation facilities on the roofs of buildings, mainly in residential areas, and then consider other power sources based on local demand and the natural environment.

Many decentralized power sources are installed by consumers themselves, such as residential photovoltaic generators. In the new smart city, only those who agree to the concept will move in, so it is possible to install distributed power sources for all users. However, in order for Japan as a whole to become a mainstay renewable energy power source of local production for local consumption, it is necessary to aim at a situation where solar power is installed in almost all buildings even in existing towns.

A subsidy system such as the one in Iida is also effective, but there are concerns over subsidy-based measures from the viewpoint of fiscal constraint and fairness. First of all, in order to encourage the majority of consumers to install distributed power sources, it will be necessary to set the unit price of the subsidies at a high level, which increases the necessary financial resources. Given Japan's extremely severe fiscal situation, fiscal sustainability could be seriously undermined as a result. Secondly, there is concern that it would be unfair in terms of the tax paid by those who live with little electricity to be used as subsidies for those who install distributed power sources.

In light of the above, it is necessary to introduce a new mechanism that does not rely heavily on subsidies and that allows the majority of consumers nationwide to install distributed power sources.

The second concern over subsidy-based measures is the adjustment of supply and demand in the region. One way of thinking about local production for local consumption is to complete the adjustment of supply and demand for each house, as in Fujisawa SST. However, a large amount of investment is required for each household. The price varies depending on the capacity and the product, but it would be a considerable burden to invest around 1 million yen for a residential photovoltaic power generation system, around 2 million yen for a residential storage battery, and around 1 million yen for EneFarm. If it is possible to adjust supply and demand among users in the region, the total capacity of storage batteries required in the region can be reduced, for example, by allowing other users to use surplus solar power generation while they are away during the day. Lithium-ion batteries, which are suitable for downsizing but have a high unit cost of capacity, can be used in homes, but NAS batteries[33] and redox flow batteries[34], which take up space but have a low unit cost of capacity, can also be used if storage batteries are installed in common areas. Thus, adjustment of supply and demand among local consumers is significant.

Under the current electric power system, there is no incentive to adjust supply and demand among local consumers unless there is a self-employed line. This is because 30% to 40% of the electricity rate is covered by the consignment fee, which is the cost of transmission and distribution. But when using the grid (transmission

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[32] However, since the operation rate of solar power generation is low, even if solar power generation facilities with a total capacity of 210 GW are installed, the generated power will be 252.7 billion kWh/year, which is about 30% of the generated power in Japan in fiscal 2020.
[33] A battery that uses sodium and sulfur. Features large capacity and large output.
[34] A storage battery that charges and discharges by ion redox reactions. There is no limit to the number of charges and discharges, and the battery has a long life. It is not suitable for miniaturization due to its low energy density, but it is highly safe.

and distribution network) of an electric power company, the consignment fee is the same whether it is procured from a neighboring house or from a large power plant hundreds of kilometers away. However, it is very expensive to set up a self-employed line nationwide, and doing so is also inefficient because it requires a double investment with the existing distribution network. The system should be changed to one in which demand and supply are adjusted among consumers using the existing distribution network.

5. Toward the Realization of a Decarbonized Society with Local Production and Local Consumption

As we have seen, the key to promoting local production and local consumption of electricity is changing the behavior of electricity users, such as installing power generation facilities and adjusting supply and demand. However, the government has yet to come up with drastic measures to do so. Conventional electric power systems have been designed to ensure a stable supply of electricity mainly by regulating the supply side under laws such as the Electricity Business Act and supervision by the government. But to make consumers change their behavior, a new viewpoiit is required. The most promising approach is to make the most of the market mechanism. In a market economy, the optimal allocation of resources is achieved by society as a whole as a result of rational actions taken by each entity using price as a signal. If the market mechanism can be used to set the price of electricity at an appropriate level, many consumers will naturally take the most appropriate action. Specifically, the following three points are proposed: (1) introduction of carbon pricing, (2) penetration of dynamic pricing, and (3) establishment of a consignment fee that is commensurate with the cost.

(1) Introduction of carbon pricing

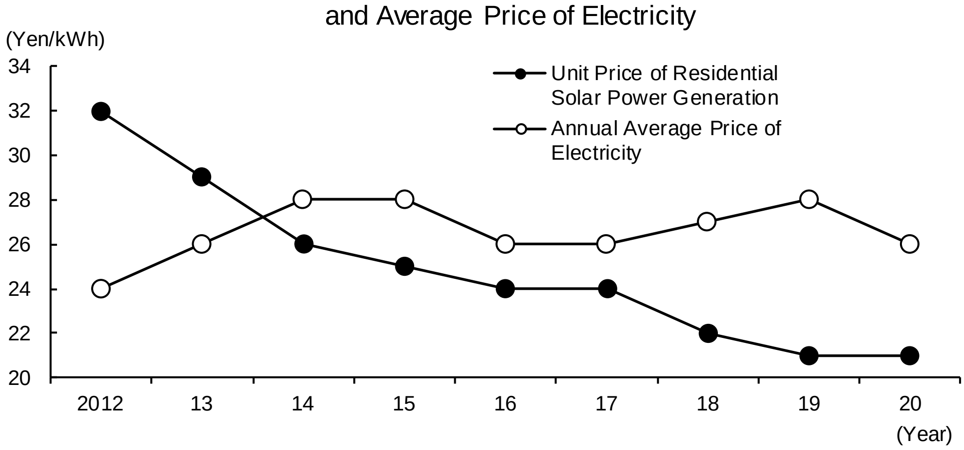
The first proposed point is the introduction of carbon pricing[35] such as a carbon tax. Externality is a typical example of market failure where market mechanisms do not work. Economic activities that involve the emission of carbon dioxide have a negative externality because they have a negative impact on the environment and society, but individuals who emit carbon dioxide do not bear the cost. It is well known that market failures due to external diseconomies can be solved by having people bear the costs borne by society. In other words, we can introduce a carbon tax that imposes a tax on carbon dioxide emissions.

The introduction of a carbon tax has the effect of reducing energy consumption and promoting the introduction of decarbonized power sources such as renewable energy. While many decarbonized power sources are problematic other than with regard to cost, such as long development times and difficulty in securing suitable land, residential solar power generation, which can be installed quickly at the discretion of real estate owners, is expected to be most strongly affected by the introduction of a carbon tax. It is estimated that the cost of residential solar power generation is already lower than the electricity rate, partly because there is no consignment charge if a power generation facility is installed in a house for private consumption (Figure 13). If the relative cost-effectiveness of residential solar power generation becomes clearer due to the increase in

[35] Carbon pricing includes emissions trading in addition to the carbon tax. For the carbon tax, the price of carbon dioxide is fixed, while for emissions trading, it fluctuates. For simplicity, we will discuss the carbon tax.

electricity charges resulting from the introduction of a carbon tax, many consumers will choose to install power generation facilities, even considering the risk of investment, failure, and maintenance[36].

Figure 13 Unit Price of Residential Photovoltaic Power Generation and Average Price of Electricity



Source: Renewable Energy Institute

The introduction of a carbon tax should broadly be imposed on activities that emit carbon dioxide, including gasoline and gas in addition to electricity. In such a case, the shift from gasoline-powered vehicles to EVs is expected to advance, assuming the use of decarbonized power sources. In this case, it is desirable that EVs are used not only for transportation but also for adjustment of power supply and demand as storage batteries. Thus, the cost of separately investing in storage batteries can be reduced.

The biggest concern about the introduction of a carbon tax is the decline in competitiveness of Japanese industries as production costs increase. All countries cooperating to introduce a carbon tax will create a level playing field. However, if Japan adopts a carbon tax while other countries do not, there is a concern that industries that emit carbon dioxide will flow out to other countries. To prevent this, it is necessary to impose a border carbon tax on imports from countries with insufficient carbon taxation. It will take a considerable amount of time for the coordinated introduction of an international carbon tax and the establishment of a framework for a border carbon tax. In the meantime, it will be necessary to take measures to mitigate the impact of the introduction of a carbon tax on industry on a provisional basis.

If we focus on electricity rates, we can mitigate the impact on industry by refunding a certain percentage of the rates for extra-high pressure electricity, which is used by industries. On the other hand, there may be a way to support industries that emit large amounts of carbon dioxide depending on their production volume. For example, certain amounts of subsidies are provided for each ton of steel produced. In the latter case, while there is room for arbitrariness in determining the amount of subsidies for each product, the burden on companies can be reduced, while there is great incentive to reduce carbon dioxide emissions.

The introduction of a carbon tax, of course, places a heavy burden on households. Rather than introducing a carbon tax, politically it would be easier to obtain concensus by issuing government bonds as investment for growth and investing national funds in the development of nationwide power transmission networks and large-

[36] In addition to monetary incentives such as carbon pricing and subsidies, regulations could also be used to encourage customers to install residential solar power systems. However, it should be noted that regulations may not be able to respond flexibly to individual circumstances, such as sunshine, snow and power usage patterns, and may force inefficient investment. At a meeting of the Study Group on Energy-Saving Measures for Houses and Buildings toward a Decarbonized Society, a mandate to install solar panels in new houses was discussed, but was not included in the proposal.

scale power generation. However, even if the immediate burden on the people can be avoided, such an act could obscure the relationship between the burden and the benefit, allow inefficient investment without proper functioning of the market mechanism, and impose an enormous burden on future generations. It is necessary to realize the introduction of a carbon tax as soon as possible without evading the debate concerning the burden placed on the people.

(2) Penetration of dynamic pricing

The second proposed point is the penetration of dynamic pricing into electricity rates. The basic principle of economics is that supply and demand are balanced by price. In the case of electric power, it is necessary to ensure that supply and demand are consistent at all times, and dynamic pricing, in which prices fluctuate in real time, is desirable in order to utilize market mechanisms to adjust supply and demand[37]. In this way, from the point of view of the demand side, there will be an incentive to utilize DR, such as shifting usage from the time when electricity charges are high to the time when charges are low.

Until now, most consumers have been using the pay-as-you-go system, mainly for low-voltage products. In recent years, however, the environment for shifting to dynamic pricing has gradually been developed. First, in April 2016, retail liberalization of the low-voltage sector was realized, enabling retailers to sell electricity at a rate that is essentially free[38]. Even if dynamic pricing is applied, there is no problem with the system. Next, smart meters are becoming more popular. The installation of smart meters, which can measure electricity consumption every 30 minutes, was completed in almost all households in TEPCO's district by the end of FY 2020, and is scheduled to be completed nationwide by the end of FY 2024. Once a smart meter is installed, power consumption can be measured in real time, enabling the application of dynamic pricing.

The immaturity of the wholesale market can be pointed out as a remaining issue for the dissemination and expansion of dynamic pricing. Dynamic pricing requires a reliable index to determine prices, and wholesale market prices are expected to play a role. However, when the supply and demand of electricity became tight in January 2021 due to cold weather and a shortage of LNG, the price of electricity at the wholesale market remained about 30 times higher than usual for a long period of time, causing an abnormal rise in prices. Because the volume of transactions in the wholesale market is small, price fluctuations can become extremely large. In this way, consumers do not want to choose prices linked to wholesale markets. While most of the power supply is still operated by major power companies, if the power generation department of a major power company supplies its own or a group's retail department and sells the remaining surplus at the wholesale market, the amount of power that is sent to the wholesale market would be depleted in times of tight supply. In order for the wholesale market to mature, it is necessary to take further measures, such as separating production and sales[39].

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[37] It is desirable that electricity rates as well as selling prices of electricity by power companies fluctuate. In this regard, it is highly commendable that, in addition to the conventional feed-in tariff (FIT) scheme, FIPs will be introduced in April 2022 for renewable energy power producers to purchase electricity at a fixed price above market price. However, since it is difficult to adjust the output of solar power generation and wind power generation (and even if output is suppressed, power generation capacity is underutilized during that time), it is more important to change the electricity rate on the demand side.

[38] Fees set by some laws and regulations, such as the consignment fee and the charge for promoting renewable energy power generation, will remain.

[39] The legal separation of the power generation and sales (retail) divisions of major power companies.

(3) Setting a consignment fee commensurate with the cost

The third proposed point is setting a consignment fee that is commensurate with the cost. Electricity transmission and distribution is still a regulated area despite ongoing liberalization of the electricity supply, and the wheeling fee, which is the cost of transmission and distribution, is also a regulated fee. If competition is promoted in the transmission and distribution business, multiple companies will be laying transmission and distribution networks. Since social costs outweigh the benefits of competition, the current practice is to impose monopolies on general power transmission and distribution companies and regulate rates. However, the fact that regulated rates are different from actual costs, such as being held constant regardless of the distance of the consignment, hinders the optimal allocation of resources, including reducing incentives for the adjustment of supply and demand in neighborhoods.

So how do you set up a fee that matches the cost? It would be good if the rates could be set according to the route, just as in the case of railways, but the electricity generated by many power plants is mixed in the electric wires, and it is extremely difficult to specify the power plant that each customer used. Therefore, the following method can be considered as an alternative. A transmission company (TSO) and a distribution company (DSO) are separated, and the distribution company pays a consignment fee to the transmission company only for using the transmission network of the higher system. In this way, power distribution companies will try to reduce the amount of consignment fees they pay to transmission companies by providing incentives to customers and installing their own storage batteries to adjust supply and demand in the distribution network.

The unit price of the transmission fee paid by the power distribution company to the power transmission company does not need to be uniform. Rather, they should be differentiated by the actual cost of laying and maintaining the grid. In this way, the higher the cost of transmission in remote areas and other areas, the higher the consignment fee and the stronger the incentive to promote local production for local consumption. If these areas become completely independent of the grid by promoting local production for local consumption, the cost of maintaining and renewing the grid in the future will be significantly reduced.

In Europe and other overseas countries, it is common that transmission and distribution companies are separated. In Japan, both transmission and distribution are managed by general electricity transmission and distribution companies, and there are currently no discussions being held on the complete separation of power transmission and distribution. However, the Electricity Distribution Business License System will come into force in April 2022, and any new utility that wishes to do so will be able to obtain a transfer of the electricity distribution business from a general electricity transmission and distribution company. We hope that this system will develop into one that will eliminate the bottleneck in promoting local production for local consumption.

6. Pursuit of benefits other than decarbonization

This paper has argued that local production for local consumption is the most efficient way to promote the use of renewable energy as a mainstay power source. However, considering the cost of adjusting supply and demand, such as using storage batteries, it is highly likely that the cost will increase compared to the current power system. It can be said this is the cost of realizing a decarbonized society, but by pursuing other benefits, substantial cost reductions can be achieved.

(1) Regional revitalization

Local production and local consumption of electric power can be expected to contribute to regional activation. Currently, large amounts of electricity charges are flowing out of regions other than those with large-scale power sources[40]. If local production for local consumption is promoted, the outflow to outside the region will be reduced and returned to the subregion. Mega solar power plants, biomass plants, and small and medium-sized hydroelectric power plants create jobs, while there are opportunities for residential solar power plants to be installed and maintained by companies in the region. In addition, the shift from thermal power to renewable energy will lead to curbing the outflow of funds overseas by curtailing the import of fossil fuels to Japan as a whole.

Also, rural areas could attract businesses and residents by taking advantage of relatively low electricity rates[41]. The lower the population density, the more room there is for providing electricity generated from renewable energy at low prices. If such moves become widespread, it will lead to correction of the current problem of centralization in Tokyo.

Moreover, in the short term, it will be possible to enjoy the effects of increasing the exchange population and the demand for accommodations, such as the acceptance of visits to areas where local production and local consumption are first pursued.

(2) Realization of a smart home

The standardization of IoT for home appliances, which is the key to adjusting supply and demand in the region, can create various added value not only by implementing DR by HEMS but also by centrally operating home appliances. In this sense, it can be seen as contributing not only to the energy field but also to the realization of smart homes.

For example, smart speakers have been put into practical use in recent years, but if you use the standard, you can control home appliances all over the house from smart speakers. In particular, if ECHONET Lite in Japan is used, it is possible that detailed operations such as temperature adjustment can be completed verbally through a smart speaker in addition to on/off function, which is convenient for elderly people who are limited in their ability to operate devices.

There is also plenty of room for further development in the field of sleep. In recent years, sleep apps that record the state of sleep using sensors and other devices have become popular, but further advances will enable services to optimally control lighting, sound, air conditioning, blinds and the like according to the state of sleep.

It is likely that robots with appendeges will work with existing home appliances if they become popular in the future. For example, a robot vacuum clean a room after a robot with an arm put away a mess on the floor,

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[40] According to an estimate by Local Energy, about 100 billion yen a year flows out of Tottori Prefecture as electricity charges.

[41] For example, Nippon Light Metal's Kanbara Plant (Shizuoka City, Shizuoka Prefecture) operates a plant that uses electricity from its own hydroelectric power plant, mainly for aluminum-related businesses. If the number of thermal power plants is reduced and the consignment fee is reformed to meet costs, there is a possibility that more plants will be built near competitive renewable energy sources, even if they are not necessarily for private use.

or a dishwasher starts operation after dishes have been placed in a dishwasher by a robot with an arm.

In addition, there could be various additional services, such as elderly monitoring service via monitoring the usage of home appliances, and home security service.

(3) Utilization of power data

Data on electricity from smart meters and HEMS can be used in other fields. For example, using electricity data enables understanding of peoples' activities each day of the week and throughout the day, which is effective for the business analysis area.

After April 2022, when the revised Electricity Business Act comes into effect, electricity data that can identify individuals without statistical data processing will be available for purposes other than the electricity business, subject to the provision of individual consent. The data could be used for a variety of purposes, including personalized advertising, reducing absentee deliveries, and monitoring for lonely deaths.

7. Conclusion

At present, Japan lags behind Europe in the expansion of renewable energy, but if we turn our attention to a decarbonized society based on local production for local consumption as proposed in this paper, we will be able to present a successful example of a new model to the world. Notably, there are likely few regions in the world where stable westerly winds blow and power grids can be spread over a wide area, such as Europe. If Japan is able to succeed in expanding renewable energy sources for local production and local consumption, other countries will try to promote decarbonization by using Japan as a reference.

Decarbonization is a promising growth area, and if Japan can act as a model for the world and exert its influence on other countries, decarbonization is expected to have a significant positive effect on Japanese industries. In particular, if ECHONET Lite, a standard for the Internet of Things (IoT), which is essential for the realization of local production for local consumption, is adopted as a standard in Asian countries and other countries, it will act as a tailwind for Japan's electric manufacturers, which have been facing a severe challenges since the Lehman shock.

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