Recommendations for Power System Restructuring in View of the Energy Crisis

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Renewable Energy Institute

This recommendation document was written by the Power System Restructuring Research Team of Renewable Energy Institute. Hiroshi Takahashi, a Senior Research Fellow at Renewable Energy Institute and Professor at Tsuru University, led the Research Team and provided overall suggestions for the writing.

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About Renewable Energy Institute

Renewable Energy Institute is a non-profit think tank which aims to build a sustainable, rich society based on renewable energy. It was established in August 2011, in the aftermath of the Fukushima Daiichi Nuclear Power Plant accident, by its founder Mr. Son Masayoshi, Chairman & CEO of SoftBank Group, with his own resources.

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Introduction

In the wake of Russia's invasion of Ukraine in February 2022, the world is facing an energy crisis. International prices of fossil fuels have soared, and Russia has halted its supplies to Europe. This has caused energy prices to skyrocket in Japan, increasing the burden on companies and households. In the power sector specifically, some new power providers have withdrawn from the market, leaving some commercial power users unable to find power providers. These users are called “electricity refugees.” In March and June of this year, concerns grew over a tightening in the power supply capacity. As to the cause of the energy crisis, some argue that the transition to decarbonization has been promoted too quickly or that we need to restart nuclear power plants as soon as possible, saying that the power system restructuring itself was a mistake.

However, the original cause of this crisis was the instability of the fossil fuel supply system, as demonstrated in several past iterations of such crises, including the 1970s oil crisis. Turning to nuclear power as an alternative is not a realistic option given that the cost of power generation is high, that it takes time to construct plants, and that nuclear power generates radioactive waste. Rather, the factors behind the crisis Japan is facing are that the country’s share of renewable energy is less than half that of typical developed countries, that the target for the future is low, and that the market mechanism is not effectively utilized. In other words, the fundamental factors are the delay in energy transformation and the insufficient power system restructuring.

From this perspective, this recommendation document focuses on the power sector and analyzes the structure of the energy crisis today, and confirms the current status of the power system restructuring in relation to the crisis. Then, we make recommendations to accelerate and thoroughly implement the initially intended power system restructuring with the goal of overcoming the crisis, securing a stable supply of electricity, and eliminating fossil fuels.

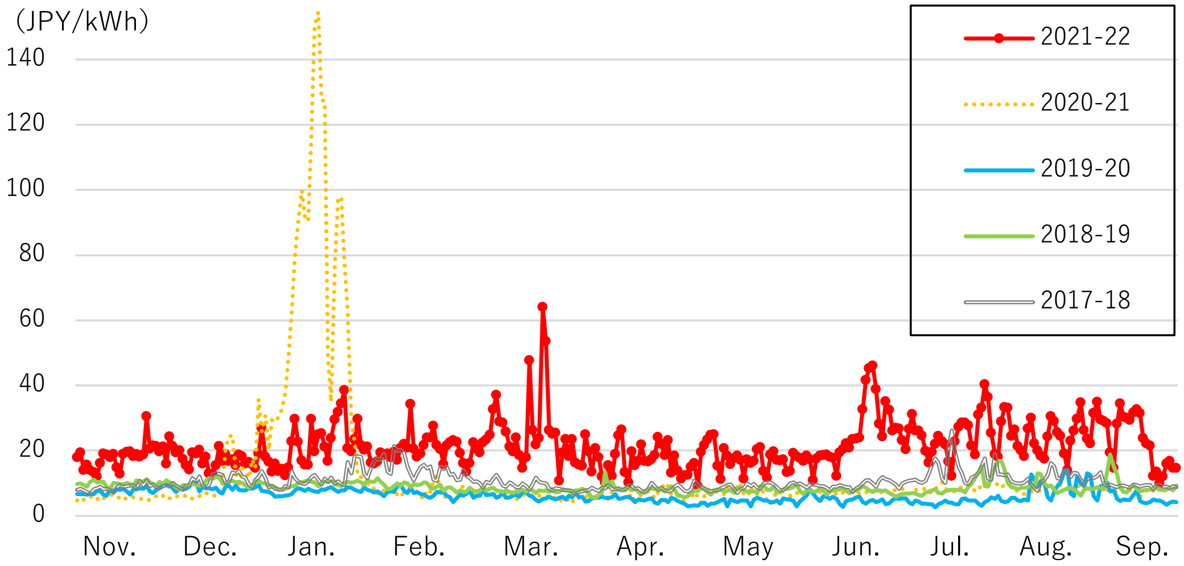
Chapter 1: The Structure of the Energy Crisis

The energy crisis Japan is facing now can be divided into two problems in the electric power sector: one is on the retail and demand side; new power providers are withdrawing due to soaring fossil fuel prices, resulting in electricity refugees. The other is on the power generation and grid operation side; as seen by the occurrence of electricity supply shortages. The two problems overlap somewhat, but their fundamental causes differ. Accurately understanding the structure of each of the issues will help us to formulate solutions.

Section 1: The background of soaring electricity prices and the problem of electricity refugees

The origins of the first problem of electricity refugees extend back to the sharp rise in spot electricity prices in January 2021. At that time, the impact of the hike in international prices of fossil fuels, which started around the end of 2021, was limited, and the power supply and demand situation was not tight, but only spot prices surged suddenly, and they remained high for one month. As the result of an investigation, the Electricity and Gas Market Surveillance Commission (EGC) stated that the surge was caused because major electric power utilities were forced to reduce the amount delivered as the inventory of natural gas decreased, concluding that it did not conflict with fair competition.

Figure 1: Trends in spot electricity prices: November 1 to September 30



Source: Created by Renewable Energy Institute based on the system prices (daily average) of the Japan Electric Power Exchange.

However, as shown in Figure 1, the spot price was apparently abnormal in January 2021 (shown with the orange dotted line) given that prices returned to the previous level of 10 JPY/kWh or less in February. It should be assumed that there were some problems with the functioning of the market, but this has not been explained sufficiently.

Prices started to soar again in November 2021 (the red line in Figure 1). The main reason for this was the hike in international prices of fossil fuels associated with the economic recovery from the COVID-19 pandemic. In addition, also due to Russia's invasion of Ukraine in February 2022, spot prices remained around 20 JPY/kWh until October. Given that electricity from thermal power generation, which is dependent on fossil fuels, accounts for 75% of Japan's electricity mix, if fuel prices doubled or tripled, electricity prices will inevitably soar.

This means that retail power providers have been experiencing backwardation for nearly a year. In fact, seven out of ten major power utilities reported net losses between April and June. Even so, in-house transactions make up a sizable proportion of the transactions of major electric power utilities. On the contrary, new power providers are vulnerable to hikes in spot prices. As a result, more than 10% of the new power providers, or 104 companies, have withdrawn from the retail market, suspended contracts, gone bankrupt, or closed down.[1]

Those who were affected the most were high-voltage power consumers who are under contract with new power providers, who accounted for 20% or more in terms of electricity sales by size. Many of such commercial users were unable to conclude new contracts with major power utilities. As a result, in October, there were more than 45,000 users who had entered into last-resort contracts (supply contracts based on final guarantee supply provisions) with general electricity transmission and distribution companies, which were originally temporary emergency measures.[2] This occurred partly because the last-resort price fell below the soaring market price, but it was also the case that those users had nowhere else to go. In order to prevent the backwardation from continuing, market-linked pricing was introduced for the last-resort rate in September 2022, causing the prices paid by customers to rocket.

Because of free competition, if a company continues to lose money, it will have no choice but to withdraw from the business. Also, some of the new power poviders may have been poorly prepared for the hike in prices. However, the reason why so many new power poviders were forced to withdraw is that even after the power system restructuring, major electric power utilities still own 80% of the thermal power generation facilities in Japan, the futures market is small and difficult to use, and the spot market, which seems to have expanded due to gross bidding, is not functioning effectively.

Section 2: The background of tight electricity supply

The second problem with the tight electricity supply occurred in 2022 in areas covered by the TEPCO Power Grid (hereinafter referred to as "TEPCO PG"). The first power supply shortage arose on March 16, when thermal power plants totaling 6.5 GW located on the Pacific coast were shut down by an earthquake off the coast of Fukushima, causing a sudden imbalance in supply and demand. When the supply capacity is apparently insufficient, general power transmission and distribution companies will partially cut the load to restore the supply-demand balance and avoid large-scale power outages. As a result, power was cut off to 2.1 million households within the TEPCO PG service area.

Then, on March 22, Tokyo was hit by midwinter-like cold weather amid a series of earthquake-induced thermal power plant shutdowns, which boosted demand for electricity. As the reserve ratio for the next day was expected to be negative as of March 21, the first tight power supply warning was issued.[3] At

[1] Survey on the withdrawal of new power providers by Teikoku Databank (June).

[2] The number of companies remained at less than 1,000 until February 2022. EGC News Release (October 17, 2022).

[3] A tight power supply warning was also issued in the area covered by the Tohoku Electric Power Network on March 22. This was because most of the thermal power plants stopped by the earthquake on March 16 were in this network's service area.

that time, the warning was issued late, so companies were late to act to save electricity. Even so, demand was eventually suppressed, and thanks to the success of electricity-sharing using cross-regional interconnection lines, there were no blackouts.

Finally, at the end of June, tight power supply advisories[4] were issued on four consecutive days in the TEPCO PG service area. At that time, Japan was experiencing a spate of record-high temperature days in June, which caused the demand for electricity to increase sharply, resulting in tight reserve power. However, there were no problems in that case either thanks to efforts to save electricity and to the sharing of electricity.

As mentioned above, most of the tight power supply situations that we have experienced recently were caused by factors that arose suddenly depending on natural phenomena. Also, the tight supply situations were limited to certain regions of the country. In the next section, we will see what kinds of supply capacity shortfalls occurred and where.

Section 3: The reality of supply capacity shortfall and the contributions of photovoltaic (PV) power

First of all, the recent tight supply situation occurred almost exclusively within the TEPCO PG service area. Both on March 22 and at the end of June, when the tight power supply warning and advisory were issued respectively, many of the 30-minute timeframes where the supply was tight were within the TEPCO PG service area (Table 1). On the other hand, annual demand is usually at its peak in July and August, and this summer too electricity demand increased due to the heat wave, but there were no warnings or advisories over the tight power supply issued in any service area. Inter-regional electricity sharing will work effectively if it is not a nationwide crisis, and it was actually utilized to a certain extent this summer too.

Table 1: Regional reserve ratios by area for March, June, July, and August 2022

	Number of frames with a ratio of less than 5%		Remarks
		Number of frames in the TEPCO PG service area	
March	58	41	42 of the 58 frames were on March 22 17 frames were in the Tohoku Electric Power Network service area
June	22	16	21 of the 22 frames were from June 27 to 30
July	30	5	
August	18	7	Record the highest annual demand

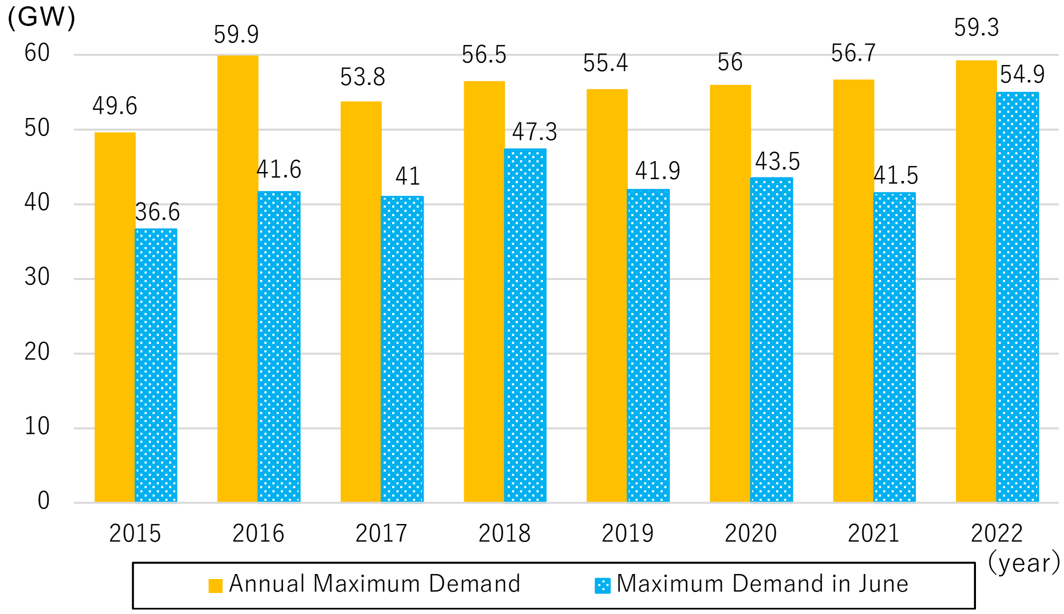
Note: We calculated the regional reserve ratios by area in 30-minute units in 10 areas from data from the Organization for Cross-regional Coordination of Transmission Operators, Japan (OCCTO). In March, the total number of frames was 48 frames × 30 days × 10 areas, or 14,400 frames.

Source: Created by Renewable Energy Institute based on data from OCCTO.

[4] A tight power supply warning is issued when the reserve ratio on the next day is 3% or less, and an advisory is issued when it is 5% or less.

Second, it is necessary to investigate what kind of supply capacity shortfall occurred in the TEPCO PG service area and when. The maximum annual demand in the TEPCO PG service area is about 60 GW in midsummer,[5] and general power transmission and distribution companies have been successfully meeting this demand, including this summer (Figure 2). However, it is rare for the maximum demand to reach 50 GW in June, and around this time of the year, 10% of thermal power plants are scheduled to be suspended every year. Although all nuclear power plants have been shut down, the shutdown is taken into account when laying out operation plans. Against such a backdrop, demand increased in June due to the extreme heat wave and the power supply became tight. The service area of TEPCO PG was also supplied by other areas with shared electricity in January and February 2017. The augmentation of the grid operation system and the introduction of renewable energy sources in the area are not sufficient to address fluctuations in demand due to changes in weather conditions, which might be a cause of the supply capacity shortfall.

Figure 2: Maximum annual demand and demand in June in TEPCO PG's service area



Source: Created by Renewable Energy Institute based on the TEPCO PG "Denki Forecast."

[5] The maximum demand in the TEPCO PG service area this summer was 59.3 GW in the frame from 13:00 to 14:00 on August 2. The reserve ratio at that time was 8%, and there was no supply shortage. TEPCO PG "Denki Forecast."

The third question is whether the promotion of decarbonization was a cause of the supply capacity shortfall. Coal-fired power plants emitting large amounts of carbon dioxide should be phased out as soon as possible toward decarbonization, and since electricity has been deregulated, it is also a rational choice to abolish old thermal power plants with low profitability. Unlike European countries, Japan has not clarified a policy for eliminating coal-fired power, and in its future energy mix of power sources with the target of 2030, the proportion of coal-fired power is still as high as 19% (Japan's 6th Basic Energy Plan).[6] Rather, the government and major power companies have been actively promoting the construction and expansion of coal-fired power plants since 2011. As a result, the installed capacity of thermal power generation in 2021 was almost the same as in 2011. Decarbonization policy is not a factor behind the supply capacity shortfall.

It is true that the total supply capacity of thermal and nuclear power plants has been reduced with the progressive decommissioning of nuclear power plants during the same period and with many nuclear power plants unable to resume operation. However, the problem is the government's inadequate energy policy. It has stuck to its unfeasible scenario under which it aims for 20 to 22% of electricity to be supplied with nuclear power in 2030, and it has not made efforts to expand renewable energy sources or otherwise worked to secure sufficient alternative power sources.

Fourth, we should rate PV power as making a positive contribution. The Ministry of Economy, Trade and Industry (METI) has reported that drops in the output of PV power were a factor that caused the tight power supply.[7] It is true that the output of PV power on March 22 was limited due to bad weather. However, this phenomenon had been predicted in advance, allowing measures to be taken to address the situation. There were not many PV power plants shut down by the earthquake. In contrast, the maximum PV power output that day reached 1.74GW against the expectation that PV supply capacity would be 0.39 GW, which means that power was generated in excess of expectations.

Some also blamed PV power for the tight electricity supply in the evening at the end of June. However, it is natural that the output of PV power generation decreases in the evening, and shortages during that time of the day should be covered with electricity from thermal power generation, pumped storage generation, inter-regional power sharing, and electricity from other renewable energy sources. Rather, around noon, power from PV power generation made up 25% of the total electricity needed in the TEPCO PG service area, contributing significantly along with the electricity from pumped storage generation, which was generated in the late afternoon. We need to utilize various means in a rational manner to integrate intermittent sources into the power system, and doing so will make the power system flexible.

[6] Agency for Natural Resources and Energy, "Energy Supply and Demand Outlook for Fiscal 2030 (Related Materials)" (October 2021).

[7] For example, Agency for Natural Resources and Energy, "Verification of the tight electricity supply in East Japan in March 2022," Material 3-4 for the 47th Subcommittee on Electricity and Gas Basic Policy, Electricity and Gas Industry Committee, Advisory Committee for Natural Resources and Energy, METI (April 12, 2022). One of the three factors is a significant drop in the output of PV power.

If there is a problem with renewable energy, it is that the introduction of wind power generation has been significantly delayed not only in the TEPCO PG service area but also nationwide. Wind power is generated even at night, whereas photovoltaic power is not, and it tends to increase in output in cloudy weather when the output of PV power is low. The two intermittent renewable energy sources, PV and wind power, are complementary to each other. Accelerating the introduction of wind power in addition to PV power will further stabilize the supply of electricity. This delay is also due large to policy factors, as we will describe later.

As discussed above, the problem of soaring electricity prices and electricity refugees originates from the inherent vulnerability of fossil fuels, but at the same time, it also stems from Japan's inadequate power system restructuring. The problem of the tight electricity supply is limited in the service area of TEPCO PG, and the energy crisis that has accelerated since the Russia's invasion of Ukraine has little to do with this problem. The insistence that decarbonization is being promoted too quickly is not the case. Rather, the problem that we should address is the delay in introducing renewable energy sources, which should replace coal-fired power generation.

What we should learn from this recent energy crisis is that we need to reduce our dependency on fossil fuels by accelerating the introduction of renewable energy, which is purely domestic products, and increasing price competitiveness, and thereby enhance the energy self-sufficiency rate. To promote the introduction of renewable energy, it is also necessary to thoroughly restructure the electric power system as well.

Chapter 2: The Outcomes of the 10-Year Power System Restructuring and Challenges for the Future

How far has Japan progressed with its power system restructuring? The restructuring began when the Electricity System Reform Expert Subcommittee was established in the Agency for Natural Resources and Energy in 2012 after the accident at the TEPCO Fukushima Daiichi Nuclear Power Plant. Unlike the liberalization of electric power market, which was already in place, this is a comprehensive system restructuring focused on the introduction of renewable energy. Ten years have passed since then, and major parts of the restructuring have been implemented, producing a certain level of outcomes. On the other hand, the recent energy crisis has revealed various issues.

Section 1: Outcomes of the 10-Year Power System Restructuring

In response to the report of the Electricity System Reform Expert Subcommittee, the government announced its Basic Policy on Electricity System Reform (approved by the Cabinet on April 2, 2013). The policy was mainly made up of three pillars: expanding the operation of inter-regional grid systems, fully deregulating the retail market and power generation, and further securing the neutrality of the power transmission/distribution sector by legally separating them. This policy was put into practice in stages until 2020.

First, the Organization for Cross-regional Coordination of Transmission Operators, Japan (hereinafter referred to as “OCCTO”) was established in 2015 to expand the operation of inter-regional power systems. This set the stage for discussions and development to step up the operation of power systems from limited cooperation among power utilities to nationwide cooperation. In addition, the full deregulation of retail and power generation was started in 2016, and by March 2022, nearly 20% of the electricity sold was supplied by newly participating retail power providers.[8] Since the unbundling of power transmission and distribution was implemented in April 2020, companies other than those in the power generation/retail sectors have been providing transmission and distribution services.[9]

In addition, EGC was established in 2015 to strengthen the administrative oversight function over liberalized markets. EGC is expected to function to ensure a fair competition environment by monitoring the market, suggesting reforms to the market system, among others.

8 Agency for Natural Resources and Energy, "Progress on the Full Liberalization of Electricity and Gas Retail," Material 5 for the 54th Subcommittee on Electricity and Gas Basic Policy (October 17, 2022).

9 Excluding Okinawa Electric Power Co., Inc.

These reforms are producing outcomes. It has become common practice for electric utilities to share electricity with surrounding areas through the OCCTO according to the supply and demand situation. In the meantime, the inter-regional transmission lines between Hokkaido and Honshu were increased from 0.6GW to 0.9GW, and the East-West frequency conversion facilities, which are used for inter-regional connection, were increased from 1.2GW to 2.1 GW.[10] The rules for the use of inter-regional transmission lines have changed from first-come-first-served to merit order in principle (implicit auction), and a system has been introduced to enable the nationwide use of low-marginal-cost renewable energy through inter-regional transmission lines. The government has also put in place a balancing market, which aims to ensure and operate the balancing capacity in a wide area. Furthermore, the formulation of "the Master Plan," the grid development plan for power systems toward 2050, is underway. The plan includes long-distance submarine transmission lines between Hokkaido and Honshu, with consideration for offshore wind power potential.[11]

The pumped storage hydropower generation uses inexpensive electricity generated by sunlight during daytime to generate electricity in the evening or later, adding flexibility to the grid system. Discussions to further utilize this system are underway.

As a result, the amount of PV power introduced was increased and reached 75 GW in total in 2021 (the third largest in the world),[12] which underpins the supply of electricity during the daytime. Wind power generation, on the other hand, has been facing problems such as grid system development and connection rules, and has been stagnant at 4.5 GW.

Discussions on power system restructuring have been continued even after the pillars of the 2013 Basic Policy were implemented. The electricity distribution business, aggregators (specified wholesale supply businesses) and the energy storage business, which were introduced when the Electricity Business Act was revised in 2020 and 2022, have been legally defined as new businesses that took advantage of the characteristics of distributed renewable energy and the deregulated electricity market.

In this way, the power system restructuring that has been promoted over the last 10 years has established a foundation for the creation of innovative industries and markets that will enable the nationwide use of renewable energy at a low marginal cost, contribute to the stable supply of power in the region, satisfy the needs of customers, and allow new businesses to grow.

Even so, as we considered in the previous chapter, the current energy crisis suggests that the goals of the power system restructuring have not been achieved adequately so far, and there are still challenging issues remaining.

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10 In the past, there was opposition to the plan to increase the East-West frequency conversion facilities, but it contributed a great deal at the time of the aforementioned power shortage in the TEPCO PG service area, and the situation would have been even worse if it had not been increased.

11 Agency for Natural Resources and Energy, "Toward the Construction of Next-Generation Power Networks," Material 4-2 for the 54th Subcommittee on Electricity and Gas Basic Policy (October 17, 2022).

12 IRENA, "Renewable Capacity Statistices 2022" (April 2022)

Section 2: Issues identified amid the energy crisis

Facing the current energy crisis is a reminder that we must stop using fossil fuels as quickly as possible. In fact, Europe is speeding up its efforts to promote both de-Russianization and de-fossilization by means of renewable energy and energy conservation. In contrast, Japan's 6th Basic Energy Plan, which was adopted in 2021, sets a target of 36 to 38% for the introduction of renewable energy by 2030, which is still low compared to the targets of European countries (Table 2). The energy crisis was exacerbated after Russia's invasion of Ukraine in February 2022, but regardless of this, there have not been any reports from the government that there are discussions about raising the target.

Table 2: The results and targets of renewable energy introduction rates in European Countries and Japan

	Germany	United Kingdom	Italy	Spain	Japan
Results in 2020	44%	43%	42%	44%	20%
Targets for 2030	80%	(Note)	70%	74%	36-38%

Note: The United Kingdom has not set a target for 2030, but it has set a target of increasing offshore wind power from 10 GW to 50 GW by 2030 and increasing solar PV from 14 GW to 70 GW by 2035.

Source: Created by Renewable Energy Institute based on IEA, Energy Atlas (Results), materials from each country, and the EMBER "European renewables target tracker" (last update: October 2022).

The government should speed up the introduction of low-cost, purely domestic renewable energy sources. To this end, it is necessary to review and accelerate the process of power system restructuring. The main issues are as follows.

The first issue is the disparity in the competitive conditions between major power utilities and new power providers. Since thermal power generation accounts for 75% of the electricity mix, it is generally inevitable for electricity prices to rise as fossil fuel prices rise. Even so, major power utilities hold large amounts of in-house generated electricity and most of their transactions are in-house transactions, as these are less susceptible to changes in market prices. This means that they will suffer lower damages than new power providers will. Because the power generation sectors of major power utilities are not completely separated from their retail sectors, the procurement conditions for new power providers are not equal to those for major utilities, and there is also a limit on the use of futures market, which is small in scale. EGC has been requiring major power utilities to ensure fair wholesaling of electricity without discrimination between group companies and external companies, but this has not been secured yet. If new power providers withdraw from the market for reasons other than fair competition, it means that power system restructuring has not been implemented thoroughly.

Second, as regards the tight electricity supply, even if the situation is sporadic in limited regions, taking measures on the consumer side will work effectively in the short term, and it is necessary to establish a system to that end. Unreasonable power saving and requests by ministers are not long-lasting measures to address the issue. Rational demand response (DR) is required. To this end, it is indispensable to have a fair electricity market in which price signals function adequately, but DR has not been utilized effectively in addressing the current tight electricity supply situation. This is thought to be due to the oligopoly of the spot market, the malfunctioning of the balancing and futures markets, and the fact that fair electricity wholesaling without discrimination between group companies and external companies is not secured.

The third issue is the delay in the introduction of renewable energy, which is a structural factor of the energy crisis. Compared with European countries, Japan is obviously one step behind (Table 2), and this has an impact on the current crisis in terms of supply and demand as well as in terms of prices. The delay was due to the fact that there are still many restrictions on the introduction of renewable energy, including access to power grid and curtailment, and that a fair green power market has not been secured. In order to drastically accelerate the introduction of renewable energy, such as by allowing the huge amount of wind power generated in Hokkaido and Tohoku to be used effectively throughout Japan, we need to augment the Master Plan that is under consideration at OCCTO and put it into action as quickly as possible.

Japan's failure to thoroughly implement the power system restructuring has affected today's energy crisis in the ways outlined above. Even so, the government did not set a plan to promote the thorough implementation of power system restructuring and accelerate the introduction of renewable energy as measures to address the energy crisis. Instead, they suggested that they would increase the number of nuclear power plants to be resumed as well as start planning the new construction and expansion of plants. In particular, constructing new plants will cost a lot given cases in other countries, and if it was feasible, it would take 10 years or more, which means it is not a practical measure to address the crisis.

Chapter 3: Recommendations for Achieving a Stable Electricity Supply Based on the Concept of Power System Restructuring

In considering future reform, we need to keep in mind the concept of power system restructuring, which is specified in the 2013 report by the Electricity System Reform Expert Subcommittee. The report suggests that “utilizing diverse supply capacities including renewable energy will become more urgent than ever,” and that “there will be upward pressure on electricity prices in the medium-to-long term” partially because “confidence in nuclear power generation has been greatly shaken.” It also clearly states that “measures taken on the side of customers and distributed power sources are expected to work more effectively in balancing supply and demand.” We should admit that those measures have not been utilized adequately in addressing the current energy crisis.

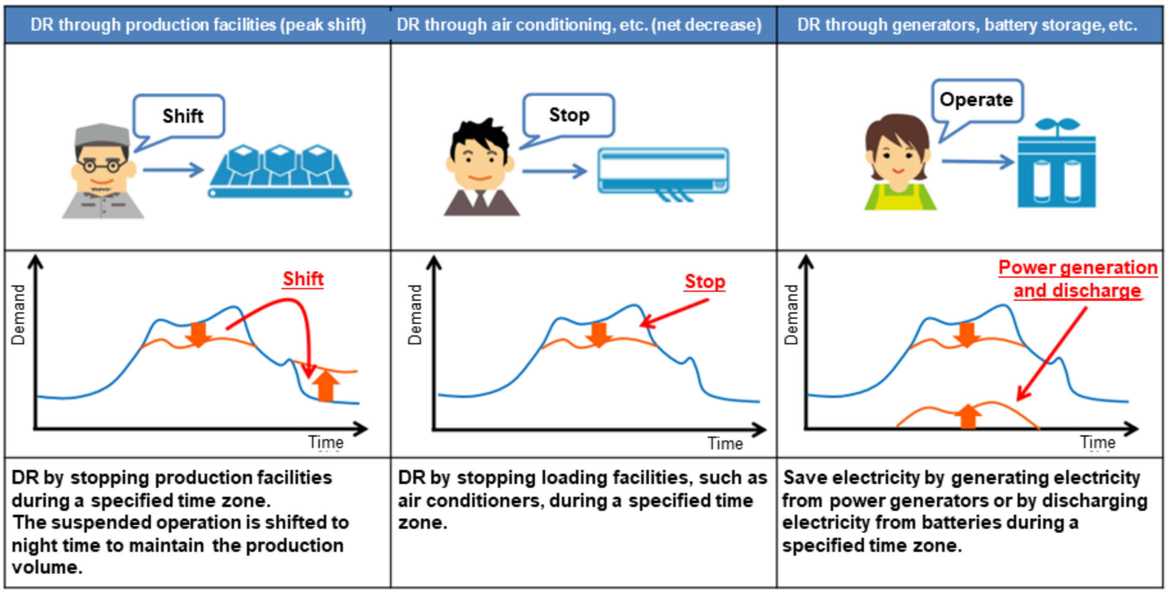
The 6th Basic Energy Plan in 2021 set out the long-term goal of achieving carbon neutrality in 2050, specifying the principle of putting the highest priority on renewable energy. In order to overcome the energy crisis, achieve carbon neutrality, and eliminate fossil fuels, it is imperative for us to turn renewable energy into a major power source. Therefore, given the concept of the power system restructuring, the possible measures are short-term measures that will produce outcomes within one or two years, medium-term measures that will be implemented over a time horizon of about five years, and long-term measures that will be implemented over 10 years or more.

Section 1: Short-term measures (within one to two years)

Short-term measures mean measures that can be taken within the current framework without major infrastructure investments, system renovations, or institutional changes. Of these measures, DR is an effective measure that was also included in the report by the Expert Subcommittee.

According to METI, DR can be divided into three approaches (Figure 3). The first approach is a peak shift, which can be applied in factories. In this approach, production processes are distributed or otherwise modified to shift peak electricity hours. The second approach is so-called “power saving,” which involves efforts to reduce net power consumption by stopping the operation of electrical products during times when power is insufficient and by other means. The third is a technical approach to address power shortages by introducing PV power generation and storage systems.

Figure 3: How to implement DR



Source: Agency for Natural Resources and Energy, "For Utilization of Demand Response (DR)."[13]

METI is also focusing on DR by means of power saving, which is mentioned as the second approach. Specifically, the approach was named as a Project to Promote the Effective Use of Electricity, and a budget of 178.4 billion yen was appropriated for the project in fiscal 2022. Under this program, when consumers announce their participation in power-saving programs, including DR programs, the government provides a payment of 2,000 yen for individuals and 200,000 yen for corporations. According to METI, more than 250 retail power providers are participating in the program and preparing for the implementation of winter DR between December 2022 and February 2023.[14]

During such period, in addition to reducing power consumption at any time during the day, saving power when the electric supply becomes tight or when prices are high will contribute greatly. To that end, it is essential to use market mechanisms and provide incentives to consumers. Subsidies should be granted to underpin such electricity rates and DR support services, and as a major premise, it is also important to develop a fair competitive environment in which appropriate price signals are conveyed.

However, there is a limit to how much a pricing system alone can do to drive consumers. It is possible to make it easier for consumers to change their behavior by using technology, such as support equipment that automatically controls air conditioning. A particularly effective method is to introduce solar PV systems and battery storage to the consumer side, as their cost has decreased remarkably in recent years. Introducing renewable energy will contribute greatly to solving both soaring prices and the tight electricity supply. In addition, installing solar PV systems in households is a method that can be achieved in a short period of time and with a small impact on existing grid systems. Therefore, providing subsidies for such equipment has a great effect. The simulations performed by REI also show that the introduction of solar PV systems (as well as the introduction of battery storage through the use of

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13 Material 4-3 for the 50th Subcommittee on Electricity and Gas Basic Policy (May 27, 2022).

14 Overview of the press conference held by the Minister of Economy, Trade and Industry Nishimura after the Cabinet meeting on October 7, 2022.

appropriate subsidies) will work effectively in increasing the supply capacity while ensuring economic efficiency (Reference 1 below).

Based on the above, we recommend the following as short-term measures (within one to two years).

(Recommendations for short-term measures)

- Suppressing demand by introducing demand response and expanding the range of application (Positive contributions by retail power providers through the development of DR menus that will be widely accepted by consumers)
- Sustainable expansion of demand response utilizing technology (solar PV systems and battery storage)
- Augmenting measures to support the introduction of battery storage

Section 2: Medium-term measures (up to five years)

There are two major approaches as measures to take over the next five years or so to ensure stable supply of electricity. One measure is to develop a system that utilizes existing renewable power generation plants more effectively so that an adequate supply capacity will be secured when the electricity supply is tight. The other measure is to promote the further introduction of renewable energy power plants, which means sophisticating the operation of power transmission lines. Each of these measures will be discussed below.

1) Securing supply capacity by utilizing existing renewable energy power plants at times of tight electricity supply

When discussing where to install battery storage for the electric power system, the three possible options are customer sites, power generation sites, and grid-scale storage systems. As for installation at customer sites, as described in the explanation of the short-term measures, battery storage prices have been decreasing over the past few years, and depending on the amount of subsidies, there is an incentive for consumers to introduce them. In other words, they might proceed with introduction only because battery storage is economical rather than as a measure to prepare for disasters, which would result in additional expenses.

By the revision of the Electricity Business Act in 2022, it was decided that the energy storage business was positioned as a power generation business, and subsidies from METI were appropriated from the supplementary budget for fiscal 2021. [15] The introduction of battery storage for power systems has started progressing. There are two major revenue sources for the grid-scale battery energy storage business: gain from the sales and purchase of electricity, which make use of the difference in electricity price by time zone (provision of kWh value), and gain from the balancing market (provision of ΔkW value). In other words, it will facilitate investment if these markets work well as sources of revenue for the battery energy storage business. Since the charge-discharge-related loss of battery storage is generally considered to be smaller than that of pumped storage power generation (the charge-discharge-related loss of pumped storage hydropower is about 30%, while that of a battery energy storage system is about 10%), it can be expected to be a stable means of supplying electric power, which will replace the

[15] Website to Support the Introduction of Grid-Scale Battery Energy Storage Systems for Accelerating the Introduction of Renewable Energy by Fiscal 2021 Supplementary.

pumped storage power generation. On the other hand, considering that the installation cost of a battery storage system per storage capacity (kWh) is several times (at least double) that of pumped storage hydropower, whose construction cost per kWh is about 20,000 to 30,000 yen,[16] it will take a certain amount of time before battery storage is regarded as a means to store electricity.

Battery storage at power generation sites has been discussed at committees set by METI (Subcommittee on Renewable Energy Mass Introduction and Next Generation Power Networks, Energy Conservation and New Energy Committee/Electricity and Gas Industry Committee, Advisory Committee for Natural Resources and Energy). Concrete measures to ensure a stable supply of electricity with existing renewable energy power generation plants are being examined through these discussions, and the introduction of battery storage to existing FiT photovoltaic power plants has also been discussed.[17]

- Approach 1: Promoting the transition to FiP to FiT power plants
- Approach 2: Incentives to introduce battery storage to existing FiT PV power plants
- Approach 3: Incentives to increase the number of panels installed at existing FiT PV power plants

These three approaches show that there is a move to integrate variable power from renewables into the electricity market. Power output from renewables has been thought to vary depending on the weather. Such approaches to address that can be in line with the concept of the power system restructuring, which includes stimulating power generating parties' economic activities in the aim of increasing their gain and thereby trying to stabilize the supply and demand situation.

In particular, Approaches 2 and 3 effectively utilize the grid access capacity of existing FiT PV power plants to increase the supply capacity of renewable electricity without installing new transmission lines. Furthermore, they will secure more electricity for provision during time zones where the supply is likely to be tight. This was the aim of the power system restructuring, the supply-demand balancing function based on price signals. In the medium run of about five years, existing FiT PV power plants will be a strong candidate for achieving the goal. We conducted simulations under the assumption that battery storage would be introduced into existing FiT PV power stations and PV panels would be oversizing. The results, which are shown in Reference 2 (posted later), make it clear that a combination of those approaches will contribute to the stable electricity supply.

2) Sophisticating the operation of power transmission lines to further install renewable energy power plants

As explained later in Section 3, it is imperative to augment transmission lines for the mass introduction of renewable energy. However, since constructing transmission lines generally takes more than five years, the Japanese version of Connect & Manage is a practical and effective medium-term measure for the next five years.

The Japanese version of Connect & Manage refers to expanding access to renewable power sources by improving the operation of existing transmission lines. Specifically, it is made up of three parts: Probabilistic evaluation of power flow, the N-1 intertrip scheme, and Non-firm access. The Probabilistic

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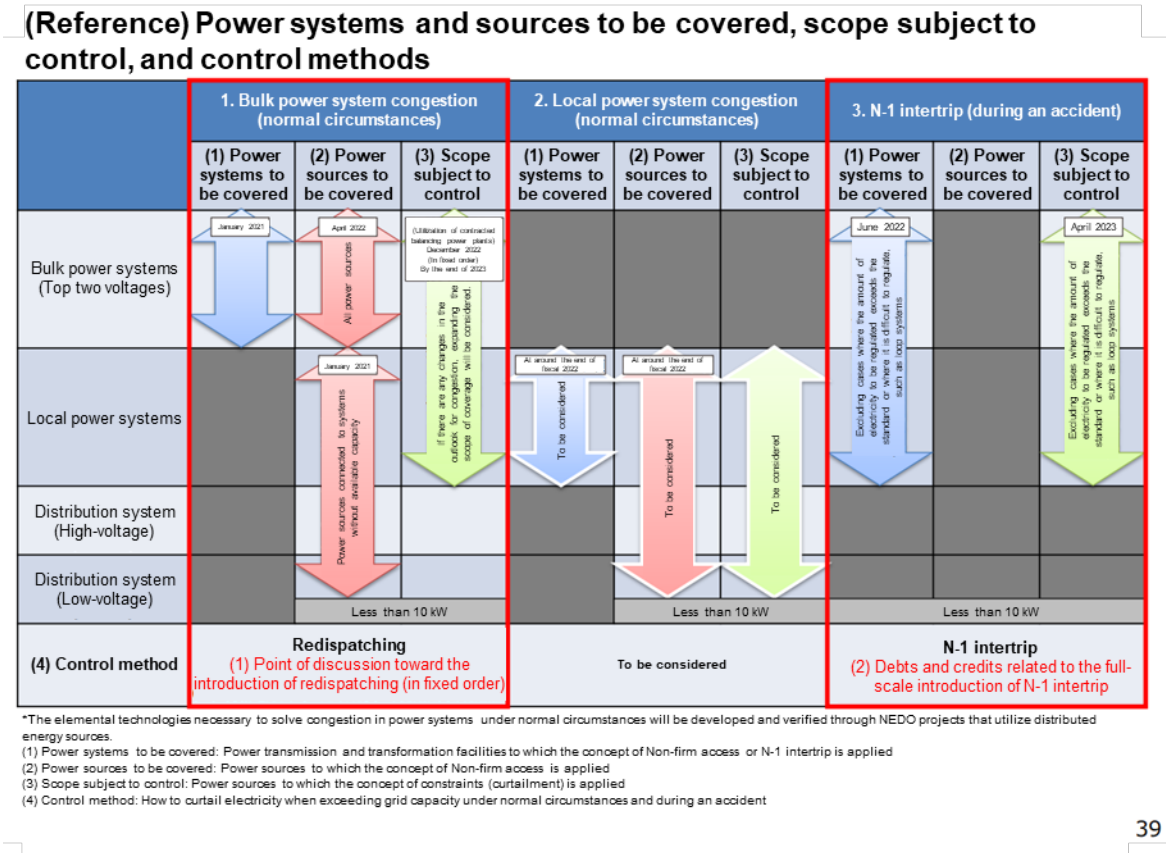
[16] Mitsubishi Research Institute, "Current Status of Energy Storage Systems" Material 5 for the 1st Energy Storage System Proliferation Study Committee Meeting (November 19, 2020).

[17] Material 1 for the 44th Subcommittee on Mass Introduction of Renewable Energy and Next-Generation Networks (August 17, 2022).

evaluation of power flow has already been implemented.[18] Non-firm access started to be applied to bulk power systems in January 2021 as shown in Figure 4, and N-1 intertrip in June 2022 to extra high-voltage systems.

Applying Non-firm access to bulk power systems alone is not enough and local power systems should also be covered. At present, some pilot projects are underway in the TEPCO PG service area.[19] Specific studies based on the results will start this fiscal year. This initiative will increase access to renewable energy power plants while utilizing existing transmission lines, and therefore, the momentum of this initiative should be accelerated.

Figure 4: Outlook for introducing Japanese version of Connect & Manage



Source: Agency for Natural Resources and Energy "Next-Generation Power Networks."[20]

Based on the above, we recommend the following as medium-term measures (up to five years).

(Recommendations for medium-term measures)

- Introducing a scheme to promote the installation of battery storage and transfer to FiP at existing renewable energy power stations
- Increasing access to renewable energy power plants by expanding Non-firm access to local power systems

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[18] OCCTO "Notice on the Application of Rationalization of Assumed Currents (February 21, 2018).

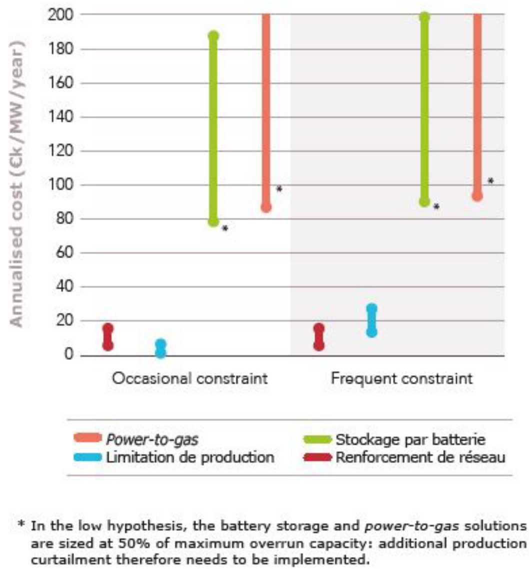
[19] TEPCO PG "Trial Application of Non-firm Access to Local Power Systems" (April 1, 2021).

[20] Material 1 for the 41st Subcommittee on Mass Introduction of Renewable Energy and Next-Generation Networks (April 26, 2022).

Section 3: Long-term measures (up to 10 years)

As a long-term measure to increase the ratio of renewables in energy mix and thereby to achieve a stable supply of electricity, it is very effective to enhance transmission lines from areas with high renewable energy potential to areas of demand. Figure 5 is a comparison by the French power transmission company RTE of the levelized costs of means for the mitigation of grid congestion. It shows that enhancement of transmission lines is more economical compared to Power to Gas, which produces hydrogen, and to battery storage. Non-firm access, which is presented as a medium-term measure, is a means of encouraging the introduction of renewable power sources within the capacity of existing transmission lines. However, in order to introduce renewables that greatly exceed the existing capacity, augmenting transmission lines is the most rational way from an economical point of view.

Figure 5: Comparison of technical options to mitigate grid congestion



Source: RTE, "French transmission network development plan 2019 edition," Figure 34[21], Economic comparison of the various solutions for managing constraints on the transmission system (2018 cost assumptions)

Table 3 shows the projected operating capacity of inter-regional transmission lines in fiscal 2024 and onward. According to the table, the operating capacity will increase in the Hokkaido-Honshu, Tohoku-Tokyo, and Tokyo-Chubu interconnection systems in fiscal 2028. As for the Hokkaido-Honshu and Tohoku-Tokyo interconnections, it was decided in fiscal 2021 that the development of transmission lines would be promoted while using the renewable energy surcharge as a source of funds. Preparations for development are underway. For the Tokyo-Chubu interconnection, 50Hz/60Hz frequency conversion stations have been augmented since the Great East Japan Earthquake and development has been promoted with the goal of increasing the capacity to 3GW by 2028. On the other hand, a concrete plan for enhancing transmission lines for fiscal 2028 and subsequent years has not been laid out yet as of October 2022.

[21] RTE French transmission network development plan 2019 edition

Table 3: Operating capacity of inter-regional transmission lines up to FY 2031

Interconnection line	Current direction	FY 2024 to 2027	FY 2028 to 2031
Hokkaido-Honshu interconnection system	To Hokkaido	90 (a)	120 (a)
	To Tohoku	90 (a)	120 (a)
Tohoku-Tokyo interconnection lines	To Tohoku	236 (a)	631 (a)
	To Tokyo	555 (b)	1028 (b)
Tokyo-Chubu interconnection system	To Tokyo	210 (a)	300 (a)
	To Chubu	210 (a)	300 (a)
Chubu-Kansai interconnection system	To Chubu	250 (d) [200 (d)]	
	To Kansai	134 (d) [25 (d)]	
Hokuriku Fence	To Hokuriku	150 (d) [70 (d)]	
	To Chubu, Kansai	190 (b) [125 (d)]	
Chubu-Hokuriku interconnection system	To Hokuriku	30 (a)	
	To Chubu, Kansai	30 (a)	
Hokuriku-Kansai interconnection lines	To Hokuriku	150 (d) [70 (d)]	
	To Kansai	190 (b) [125 (d)]	
Kansai-Chugoku interconnection lines	To Kansai	455 (c)	
	To Chugoku	278 (a)	
Kansai-Shikoku interconnection system	To Kansai	140 (a)	
	To Shikoku	140 (a)	
Chugoku-Shikoku interconnection lines	To Chugoku	120 (a)	
	To Shikoku	120 (a)	
Chugoku-Kyushu interconnection lines	To Chugoku	278 (a) [157 (d)]	
	To Kyushu	23 (d) [0 (d)]	

Note: The numbers in parentheses indicate the operating capacity determinants ((a) heat capacity, etc., (b) synchronous stability, (c) voltage stability, and (d) maintenance of frequency). The figures in square brackets indicate the estimated values for times when the available capacity is small aside from times of peak demand.
Source: Created by REI based on OCCTO's "Operational capacity of interconnection lines (annual and long-term) from FY 2022 to FY 2031.[22]"

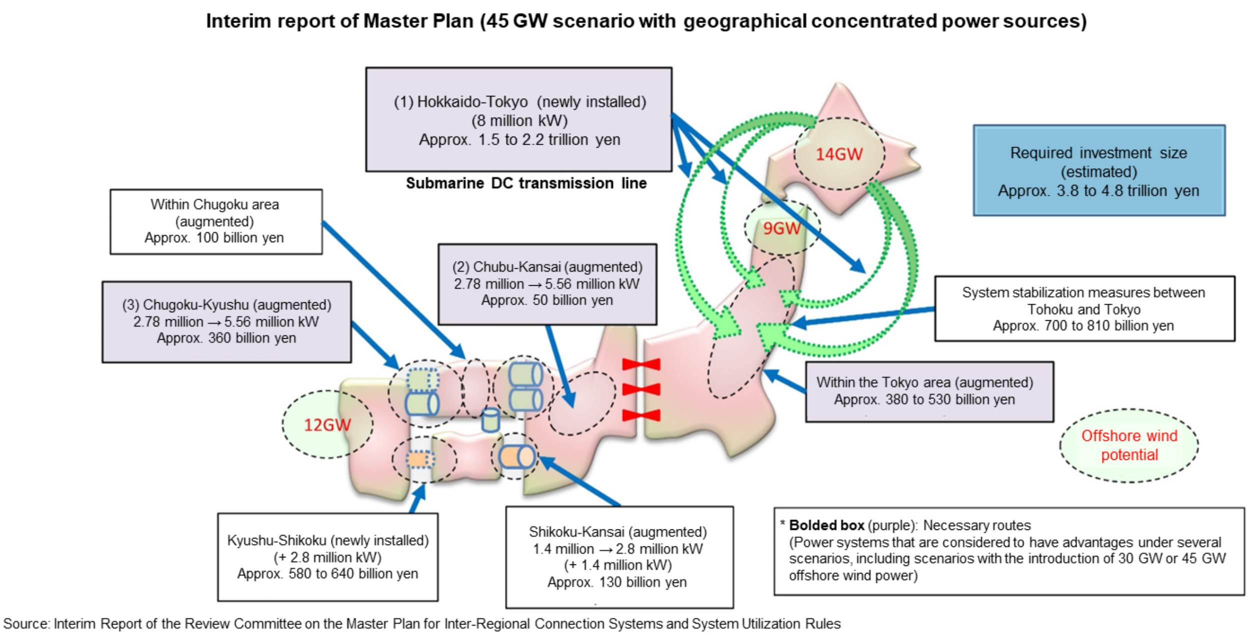
However, the 6th Basic Energy Plan promotes the introduction of offshore wind power and aims to launch projects with the goal of achieving 10 GW by 2030 and 30 to 45 GW by 2040. Since most of the potential for offshore wind power generation exists in the Hokkaido, Tohoku, and Kyushu areas, the plan also shows examination results of enhancing transmission lines for the transfer of generated power to the Tokyo, Chubu, and Kansai areas, where demand is large (Figure 6).

[22] OCCTO, "Operating Capacity of Interconnection Lines from FY 2022 to 2031 (Annual/Long-Term) Attachment 1 (March 1, 2022).

In July 2022, the Cross-Regional Network Development Committee of OCCTO set about formulating a specific power system plan for the introduction of offshore wind power generation in the future, and it is currently examining a system development plan toward January 2024.[23] For the inter-regional connection between Hokkaido and Tokyo, however, the introduction of a capacity of 2 GW, for the Sea of Japan route, is being considered in principle. This is smaller than the required increase of 4 to 8 GW indicated in the interim report[24] of the master plan. In order to make the most of the offshore wind power potential (more than 20 GW) in the Hokkaido and Tohoku areas, it is clear that, sooner or later, inter-regional transmission lines should be increased further, more than the interconnection lines enhancementplan (the 2 GW for the Sea of Japan route), which has been discussed by the Cross-Regional Network Development Committee.

In addition, for the inter-regional connection between Kyushu and Chugoku, enhancement of the Kanmon Interconnection Line and enhancement within the Chugoku area have been discussed.

Figure 6: Image of the enhancement of inter-regional transmission lines presented in the 6th Basic Energy Plan



Source: Agency for Natural Resources and Energy, “Energy Supply and Demand Outlook for Fiscal 2030 (Related Materials)” (October 2021).

Based on the above, we recommend the following as a long-term measure (up to 10 years).

(Recommendation for long-term measure)
• Setting a transmission line enhancement plan that makes the most of the renewable energy potential, mainly offshore wind power potential, and proceeding with the development thereof

23 The Review Committee on the Master Plan for Cross-Regional Interconnection Systems and System Utilization Rules (Master Plan Review Committee) will present the necessary nationwide power system plan, and routes will be discussed in more detail at the Cross-Regional Network Development Committee.

24 OCCTO, “Master Plan Interim Report” (May 31, 2021).

Conclusion

The current energy crisis is extremely serious, causing the prices of fossil fuels and electricity throughout Japan to spike. The situation facing the electric power sector was caused not because decarbonization had been promoted excessively or because the power system restructuring itself was wrong; rather, as explained in these recommendations, the major cause was the delay in the mass introduction of renewable energy and power system restructuring. The need for DR that makes use of the market mechanisms and inter-regional connection of electricity utilizing transmission lines has been discussed since 2012. Even so, many of those measures have not been implemented adequately. Now is the time for us to accelerate those efforts to address the energy crisis in the most effective manner.

In the short term, suppressing demand through the introduction of DR and expanding the range of application will work effectively. In addition, DR utilizing technologies like battery storage should also be enhanced. In the medium term, with the transition to FiP, efforts should be made to increase the supply capacity of renewable energy power plants. In addition, Non-firm access should be extended to local power systems in order to effectively utilize existing power systems. In the long term, long-distance transmission lines should be enhanced in an accelerated manner to establish connections between sites suitable for offshore wind power plants and the sites of demand for electricity.

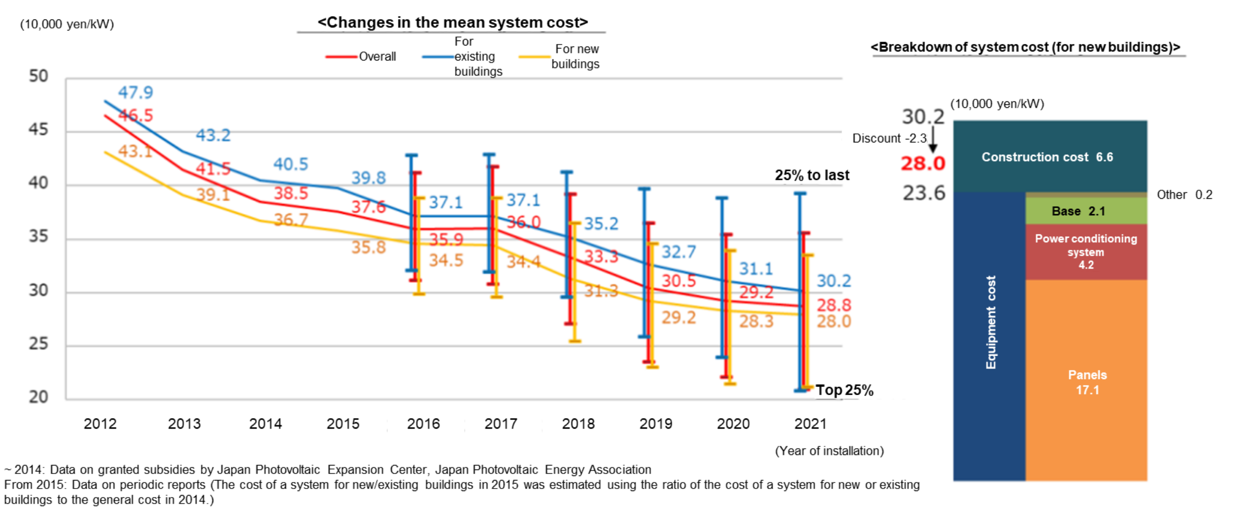
Europe, which is facing a more serious energy crisis, is simultaneously speeding up its efforts to address the twin challenges of de-Russianization and de-fossilization. The energy crisis is a fossil fuel crisis, and decarbonization and de-fossilization are on the same course. Japan, which has almost no fossil fuels, must urgently shift its energy sources by means of renewable energy and energy conservation. To this end, all of the measures recommended herein should be mobilized to accelerate and thoroughly implement power system restructuring.

Reference 1: Introduction of household solar PV systems and battery storage and simulation of economic efficiency

In light of recent technological developments and other factors, the short-term measure that is most effective in securing a stable supply of electricity and that is advantageous to customers is introducing PV power and battery storage to the customer side.

Since the introduction of the FiT system, the cost of household solar PV systems has dropped remarkably. According to the Procurement Price Calculation Committee of METI, the price of solar PV systems has fallen to 288,000 JPY/kW on average nationwide (Figure 7). The price has dropped by approximately 40% compared to 465,000 JPY/kW in fiscal 2012.

Figure 7: Prices of household solar PV systems



Source: Procurement Price Calculation Committee of METI, "Opinions on Procurement Prices, etc. for Fiscal 2022 and Beyond" (February 4, 2022).

Prices of battery storage are also gradually falling. According to the data published by the Mitsubishi Research Institute in fiscal 2021,[25] system cost, including the installation cost of a household battery storage, was 187,000 JPY/kWh in fiscal 2019, and the target for fiscal 2030 was 70,000 JPY/kWh. As of October 2022, however, the market price of some products had already fallen below 100,000 JPY/kWh, and depending on the capacity, prices are approaching the target price for fiscal 2030.

This section simulates the economic efficiency of the measure of introducing household solar PV systems and battery storage. The calculation conditions are shown in Figure 8. In this case, the annual power output is 6,833 kWh, and a surplus of 4,783 kWh is generated. If the electricity is sold at the fiscal 2022 FiT price of 17 JPY/kWh (tax included), the sales amount will be 81,311 JPY (tax included), which means revenue of 813,000 JPY over 10 years. In addition, given that the amount of electricity used privately is 2,050 kWh, electricity costs will be reduced by 67,117 JPY (tax included). Furthermore, assuming that the surcharge on renewable energy is set at 4.00 JPY/kWh (tax included) on average for

[25] Mitsubishi Research Institute, "Examination of Target Prices and Prospects for the Introduction of Stationary Energy Storage Systems," Material 4 for the 3rd METI Stationary Energy Storage System Proliferation Study Committee Meeting (January 19, 2021).

the next 10 years and that the fuel cost adjustment rate is 6.00 JPY/kWh (tax included), a reduction of 10 yen/kWh can be taken into account. As a result, the charge for personally consumed electricity will be reduced by 87,617 JPY annually, which equals a reduction of 8,760,000 JPY for 10 years. Therefore, the combined revenue from sales of electricity and the reduction in electricity cost amounts to 1,689,000 JPY, close to the investment amount of 1,728,000 JPY. This shows that introducing solar PV systems contributes to increased supply capacity while ensuring economic efficiency for customers.

Figure 8: Calculation conditions of a simulation on the introduction of household solar PV power generation and storage batteries

(Solar PV power system) • Solar PV system capacity: 6 kW • Oversizing: Not applied • Installation cost: 288,000 JPY/kW (tax included) • Capacity factor: 13% • Ratio of electricity self-consumption: 30% • Ratio of electricity sold: 70%	(Electricity rates) • TEPCO Energy Partner Nighttime Toku 8 • 7:00–23:00: 32.74 JPY/kWh (tax included) • 23:00–7:00 next morning: 21.16 JPY/kWh (tax included) (Energy storage systems) • Energy storage systems: 13.5 kWh • Installation cost: 130,000 JPY/kWh (tax included)

Source: Created by Renewable Energy Institute.

In the recent cases of the introduction of solar PV systems, the so-called “oversizing,” a method of introducing a PV power generation capacity larger than the power conditioner capacity, is generally introduced. When oversizing is used, the increase in capacity ratio becomes larger than the increase in the installation cost, leading to enhanced profitability. In other words, depending on the design, it may be possible to introduce solar PV systems while securing economic efficiency.

Here is a case where a solar PV system is introduced along with battery storage. If 80% of the 4,783 kWh of excess electricity sold is consumed privately with the use of the battery, the electricity utilized will be 3,826 kWh. Assuming that half of the electricity is used during daytime hours and half during late-night hours, the reduction in electricity costs will increase by 103,111 JPY (tax included) per year. The reduction in electricity costs will increase by 141,371 JPY (tax included) per year if the renewable energy surcharge and the fuel cost adjustment rate are taken into account as well. On the other hand, revenue from sales of electricity would decrease to 16,262 JPY per year (tax included) as the amount of electricity sold decreases. Taking into account the reduction in electricity costs due to the introduction of battery storage and the decrease in revenue from sales of electricity, the introduction of a solar PV system and battery storage will reduce the electricity cost by 2,453,000 JPY (tax included) over 10 years. As shown in Figure 8, the cost of installing battery storage is 1,755,000 JPY (tax included), so the total investment cost including the solar PV system is 3,483,000 JPY.

If battery storage is to be introduced, the revenue from the sales of surplus solar PV power does not account for a large share depending on the capacity. Therefore, it is also effective not to use the FiT system from the beginning and to utilize subsidies to reduce the investment cost. For example, when utilizing the subsidy for the introduction of solar PV systems and battery storage offered by the Tokyo Metropolitan Government in fiscal 2022, a subsidy of 100,000 JPY/kW (for new buildings) or 120,000

JPY/kW (for existing buildings) is granted for the installation of a solar PV system of 3 kW or more, and half of the installation cost of battery storage (100,000 JPY/kWh, up to 800,000 JPY/household) are also subsidized.

If both subsidies are applied to this simulation, a total of 1,400,000 to 1,520,000 JPY is subsidized, or 600,000 to 720,000 for the solar PV system and 800,000 JPY for the battery. This means that consumers will be able to recover their investment within 10 years and at the same time contribute to the stable supply of electricity. We can say that these subsidies have achieved the target cost of 70,000 JPY/kWh for the introduction of battery storage, which is presented in the document of the Mitsubishi Research Institute. In other words, the reasonable subsidizing measures are measures to increase the number of installations so that the installation cost will fall to achieve the level where the autonomous introduction of battery storage can be facilitated even without subsidies.

Reference 2: Simulation of an electric power supply from a 49 kW PV power station operated under FiP with the introduction of oversizing and battery storage

This study analyzes the electric power supply to the grid system from an existing PV power plant where the power generation capacity has been oversizing and a battery storage has been installed later on. The analysis conditions are as follows.

- Power plant: PV power plant
- Plant capacity: 49 kW (existing)
98 kW (when oversizing)
- Specifications of battery storage: 5 kW/27 kWh (Case 1)
25 kW/135 kWh (Case 2)
- Solar radiation data: NEDO solar radiation data (Hamadori, Fukushima)
- Market price: 2020 JEPX spot market (Tokyo area)
- Operation of battery storage: Storage or discharge is determined by comparing the current price and the average price for the subsequent five hours
- Charging from the grid system: None

The calculation results are shown in Figure 9. The horizontal axis represents 24 hours, and the vertical axis represents the amount of power supplied to the grid system. The mean in the figure is the annual mean, and σ is the standard deviation. In other words, the output is within the dotted lines on about two-thirds of the 365 days.

The graph on the upper left in Figure 9 is the estimated output from an existing power plant with a capacity of 49 kW. It shows that most of the secured system capacity (meaning the station capacity of 49 kW) is not utilized. In other words, the time duration when the output reaches the secured system capacity of 49 kW is limited to a short period of time.

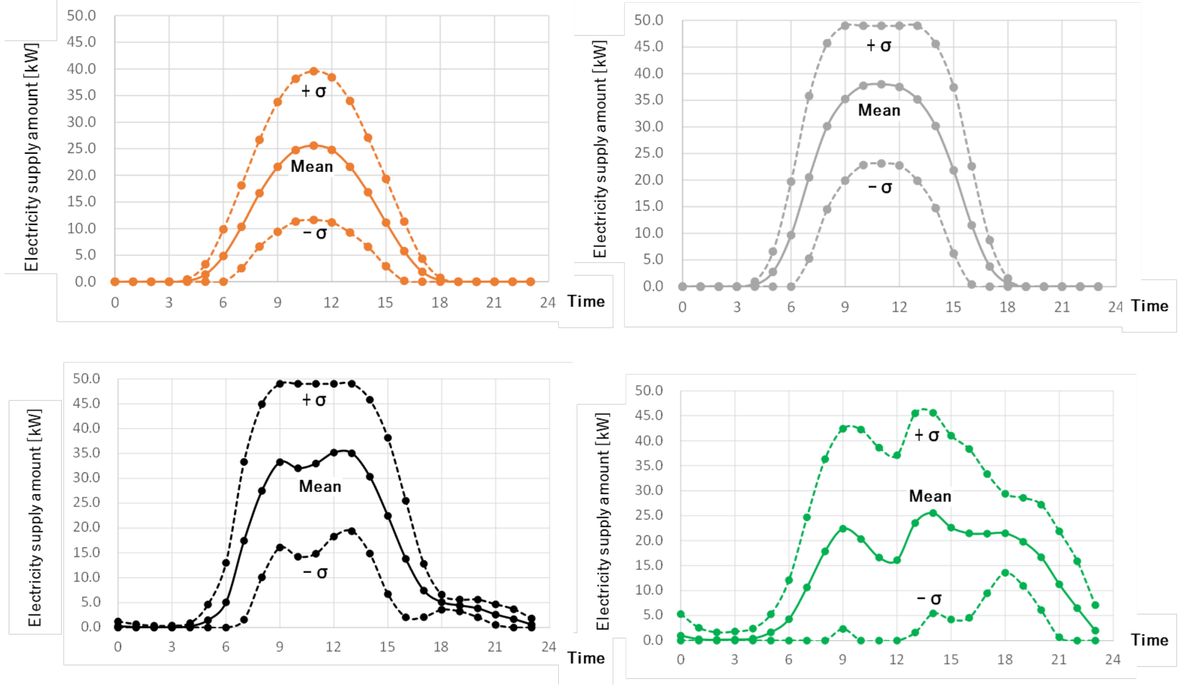
Therefore, in order to utilize the system capacity more effectively, overloading PV panels to increase the amount of electricity to supply is an appropriate method that contributes to the stable supply of electricity. The graph on the upper right in Figure 9 is a profile of the annual mean output when two-fold overloading is introduced. It shows that electricity of more than 25 kW is supplied to the grid during peak hours (11:00 to 13:00) on two-thirds or more of the 365 days.

Simulations were also conducted under the assumption that a battery storage system is installed at an oversizing PV power plant (PV panels of 98 kW). Two cases of battery capacities were assumed: 5 kW/27 kWh and 25 kW/135 kWh. According to the graphs, if the electricity is sold on the market under the FiP system, the introduction of battery storage of 5 kW/27 kWh, which is a small battery capacity compared to the output, would have little impact on the electricity supply amount (lower left in Figure 9), while when a certain capacity of battery storage, 25 kW/135 kWh, is installed, the electricity supply to the grid is reduced during daytime and increased in the evening (lower right in Figure 9). That means that if PV power plants and other variable renewable energy power plants install battery storage and use the FiP system at the same time, the PV power plants will further contribute to stabilizing the electricity supply. When introducing oversizing and installing battery storage at existing power plants, the economic efficiency for power generation businesses depends on the design of FiP scheme. Among renewable energy power generation companies, there is a movement to seriously consider how to roll out businesses with the power plants whose FiT period has passed for a certain period, looking ahead to the end of FiT. Incorporating these companies' efforts into the FiP scheme will probably create a situation that allows PV power plants to contribute to the supply of electricity during peak demand in the evening.

Regarding the renewable energy surcharge, combining FiP, oversizing, and introduction of battery storage will not always result in an increase. Such plants supply electricity to the grid during times when the market price is high, but high market prices also increase the avoidable costs based on which the renewable energy surcharge is determined. On the other hand, introducing more PV power during daytime when electricity prices are low will depress avoidable costs and lead to an increase in the renewable energy surcharge. In other words, if PV power plants introduce oversizing and battery storage and shift the time of power supply to the grid based on FiP scheme, the grid system capacity will be utilized effectively, and furthermore, the renewable energy surcharge may be suppressed to some extent.

Figure 9: Simulation results of an electric power supply from a 49 kW PV power station that has introduced oversizing and battery storage and is operated under the FiP scheme

(Upper left: Without oversizing; Upper right: Two-fold oversizing; Lower left: Two-fold oversizing + installation of 5 kW/27 kWh battery storage; Lower right: Two-fold oversizing + installation of 25 kW/135 kWh battery storage)



Source: Created by Renewable Energy Institute.

Recommendations for Power System Restructuring in View of the Energy Crisis

December 2022

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