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RENEWABLE ENERGY INSTITUTE

Proposal for the 2035 Energy Mix (First Edition)

Toward Decarbonizing Electricity with Renewable Energy

Preliminary Translation
May 2023

This report is the English excerpt of "Proposal for the 2035 Energy Mix (First Edition)Toward Decarbonizing Electricity with Renewable Energy," originally published in Japanese on 11 April 2023. In the English version, only topics which are particularly relevant to Japan are translated.

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Authors

The 2035 Energy Mix research team at Renewable Energy Institute

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 Corp., with his own resources.

Note: The English version of the report is a preliminary and partial translation of the Japanese original.

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Key Findings

Chapter 1: Accelerating the energy transformation to overcome the climate and energy crises

The 2022 G7 leaders' communiqué agreed “to commit to achieving a fully or predominantly decarbonized power sector by 2035”. A review of national policies and development trends shows that, with the exception of France, five countries have set a target of supplying 70% or 80% of their electricity from renewables by 2035, or are taking measures in this direction.

The Green Transformation (GX) Basic Policy, decided by the Japanese Government in February 2023, does not raise the target of 36%–38% renewables by FY2030 nor does it mention about decarbonization pathway target for 2035. The Kishida Government's emphasis in the GX Basic Policy is on the use of nuclear power and 'zero-emission thermal power', neither of which are expected to generate significant supplies in the 2030s, nor are they sustainable sources of generation. It is not a rational choice in terms of cost.

Considering the GX Basic Policy, the only way to achieve an electricity mix in 2035 in line with the IPCC 1.5-degree decarbonization pathway is to further accelerate the introduction of renewable energy sources, which are becoming increasingly cost-effective in Japan. If Japan fails to expand renewable energy, it will not be able to achieve the emission reductions proposed by the IPCC by 2035. In addition, Japan's dependence on fossil fuels and the high emission factor of electricity will make it an unsuitable location for businesses. While the delays and distortions in national policy are serious, Japan inherently has abundant renewable energy potential, and companies, local governments, and communities are taking various progressive steps to utilize this potential. If national energy policy can be transformed by accelerating the movement of these non-state actors, it is entirely possible for Japan to achieve a 2035 decarbonization pathway electricity mix in which the vast majority of electricity will be supplied by renewables.

Chapter 2: Solar PV development potential

Since the introduction of the FIT system in 2012, solar power generation has increased, reaching 79.2 GW by the end of FY2021. The cost of power generation in Japan, which was relatively high compared to international standards, has been declining and is estimated to reach 5 JPY/kWh by 2030. Up to now, the introduction of ground-mounted large-scale solar power generation has been the driving force. However, the biggest driver towards 2035 will be solar installed on building rooftops. The introduction of solar PV not only in new buildings but also in existing buildings is increasing due to the fact that solar PV is now cheaper than grid electricity and the development of lightweight, space-saving solar panels. By accelerating this trend through the introduction of appropriate regulation and guidance measures, it is possible to increase this fivefold from 31.6 GW at the end of FY2021 to 159 GW by the end of FY2035. In the case of ground- mounted systems, solar sharing coexisting with agricultural operations and the use of abandoned land are progressing, and installation has also started in parking lots, on infrastructure lands such as roads, airports, and railways, and on water surfaces. Together, these could increase by 2.5 times from 47.6 GW at the end of FY2021 to 121.2 GW by the end of FY2035. Combined with rooftop and ground installations, 280.2 GW of solar PV could be installed by the end of FY2035, generating 343.7 TWh of electricity.

Chapter 3: Wind power development potential

The introduction of wind power in Japan has lagged far behind, standing at 4.6 GW at the end of FY2021. Offshore wind power was only 135 MW. This delay is due to the restriction to connecting to the grid and lengthy environmental assessment procedures. On the other hand, Japan has great potential for wind power generation, which according to a survey by the Ministry of the Environment amounts to 264 GW onshore and 392 GW offshore, for a total of 656 GW. For onshore wind power, the total installed capacity of projects currently undergoing environmental assessment procedures is 29.7 GW. Based on an assumption of the extent to which projects are scaled down or cancelled due to environmental conservation considerations and other factors at each stage of the assessment procedure, and after examining the status of applications for connection contracts to the power grid, it was estimated that 34.4 GW could be installed by 2035 if various regulations are relaxed and environmental assessments are accelerated.

In offshore wind, the total installed capacity of projects undergoing environmental assessment procedures is 18.6 GW, if overlaps in the same sea area are excluded. Taking into account the status of procedures under the Renewable Energy Sea Area Utilization Act, it is estimated that 14.3 GW will be in operation by 2035. In addition to this, the introduction of new projects, including floating projects, could be expanded to a total of 25.4 GW by accelerating the formation of new projects and the designation of promotion areas. As a result, the total installed capacity of onshore and offshore wind power generation is estimated to reach 59.8 GW, with an estimated generation of 174 TWh.

Chapter 4: Potential for non-variable renewables

The introduction of bioenergy power generation has increased due to the FIT scheme, with 6.4 GW in operation at the end of June 2022. Outside of the FIT scheme, it can be assumed that the existing coal-fired power used for on-site industrial power generation will be converted to 100% biomass as an emission reduction measure. Based on this situation, the installed capacity of bioenergy power generation is estimated to be 9.2 GW in 2035, with a generation capacity of 85.7 TWh.

The total installed capacity of hydropower (excluding pumped storage) at the end of FY2021 was 22.5 GW, of which 9.8 GW was small and medium hydro of less than 30 MW in size. The amount of electricity generated is 77.8 TWh. For large hydropower, a certain increase in electricity generation is expected due to the refurbishment of facilities. Small and medium hydropower is estimated to increase by 2 GW in the future, based on the introduction trends to date. Based on the above, hydropower generation is projected to be 99.6 TWh in 2035.

Japan's geothermal power potential is estimated to be around 23 GW, the third largest in the world. However, as of FY2021, only 0.54 GW of installed capacity was in operation and only about 2.3% of geothermal resources were being utilized. The development of geothermal power generation requires a resource survey, a grid connection to the area where the power plant is to be installed, and the formation of an agreement with the surrounding hot spring operators. The current lead time for geothermal development is more than seven years. Fundamental institutional reforms are needed to utilize the great potential of geothermal power generation. By implementing these institutional reforms promptly, it is assumed that the installed capacity will increase by 1 GW by 2035, with an annual electricity generation capacity of 11.5 TWh.

Chapter 5: Electricity supply mix in 2035

Electricity demand outlook in 2035

In order to achieve the emission reductions by 2035 proposed by the IPCC, it is necessary to thoroughly promote energy efficiency and electrification on the demand side as well as decarbonization on the supply side. In particular, it is important to reduce energy consumption by shifting to a circular economy in the future. While electrification increases electricity demand, it also increases energy efficiency, as exemplified by heat pump equipment, which can limit the increase in electricity demand.

Based on this consideration, final energy consumption and electricity demand in 2035 were estimated for the industrial, commercial, residential, and transport sectors. The industrial sector, particularly the steel industry, which accounts for nearly half of the industrial emissions, is expected to convert 15% of blast furnaces that will reach the end of their lifetime by 2035 are expected to be converted to electric furnaces. In the transportation sector, we assumed a policy shift from the use of hybrid passenger cars to the promotion of EVs. In the commercial and residential sectors, efficiency improvements through equipment upgrades, the use of heat pumps for air conditioning and hot water supply, and improvements in building insulation and heat shielding performance can be expected. Through the promotion of these measures, final energy consumption in FY2035 was estimated to be 24% lower than in FY2019, and electricity demand was estimated to be 850 TWh, 8% lower than in FY2019, even with the promotion of electrification.

Projected supply potential of each power source

Renewable energy generation

When the potential deployment of each of the renewable sources estimated in Chapters 2 to 4 is added together, it is assumed that the amount of electricity generated from renewables in 2035 can be expanded to

714.5 TWh. This is more than three times the current level and more than twice the government target of 353 TWh for FY2030. Solar PV deployment needs to increase to 3.5 times the current level by 2035, while the European REPowerEUPlan aims for a fourfold increase by 2030. Wind power will need to increase by a factor of 13 by 2035, which is a more rapid expansion than solar power. However, this is a lagging result of the current installed capacity of only 4.6 GW and only 135 MW of offshore wind power. Based on the experience of the countries that have led the way, it is entirely possible to achieve this high target by taking the measures and regulatory reforms proposed in Chapter 6. In addition, decreasing costs, technological development, and progress in regulatory reform may make it possible to introduce more than this time envisioned.

Nuclear power generation

The roadmap in the GX Basic Policy does not envisage the operation of new reactors as of 2035. As of March 2023, only 10 (10 GW) of the 33 (33 GW) reactors in Japan were in operation, and of these, only two will be operational in 2035. If we add to this the two reactors that are not in operation at the moment but have passed the new regulatory standards and have a scheduled start-up date, a total of four reactors will be able to supply approximately

17 TWh of electricity, which is only 2% of the forecast demand in 2035. A maximum of 16 reactors would operate and may supply 11% of power in FY 2035 if all the following assumptions are realized, which would be extremely difficult to achieve: (i) all reactors under review will restart, (ii) all the reactors that have applied for 60-year operation are granted an extension, and (iii) the two reactors under construction go into operation. This estimate assumes a capacity factor of 70%, but existing nuclear power plants are not immune from the effects of aging, and the operating rate is expected to decline due to frequent problems. Furthermore, half of the 14 existing reactors, seven reactors will cease operation by 2038.

Fossil fuel power generation

At the end of FY2021, there were 50.4 GW of coal, 79.1 GW of natural gas, and 22.7 GW of oil-fired power generation capacity in Japan. In terms of generation share, coal accounted for 31%, natural gas 34.4%, and oil and waste 7.4%, with fossil fuels accounting for 72.8% of total electricity generation in FY2021. The government intends to continue using coal-fired power generation beyond the 2030s through ammonia co- firing and the use of CCS, but cutting emissions of thermal power generation in this way is not a reasonable option in terms of both emission reduction effectiveness and cost. The government's CCS strategy also aims to export and store carbon dioxide emitted domestically to Southeast Asia and elsewhere. Coal-fired power generation needs to be phased out by 2030.

Natural gas-fired power generation needs to be phased out as well, as soon as possible, but it will supply the part that renewables cannot supply until achieving 100% renewables. If we assume the 79 GW of existing facilities will be shut down after 40 years of operation and even if the construction of 2.3 GW of facilities that are planned but not yet built are suspended, there will still be approximately 58 GW of natural gas-fired capacity in 2035. Assuming that these generating facilities operate at 70% of capacity, a supply of 356 TWh would be possible. This corresponds to 42% of the electricity demand assumed earlier.

The shape of the 2035 electricity mix toward decarbonization

Renewable energy sources, mainly solar PV and wind power will supply 714.5 TWh, or 80.3% of the total power supply requirement of 890 TWh (850 TWh of electricity demand plus transmission losses) envisaged for 2035. The remaining 175.5 TWh will be supplied by natural gas. Coal-fired power generation is not envisaged to be used. Nuclear power generation is not assumed to be used, as it cannot be assessed as a sustainable power source, although it could supply up to 11% of the electricity in 2035, according to our calculations.

This decarbonization pathway electricity mix would reduce carbon dioxide emissions from the power generation sector by 73.2%. The overseas fossil fuels import cost required for thermal power generation can be significantly reduced by JPY 4.209 trillion, from JPY 5.368 trillion to JPY 1.159 trillion annually. As 80% of electricity would be generated from domestic renewable energy resources, this would contribute to increased energy self-sufficiency and strengthen energy security.

Decarbonization Pathway Electricity Mix in 2035

Source of Electricity		Generation (TWh)	Share (%)
Renewable Energy	Solar	343.7	38.6
	Wind	174.0	19.6
	Geothermal	11.5	1.3
	Biomass	85.7	9.6
	Hydro	99.6	11.2
	Subtotal	714.5	80.3
Fossil Fuel	Natural Gas	175.5	19.7
Total		890.0	100

Source) Renewable Energy Institute

Chapter 6: Proposals for 2035 decarbonization pathway electricity mix

1. Promptly revise the Strategic Energy Plan, with a 2035 renewable energy target of 80%

As a first step towards decarbonizing power sources as of 2035, the current Strategic Energy Plan renewable energy target needs to be revised to at least 80% in 2035 as the cornerstone of national energy policy. In conjunction with this, the annual roadmap for the introduction of solar power, wind power, etc. will be presented to enhance the predictability of investment. This will also support the formation of a domestic supply chain to supply renewable energy generation facilities.

In the Strategic Energy Plan, which was first revised in 2014 after the Great East Japan Earthquake and Fukushima Daiichi Nuclear incident, the government set the 2030 renewables target at a low level of 22-24% and left it unchanged in the 2018 revision. This should not be repeated in the next revision.

2. Implement regulatory reforms to significantly accelerate the introduction of wind and solar power

Wind power development in Japan remains significantly lower than in Europe, the U.S., and China, and acceleration of deployment is the most important issue to achieve power source decarbonization by 2035.

What is needed to accelerate the deployment of wind power is to speed up the permitting process, accelerate the development impact assessment process, and improve the process for coexistence with local communities. In particular, in terms of speeding up licensing procedures, it is necessary to centralize procedures that span multiple administrative agencies and shorten the time required to review safety standards for power generation facilities.

To accelerate the deployment of solar PV, the installation of PV systems in new buildings, including residences, should be made mandatory nationwide, as Tokyo metropolitan government and Kawasaki city have done in the past. In addition, for existing buildings, it is necessary to promote 100% installation in public buildings by 2035 and to work on the diffusion of lightweight PV systems.

3. Reform of the electricity system with a focus on the separation of ownership

Since 2022, there have been revelations of acts in breach of the Anti-Monopoly Act and the Electricity Business Act, including alleged collusion by major power companies, leaks and unauthorized access to customer information of new power companies, and unauthorized access to METI's renewable energy management system by those incumbent utilities. As former monopolies, the major power companies still have overwhelming market dominance and monopolize the power transmission and distribution networks. If the transmission and distribution business is not independent, grid connection will be difficult for renewable energy generators, many of whom are new entrants. As the legal separation of the transmission and distribution business implemented in 2020 has proved inadequate, separation of ownership is necessary. Under a transmission and distribution utility that is also independent in terms of capital, priority connection, and supply of renewables to the grid; wide-area and rational supply-demand coordination; and transmission network reinforcement must be accelerated.

4. Start of grid reinforcement for decarbonization through renewables

In the decarbonization pathway electricity mix presented here, 58% of the 890 TWh of electricity generated in 2035 will be supplied by variable sources: solar PV and wind power. In parallel with the study of the 2035 energy mix, Renewable Energy Institute conducted a study and published a report on how the power grid can be decarbonized with renewables. Based on the results of this study, the transmission network development required to realize a decarbonized electricity mix was examined, and it is considered that 4 GW of transmission network reinforcement is needed between Hokkaido and Honshu. Currently, 2 GW of grid reinforcement between Hokkaido and Tokyo transmission system operators is underway in Japan. Since it will take a long time to build the grid, it is necessary to reach a consensus on the 2035 energy mix that will decarbonize Japan by 2050 and start the planned grid development.

5. Early introduction of carbon pricing to attract global decarbonization investment to Japan

The carbon pricing concept set out in the GX Basic Policy is a voluntary system under which companies that do not want to participate are not required to do so. The transition to a mandatory system and the start of paid auctioning of emission allowances will take place 10 years later, in FY2033, and is limited to power generators only. The level of the carbon tax will be as low as one-tenth of the $130 in 2030 required of developed countries estimated by the IEA. In addition, GX Transition Bonds, which will be issued with revenues from carbon pricing as a reimbursement source, will also include the development and use of grey hydrogen and grey ammonia. In order to attract global decarbonization investment to Japan and achieve an energy transition, carbon pricing must be introduced as soon as possible as a global standard, and an effective carbon price for emission reductions must be achieved.

6. Acceleration of corporate PPAs

A comparison of country-specific renewable electricity utilization rates among RE100 member companies shows that in Japan, the rate is only 15%, compared to 68% in the USA, 99% in the UK, and 85% in Germany. The first reason for this is the low share of renewables in the country's overall electricity in Japan, while the second is the slow utilization of corporate PPAs. Corporate PPAs are increasing in Japan, but the scale of power generation is small, totalling less than 1% of the global contracted amount. In order to further dramatically increase the number of contracts in the future, it is necessary to provide economic incentives, such as tax credits, to accelerate corporate initiatives.

7. Strengthening the responsibilities and implementation capacity of municipalities in renewable energy development

The most fundamental responsibility of local authorities is to protect the safety, lives, and property of their residents. At a time when the climate crisis threatens this, it is the responsibility of the state as well as local governments to reduce greenhouse gases, and the expansion of renewable energy, the most important means of fulfilling this, as well as energy efficiency, is a responsibility that local governments should take on. The ordinances enacted successively by the Tokyo Metropolitan Government and Kawasaki City requiring housing manufacturers to install solar PV generation in new homes are a recognition of the role that local authorities should play in the climate and energy crises. In order for local governments to be able to play a greater role in expanding renewable energy, it is essential that, in addition to strengthening their responsibilities, they also strengthen their financial base, secure human resources, and otherwise enhance their ability to implement.

Conclusion

In light of the IPCC's 6th Assessment Report target of a 65% reduction in CO2 emissions by 2035 compared to 2019 levels, Japan must aim to supply at least 80% of its electricity from renewable energy sources by 2035 as a minimum requirement. What is needed now is a complete break from the stereotype that Japan must remain forever dependent on fossil fuels and nuclear power. It should move forward with a new, decarbonized, sustainable, and globally compatible energy system that relies almost entirely on domestically produced renewables.

The English version of this report is a preliminary and partial translation of the Japanese original. Please note that some parts are not translated into English, and they are marked with an asterisk.

Chapter 1 Accelerating the energy transformation to overcome the climate and energy crises

1. A world in which renewable energy is accelerating electric power decarbonization

Impact of the (U.S.) Inflation-Reduction Act (IRA)*

The G7 consensus*

China*

2. The risks of Japan's "GX strategy"

While Europe, the U.S., and China each formulated their own energy strategies in 2022 to address the ongoing energy and climate crises, in February 2023 Japan's Cabinet approved the Basic Policy for the Realization of Green Transformation (GX) (hereinafter "GX Basic Policy"). Although the GX Basic Policy maintains the policy of making renewables a major source of electric power, as set forth in the 6th Strategic Energy Plan of 2021, and includes some constructive statements, in terms of implementation goals it does not move an inch beyond the previous target of 36–38% for 2030. Neither is there any reference to the decarbonization of power sources by 2035, as agreed by the G7 in 2022.

In the GX Basic Policy and successive legislative initiatives, the Kishida administration seems to have focused more on nuclear power than anything else. The GX Basic Policy clearly describes nuclear power as a "highly effective energy source for decarbonization" that should be "utilized to the maximum extent possible." A proposed amendment to the Atomic Energy Basic Law even describes "the realization of a decarbonized society" as a new objective of nuclear power. The government also abruptly changed its position on the construction of new nuclear reactors after a longstanding policy freeze since the time of the Fukushima Daiichi Nuclear incident. Without any public debate or deliberation in the Diet, it moved away from the rule for the operating life of nuclear power plants ("40 years in principle, with an extension of up to 20 years"), announcing a new policy of "allowing additional extensions if plants are shut down for a certain period."

On the question of new and additional nuclear power plant consturction, the government is touting the development of "next-generation innovative reactors," but even in the case of "innovative light water reactors," which is the only one of five listed technologies that is anywhere near commercialization, the GX Basic Policy roadmap does not foresee production and construction beginning until well into the 2030s. Taking into account the policy of "rebuilding on the sites of nuclear power plants that are earmarked for decommissioning," it is difficult to see how such a reactor can be realized by the 2040s, let alone the 2030s.

Even if existing nuclear power plants are successfully restarted as planned by the Kishida administration, the goal of supplying 20–22% of Japan's electricity needs by 2030 can never be met. Taking into account delays by power companies in responding to safety reviews, repeated scandals at power companies, difficulties in obtaining the consent of local governments, and litigation risks, nuclear power is unlikely to account for any more than 10% or so of Japan's total electricity supply by 2030 or 2035. As for the Kishida administration's goal of extending the operating life of nuclear power plants, there is little chance that this goal will be realized even if the rules are changed. No nuclear reactor in the world has ever operated for over 60 years, while the average operating life of reactors is just 28 years.

Ultimately, nuclear power is simply unable to make a major contribution to the decarbonization of Japan.

Government's "zero-emission thermal power" to extend the life of coal power

Another decarbonzation power source option that the Kishida administration is eagerly pushing is "zero-emission thermal power." Power generation using green hydrogen as a fuel has the potential to play a useful role in balancing power supply and demand at the stage when solar and wind power are the dominant sources of electricity. However, the government is also pushing quite different things under the banner of "zero-emission thermal power," including ammonia co-firing in coal-fired power generation.

Even if co-firing with ammonia in coal-fired power plants uses green or blue ammonia, which involves less CO_2 emissions at the production stage, and 50% co-firing, which is aimed for full operation in the 2030s, can be achieved, total CO_2 emissions will still be higher than those of existing natural gas-fired power plants. Given the fact that the G7 nations set a common goal of achieving a fully or predominantly decarbonized electricity supply by 2035, it does not seem a rational plan to start using of coal-ammonia co-firing, which emits more CO_2 than natural gas-fired power plants, at exactly the same timing. The Japanese government and power companies are aiming to deploy coal-ammonia co-firing in Southeast Asia, but local environmental NGOs and other stakeholders have already started criticizing this initiative as an impediment to carbon neutrality in the region.

Another key component of this "zero-emission thermal power" push is power generation with CCS (carbon capture and storage). The GX Roadmap only calls for "a business environment to facilitate the start of CCS projects (CO_2 injection) by 2030," but there is no mention of any goal for when CCS will be ready for commercial operation in thermal power plants. Thermal power generation with CCS has been under development since the 1970s, but the only operational facility that utilizes this technology in the world is the Boundary Dam Power Station in Canada, a small-scale 115 MW power plant. Furthermore, since only 60% or so of CO_2 emissions are captured, the plant cannot be considered a carbon neutral power source.

A further problem with the use of CCS in Japan is that no domestic storage sites have been secured. A document submitted to a government council when the 6th Strategic Energy Plan was formulated in 2021 envisaged a scenario in which 235 to 282 million t-CO_2 that cannot be stored in Japan are exported overseas each year. Even according to the final report of the government's CCS Long-Term Roadmap Study Group, issued in March 2023, "the use of favorable overseas storage potential is a promising option" and "the availability of storage sites in Japan and overseas cannot be currently determined due to the lack of established CCS projects, so all options should be pursued." The report also states that "concrete negotiations regarding exports of CO_2 from Japan will begin." The countries envisioned as CO_2 export destinations are the same Southeast Asian countries targeted by the Kishida administration in its "Asia Zero Emission Community" initiative. Is it a right and reasonable policy for Japan, a country aiming to lead the decarbonization of Asia?

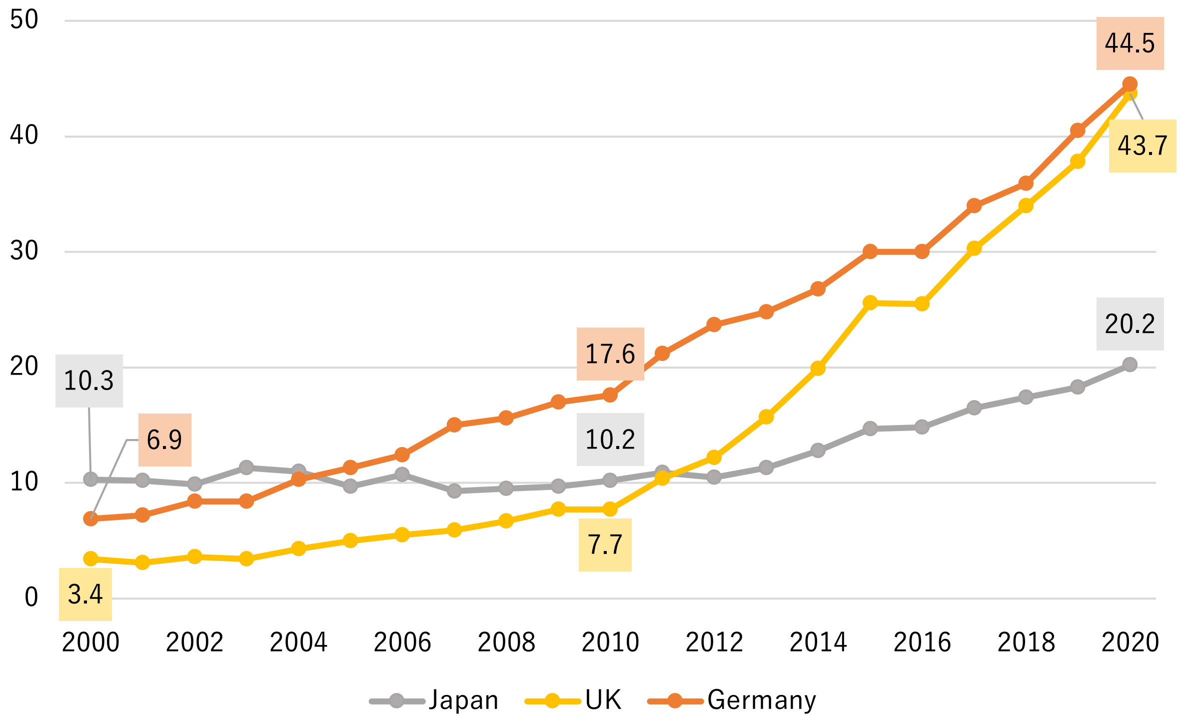
3. Decarbonizing Japan's electric power sector through renewables by 2035

A review of the contents of the GX Basic Policy leads to an obvious conclusion: the only way for Japan to drastically cut its CO2 emissions by 2030 and achieve electricity decarbonization by 2035, as per the consensus of G7 nations, is to further accelerate the adoption of renewable electric power sources, which are already practically viable and falling in cost in Japan.

After experiencing the Fukushima Daiichi Nuclear inciden in 2011 and being forced to rely heaviliy on fossil fuel imports from overseas for many years, Japan should have jumped at the opportunity to make the energy transition to renewables and play a role as an international leader in decarbonization and fossil fuel-free energy. Yet, its national policy seems to be to persist with the old energy supply system.

This error of national policy is clearly highlighted by the fact that while Germany, a similarly advanced industrial economy, and the UK, another island nation, have increased the share of renewables in their electricity supply mix by around 40 percentage ponts (from just a few percent to more than 40%) in the past 20 years, Japan has increased its share of renewables by just 10 percentage points (from approx. 10% to 20%) over the same period.

Fig. 1-3 Share of renewable electricity in Japan, the UK, and Germany (2000–2020)



Source) Created by REI based "World Energy & Climate Statistics - Yearbook 2021" by Enerdata

Given that it only produces just over 20% or so of its electricity from renewables and has no real hope of producing significant quantities of nuclear power, it will not be easy for Japan to get anywhere near the goal of total electricity decarbonization by 2035. On the other hand, if Japan abandoned this goal as impossible, it would be turning its back on the global challenge of the climate crisis. The AR6 Synthesis Report of the Intergovernmental Panel on Climate Change (IPCC) clearly states that to achieve the 1.5°C target it will be necessary to cut CO2 emissions by 65% relative to the 2019 level by 2035.

If it continues to rely on fossil fuel-dependent, high-emission, high-cost electricity, Japan will find itself at an economic disadvantage as the rest of the world pursues decarbonization (largely) through the deployment of inexpensive renewable energy. Fears of a new pandemic and heightened international tensions in the wake of Russia's invasion of Ukraine are driving efforts to restructure supply chains and bring manufacturing back to Japan. These efforts will be frustrated, however, if there are fears that Japan's delay in developing renewable electricity sources will make it impossible to achieve necessary emission reductions.

Although the backwardness and distortions of national policy are serious concerns, Japan is naturally blessed with abundant renewable energy potential, and companies, local governments, and communities are taking a variety of progressive initiatives to take advantage of this potential. If accelerated, the efforts of these non-state actors could transform national energy policy. It is even quite possible for Japan to rapidly catch up with other countries and successfully decarbonize most of its electric power sector through renewable energy by 2035.

Positioning of this report and discussion and action proposal for 2035

With an understanding of these circumstances, the Renewable Energy Institute (REI) decided to conduct a series of studies on the decarbonized energy scenarios that Japan should aim for in 2035. The government's Strategic Energy Plans are usually revised every three yars. The 6th Strategic Energy Plan, issued in 2021, will be revised in 2024, with work on examining the next revision expected to begin as early as later this year.

This report is the first in the series, focused on electric power, the industrial sector that needs to be decarbonized first and foremost. In March 2021, REI issued a report titled "Renewable Pathways: The Strategies to 100% RE for a Carbon-neutral Japan" to outline energy systems for achieving decarbonization by 2050. Keeping this strategy in mind, in this report we examine the potential for introducing different types of renewable energy sources by 2035 in a concrete or "layered" manner. In terms of achieving decarbonization by 2050, there are some power sources that will be inadequate if they continue to be deployed at the current rate. In Chapter 6, the final chapter of this report, we focus on seven key points, such as regulatory reforms, that are essential for accelerating the deployment of renewable energy.

Following up on this report, REI plans to study the ideal energy mix in 2035, including sources of energy other than electricity. As part of this process, we will also re-examine the suitablity of electric power demand and supply for the different power sources presented in this report. In addition, to investigate whether the power supply mix proposed in this report can ensure a stable power supply, we conducted a simplified analysis, drawing on the results of a study on power transmission networks for decarbonization through renewable energy. We plan to cover this point progressively in the second and subsequent reports, which will also include assessments of the overall cost of electricity and electricity supply-demand simulations.

In Japan, discussions on the energy mix in 2035 have barely started. The primary purpose of this report is to call on Japanese companies, local governments, NGOs, communities, as well as the national government to immediately begin discussions on the ideal energy strategy for enabling Japan to properly participate in the international efforts and discussions necessary for realizing the 1.5°C goal. REI hopes that these discussions will be actively and rapidly held, to outline a clear path for enabling Japan to achieve substantial emission reductions by 2030 and 2035. We also hope that this path will be followed step by step, and we will make every effort toward this goal.

Chapter 2 Solar PV development potential

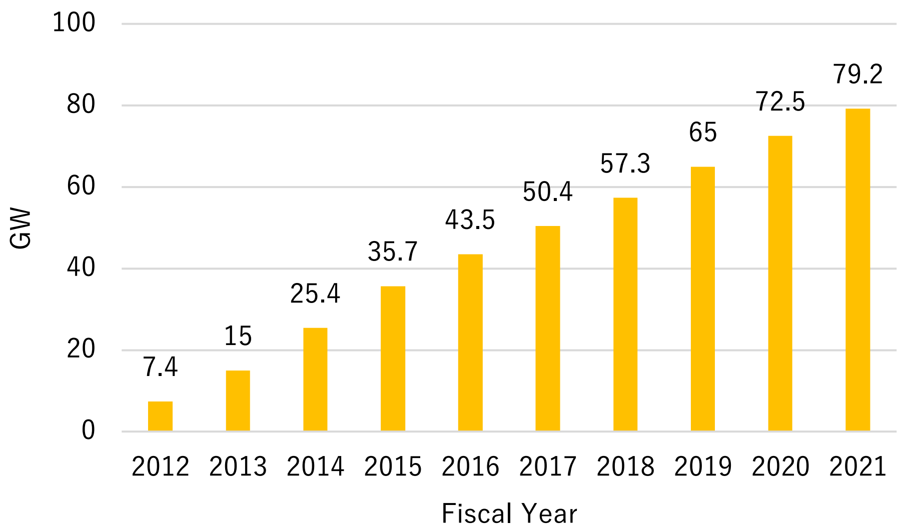
1. State of solar PV development

State of development

RTS Corporation, a leading Japanese consulting firm in the field of solar photovoltaic (PV) power, estimates that as of the end of FY2021, total installed PV power capacity in Japan was 79.2 GW (on a DC basis). It arrived at this figure based on a database of individual projects it developed independently and various other data. This figure is comparable to the figure of 78.4 GW reported by Japan to the International Energy Agency's Photovoltaic Power Systems Programme (IEA-PVPS) for the corresponding calendar year.

The governments Total Energy Statistics reported that PV systems in Japan generated a total of 86.1 TWh of electricity in this same fiscal year.

Fig. 2-1 Cumulative installed PV power capacity in Japan



Source) Created by REI based on data from RTS Corporation

A look at installed PV systems by scale shows that systems of 10 kW or more account for a total of 52.5 GW_{AC} of capacity, while systems of less than 10 kW account for a total of 13.0 GW_{AC} of capacity (with the connection by the 10 major power companies) According to data reported under the feed-in tarriff (FIT) scheme, there is little unoperational capacity in systems smaller than 10 kW, which are assumed to be mostly residential; nearly all such PV systems commence operation within one year. On the other hand, many projects of 10 kW or higher capacity are unoperational. A particularly high proportion of projects approved from 2013 to 2016 have not started operation, but this number has been declining in recent years. Total unoperational capacity as of the end of FY2021 was estimated to be just 16 GW_{AC}.

To make predictions about future capacity, it is important to know where systems will be installed. However, up to now data on FIT has only been categorized in terms of system size; no other official statistical data exists. Based on its own database of specific projects, RTS Corporation estimates total installed solar PV capacity at the end of FY2021 as 31.6 GW for building systems (including 5.1 GW installed before FIT) and 47.6 GW for land (ground-mounted) systems, totaling 79.2 GW.

Development potential

The potential for solar PV power in Japan is huge. According to a survey by the Ministry of the Environment, the total deployment potential is estimated to be 455 GW (598.5 TWh of energy) for buildings and 1,005 GW (1,272 TWh of energy) for ground-mounted systems, for a total potential of 1,460 GW (1,871 TWh of energy). This amounts to approximately twice Japan's current total electric power demand.

2. Current and future costs of power generation

The cost of solar PV systems has fallen dramatically worldwide, serving as a driving force for energy transition. In Japan, the cost of PV power has steadily fallen ever since the introduction of the FIT scheme. In fact, PV is already the most economical source of electricity available.

So, what is the current cost of PV power generation (for commercial use)? The cost of "medium-class" (high voltage) power generation was calculated to be ¥12.0/kWh based on the figures of the government's Procurement Price Calculation Committee (PPCC). According to empirical data collected and organized by the PPCC, both system costs (panel costs) and construction costs have been steadily falling both for rooftop and ground-mounted PV systems. As for estimates by other organizations, RTS Corporation has reported figures in the range of ¥8.1 to ¥12.6/kWh (residential and mega solar), while international research firm Bloomberg NEF (BNEF) reports ¥8.8/kWh as a typical cost.

Costs are expected to fall further over the coming years. A study by REI indicates that in addition to lower hardware prices (e.g., unit prices for solar modules) and higher performance, further cost reductions are likely to occur through the development of new design, construction, and management methods that are optimized for Japan's geographical conditions. Furthermore, the number of development projects that involve the reclamation of forests is expected to decrease over the coming years, leading to a fall in the cost of forest reclamation.

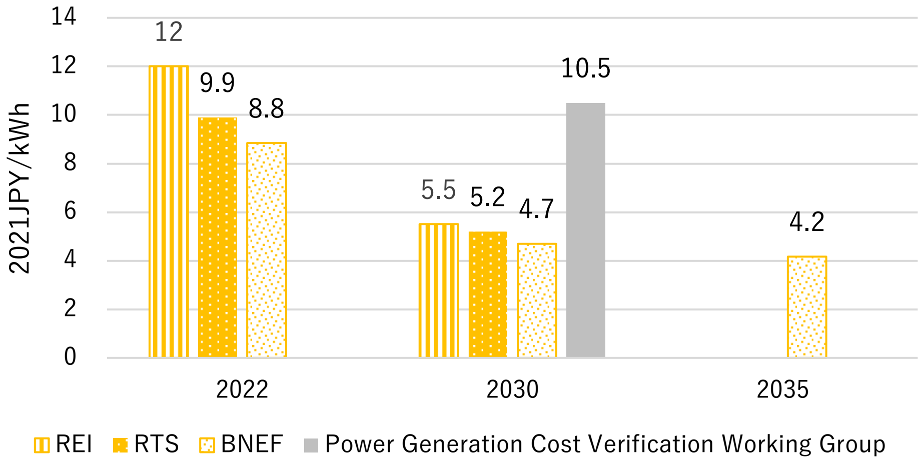
More specifically, REI, RTS, and BNEF all forecast the cost of PV power in 2030 to be around ¥5/kWh (Fig. 2-2). BNEF predicts that by 2035 the cost will fall even lower, to ¥4.2 /kWh. The Japan Photovoltaic Energy Association (JPEA), an industry body, is a little more cautious, but it foresees a cost of ¥7/kWh for some forefront projects under favorable conditions as early as 2025, with the same price level reached for all projects by 2030.

On the other hand, it is problematic that the government's Power Generation Cost Verification Working Group (hereafter "PGCV WG") expects that costs will fall only marginally because there will be no more suitable sites for solar PV development, estimating a cost of ¥10.5/kWh in 2030 as the basis for policy formation.

As a result of these cost reductions, a situation has emerged in which it is now more economical to consume PV power on site than to purchase grid power. This is backed up by the flurry of corporate power purchase agreements (PPA) plans announced in recent years. As we move toward 2035, it will be important to avoid volatility in electricity prices, so it is likely that solar PV power will be increasingly chosen for the economic advantage it offers in eliminating or reducing reliance on FIT/FIP schemes.

Note that prices rose from 2020 to 2021 due to restricted supplies and supply chain disruptions arising from raw material shortages and other factors. In a survey of its member companies, an industry body also revealed that the prices of parts and materials rose. However, the supply shortage is likely to be temporary and the prices are expected to continue falling in the the medium to long term.

Fig. 2-2 Solar PV power generation costs (actual and forecast)



Note) Useful life: PGCV WG and REI both assume 25 years; BNEF assumes 30 years. Discount rate: BNEF calculates discount rate as 3.3% plus inflation rate, whereas PGCV WG and REI assume 3%, without taking into account inflation. Grid connection costs are not included in any of the calculations. Since BNEF calculations are made in 2021 USD prices, they were converted to JPY using the average exchange rate in 2021 (¥110/$).

Source) Created by REI based on "Solar Power Generation Costs in Japan: Current Status and Future Outlook" (REI, July 2019), "Forecasting PV Installed Capacity in Japan toward FY 2030 (2022 Edition)" (RTS Corporation, March 2022), Bloomberg NEF (2H 2022 LCOE Update, 2022), and "Summary (draft) of Power Cost Verification" (PGCV WG, 2021)

3. Promise and challenges of developing building rooftop solar PV systems

Rooftop PV systems for private residences have long been the most widely installed form of solar PV power. Looking ahead to 2035, this segment of the market still has the highest growth potential, with deployment expected to accelerate in non-residential as well as residential buildings, both in the public and private sectors. Compared to ground-mounted PV systems, which require exclusive use of land, rooftop PV systems have the advantage of sharing land space with the building they are installed on, largely eliminating any competition for land.

The current economics of PV systems are affected by falling costs, as mentioned above, and the electricity price rises that have occurred since 2022. In light of these factors, there are significant economic advantages to switching to systems focused on on-site consumption of PV-generated electricity. On top of this, installation on the roof of a building is unlikely to cause problems with grid connection, surplus power can be sold off, and basic charges can be reduced in some cases. Furthermore, the incorporation of storage batteries in PV systems is becoming more and more economically compelling.

Homes

The proportion of new homes that include PV power systems is on the rise, due in part to improved economical performance of PV systems. The increasing (conversion) efficiency of PV panels and improvements in mounting technology have enabled space and weight savings, further driving the installation of PV systems. Nevertheless, less than 30% of new homes include PV systems, so policies are needed so that PV systems are fitted to practically all new homes.

The proportion of existing homes with high seismic performance built since the 1990s is increasing, which means that more and more homes are suitable for the retrofitting of solar

PV systems. As with new home construction, support for the development of lightweight PV modules is needed, as well as support that takes into account the useful life of homes.

As for apartment buildings, deployment is currently limited by the small roof area per apartment, as well as the complexities associated with developing consensus among residents and managing the distribution of generated electricity. On the other hand, it is likely that sooner or later developers of codominium (apartments for sale) buildings will include PV systems as standard equipment and that developers or owners of rental-apartment buildings will also install PV systems. Policies are needed to support this trend.

Private commercial buildings (non-residential)

In the cost-conscious private-sector, the adoption of solar PV power systems for commercial buildings has been limited to symbolic expressions of environmental awareness or to efforts aimed at improving resilience in the event of a disaster. However, a growing number of companies in recent years have installed PV systems on the roofs of production facilities and distribution warehouses to generate electricity for their own consumption.

Behind this move is the commitment by many companies to decarbonize their activities, including entire supply chains, motivated to some extent also by the demands of financial institutions and other stakeholders. The economic advantages of generating electricity compared to purchasing electricity from outside parties have also become more significant. As a result of this trend, the deployment of PV systems is likely to continue growing, not only on rooftops, but also in parking lots and other areas, to maximize the use of on-site space.

Public buildings

As in the private sector, we are likely to see a shift to greater use of solar PV systems in public buildings too, for economic reasons. Furthermore, the government's action plan based on the Act on Promotion of Global Warming Countermeasures(hereinafter "Global Warming Act") incorporates, in principle, the installation of PV systems in public buildings. The government's goals are 50% of total installable capacity in public buildings (7.9 GW_{AC}) by 2030, with 100% (15.9 GW_{AC}) by 2040.

Infrastructure facilities*

Parking lots*

Development of new technologies*

4. Promise and challenges of developing ground-mounted solar PV systems

The installation of PV panels on frames fixed to the ground has been the fastest growing method of installation since the start of the FIT scheme. Until now, many of these projects have been large-scale installation for invetment purposes, due to the previous high purchase prices guaranteed under the FIT scheme. At the same time, due to strict regulations on the conversion of farmland, many projects were developed by clearing forest land. In numerous cases, such developments led conflicts with local communities.

However, the number of projects that rely on forest conversion are declining, in part because lower FIT prices have made it more difficult to justify the land clearing cost. On the other hand, now that the temporary conversion of farmland is permitted, the number of small-scale agrivoltaic projects (solar sharing) or that use abandoned farmland outside of "agriculural promotion areas" is increasing in various parts of Japan. This trend is also expected to be the key driver of PV power growth in the coming years.

At the same time, low-voltage/high-voltage PV power generation systems, which are expected to grow significantly in coming years, must be connected to a lower-level grid (the local grid or a distribution system). To solve the issues of connecting to these grids, it has been decided that non-farm connections will be applied from April 2023, in the same way as bulk power ("trunk") systems. Still, it will be necessary to analyze congestion and disclose information.

Forests and golf courses*

Farmland

Despite the fact that farmland is considered difficult to convert, the deployment of solar PV systems on farmland is steadily growing. From 2015 to 2020, just under 1,250 to 2,000 ha of farmland (8,000 to 10,000 projects) was converted each year, corresponding to an estimated average of 1.2 to 1.6 GW of installed PV capacity per year, and a cumulative total of 11 GW of capacity over the period, which is more than the total capacity of PV systems installed on cleared forest land. The average land area of these projects was as small as 0.17 ha, suggesting that PV power systems have been selected as a means of effectively utilizing farmland that is convertible in the event that its continued agricultural management becomes difficult due to a lack of farm successor or other reason.

Another trend in recent years is the growth in PV power systems installed as part of agrivoltaic (dual use) operations ("solar sharing"), in which agricultural production is conducted under PV panels mounted on high frames. The current installed capacity of such PV systems, based on temporary conversion permits, grew to a total of 779 projects in 2020. Even on the basis of FIT business plan certification, it can be confirmed that even the number of low-voltage projects (less than 50 kW) is growing, to 3,559 in 2020 and 4,070 in 2021. Furthermore, while the average capacity to date has been around 150 kW, plans for large-scale "special high-voltage" and "high-voltage" projects have also been announced.

The adoption of agrivoltaic projects is being helped along by the fact that the temporary conversion of agricultural land within agricultural zones and Type I farmland is now permitted, and that the yield requirement of "at least 80% of the average level of surrounding farmland" has been abolished. In addition, the social acceptability of agrivoltaic systems is high, while the generated electricity can be used as private power supplies for agriculture. They are also finding growing demand as partners for companies in PPAs. For all these reasons, the quantity of such systems is expected to grow over the coming decade.

Fig. 2-4 Example of an agrivoltaic solar PV power system (Okido Solar Sharing)

Source) Chiba Ecological Energy Inc.

According to the Ministry of the Environment's Renewable Energy Potential System (REPOS), the potential of PV power generation on arable land based on agrivoltaic (dual use) projects is very large, amounting to 298.6 GW on rice fields and 472 GW on other cropland. The Alliance for Solar Power Entrepreneurs (ASPEn), a business federation that promotes agrivoltaic projects, calls for the deployment of 45 GW_{AC} of capacity by 2030 and 90 GW_{AC} by 2050.

Systems on water (e.g., dams, reservoirs, lakes, sea surfaces)*

Other types of lands*

5. Estimating total installed capacity by 2035

Based on the above, we broadly divided PV projects into building and land-based (ground-mounted) systems to estimate total installed capacity for each segment in 2035. Since most government policy targets are expressed on the basis of AC capacity, we converted figures to DC capacity by multiplying by 125% in the case of building PV systems and 140% for ground-mounted systems, in accordancde with the empirical "overload factors" reported by the Procurement Price Calculation Committee and the vision of the Japan Photovoltaic Energy Association.

Building rooftop PV systems: 159 GW by the end of FY2035

For homes, the 6th Strategic Energy Plan sets a target of installation in 60% of new homes by 2030. Given the urgency of boosting renewable electricity production, there needs to be a commitment to try and install solar PV power systems in all new homes by 2035. Progressive municipalities such as the Tokyo Metropolitan Government and Kawasaki City have already made the installation of PV systems mandatory for all new homes. The rate of new home installation is therefore expected to rise steadily, but it is still important to accelerate this process.

We have therefore assumed installed capacity to grow to 80% by 2030 and 95% by 2035. As a result of advances in space and weight-saving technologies, we also foresee capacity per home increasing from the current level of 5.3 kW to 6.0 kW in 2030, with continued growth at a similar pace through to 2035. To estimate the total installed capacity in Japan, we multiplied the number of new housing starts for detached homes by this average PV system capacity per home. We also assumed that the number of PV system installations in existing homes will also increase at a rate of 4% per year due, driven by weight and space savings and other technological advances.

For roof-mounted solar PV systems of 10 to 20 kW for apartment buildings, a policy has been adopted to promote the installation of systems that enable the sale of surplus power through FIT/FIP schemes if it can be confirmed from wiring diagrams or by other means that the system is designed for self-consumption (it would be regarded that the building is consuming at least 30% of the power generated). We assumed that appropriately implementing such policies will lead to a steady growth in PV capacity of approximately 0.1 GW/year, resulting in a total of 1.5 GW of additional capacity over the period (2020 to 2035).

For public facilities, for which the otal capacity already installed is 1.9 GW_{AC} (2.4 GW), current government targets are 100% PV system installation (17.5 GW = 15.9 GW_{AC}) by 2040 and 50% (9.9 GW = 7.9 GW_{AC}) by 2030. However, we want to see these targets pushed forward, to achieve 100% by 2035 and 75% by 2030. Note that in calculcations to evaluate these government targets, deteriorated buildings are subtracted from the total building stock in advance.

In addition to this, 5 GW_{AC} (6.3 GW) of capacity is expected to be installed in infrastructure facilities and parking lots, including airports, railways, and other private sector facilities, through policy initiatives led by the Ministry of Land, Infrastructure, Transport and Tourism. This includes 2.3 GW_{AC} of PV systems to be installed by 2030 through the government's initiative to "promote airports as renewable energy hubs."

For general buildings, the economic barriers are almost gone now. Apart from limitations of installation space, their full potential can probably be used. Firstly, for factories and warehouses, we assume that 20 GW of the 25 GW of potential estimated by REPOS will be installed. On top of this, the total potential for other kinds of buildings is more than 230 GW, with 35 GW of capacity expected to be in place by 2035 according to industry forecasts and other indicators. In addition, on-site PPA subsidies (a joint project of the Ministry of the Environment and Ministry of Economy, Trade, and Industry) will help to promote PV system installations in cases of unfavorable economic conditions. We assume that the target capacity of 10 GW_{AC} (12.5 GW) will be achieved from this initative.

Finally, new applications of solar PV technology will also make a contribution, integrated in building materials and other new products, such as wall surfaces and railing. The government has also set a goal of establishing a GW-class mass production system for perovskite by 2030. As a result, we expect a cumulative total capacity of 7 GW of perovskite solar cells to be installed by 2035.

Summing up the above, total installed solar PV system capacity after 2022 will be approximately 127.4 GW. Combined with the 31.6 GW of capacity installed up to 2021, the cumulative total capacity installed by 2035 will be 159 GW (Table 2-1).

Table 2-1 Installed capacity of building rooftop solar PV systems by 2035 (GW)

<table>
<tr><th colspan="3">Category</th><th>By FY2021</th><th>In/after FY2022</th><th>By end of FY2035</th></tr>
<tr><td rowspan="10">Building rooftop PV systems</td><td rowspan="3">Homes</td><td>Detached homes (new)</td><td rowspan="3">16.6</td><td>18.4</td><td rowspan="3">45.8</td></tr>
<tr><td>Detached homes (existing)</td><td>9.2</td></tr>
<tr><td>Apartment buildings</td><td>1.5</td></tr>
<tr><td rowspan="6">Non-residential</td><td>Public buildings</td><td>2.4</td><td>17.5</td><td>19.9</td></tr>
<tr><td>Infrastructure (buildings)</td><td rowspan="4">12.6</td><td>6.3</td><td rowspan="5">93.4</td></tr>
<tr><td>Factories/warehouses</td><td>20.0</td></tr>
<tr><td>Other general buildings</td><td>35.0</td></tr>
<tr><td>Government support</td><td>12.5</td></tr>
<tr><td>New applications (e.g. wall surfaces)</td><td>0.0</td><td>7.0</td></tr>
<tr><td colspan="2">Cumulative total (for buildings rooftops)</td><td>31.6</td><td>127.4</td><td>159.0</td></tr>
</table>

Source) Created by REI

Ground-mounted: 121 GW by the end of FY2035

For ground-mounted solar PV systems in particular, it is essential to promote their development in a way that ensures harmony with the local community. In accordance with the revised Act on Promotion of Global Warming Countermeasures (hereinafter "revised Global Warming Act"), unused local land has to be utilized effectively, e.g., by designating it as a "promotion area."

Another challenge is connecting to local grids. It is assumed that further accumulating and disclosing information on congestion conditions for conducting appropriate simulations, will help to locate power sources in appropriate locations, and to upgrade distribution systems and substations if necessary.

Firstly, there are 22.4 GW (16 GW_{AC}) of already approved projects that are not yet operational, so assuming a utilization rate of 75% (as in the case for long-term energy demand and supply forecasting), we estimate that a further 16.8 GW (12 GW_{AC}) of capacity will be available in the future. Developments in forests and other areas are included here, but it is important to make construction more environment-friendly, e.g., by appropriately following the forest development permission system, which was revised in FY2022. For golf courses, we assume that installation of PV systems will proceed at the pace projected by the industry (50 MW_{AC} /project × 10 projects/year).

For solar PV systems that use farmland, we expect to see continued growth in dual-use agrivoltaic ("solar sharing") systems. In the case of farmland conversion, as farms are increasingly consolidated and expanded in scale due to a lack of farm successors, providing a portion of land for PV development can generate a source of income for farmers and communities. Furthermore, advanced management using robots, IoT, and other sophisticated "smart farming" technologies for labor-saving will become necessary, so the ability to cover essential electricity demand in-house offers potentially significant business benefits.

Based on this assumption, an additional 15 GW of total capacity is expected to be deployed for development by converting farmland (i.e., discontinuing agricultural practices) at a rate of around 1.0 GW/year, although this pace is likely to fall somewhat over the years. The total area to be converted is estimated at about 1,200 ha/year, assuming that a portion of the 280,000 ha of deteriorated farmland (of which 192,000 ha cannot be reclaimed as farmland and 91,000 ha can be reclaimed) will be utilized. On the other hand, due to a lack of farm successors and other factors, the area of farmland has been shrinking at a rate of 25,000 ha per year for the past five years, so even if this much (1.0 GW) of PV power generation is newly started (using 1,200 ha of converted farmland) per year, it would mean only 5% of the newly abandoned farmland will be used.

In addition to this, development of agrivoltaics is also expected to accelerate with the active backing of the Ministry of Agriculture, Forestry, and Fisheries and other support, with deployment progressing at a rate of 1.0 GW/year, corresponding to a total of 15 GW of addional capacity by 2035. The required area at this time is about 1,200 ha/year. This will contribute to the prevention of farmland conversion, as well as to the conservation of farmland by enabling the utilization of some of the deteriorated farmland (91,000 ha) that can be reclaimed.

Development of solar PV systems on other types of land is also expected to increase steadily. Specifically, these are installations on water bodies such as reservoirs, in large parking lots, and on other land used for roads, railways, and other kinds of infrastructure. PV systems in this category are expected to total 17 GW of capacity, based on surveys of operators and other data.

Summing up the above, the total capacity of solar PV systems to be developmed in and beyond 2022 will be 73.6 GW. Combined with the 47.6 GW of capacity installed up to 2021, the cumulative total installed capacity in 2035 will be 121.2 GW.

Table 2-2 Installed capacity of ground-mounted PV systems by 2035 (GW)

<table>
<tr><th colspan="3">Category</th><th>By FY2021</th><th>In/after FY2022</th><th>By end of FY2035</th></tr>
<tr><td rowspan="6">Ground-mounted PV</td><td colspan="2">Already approved</td><td rowspan="5">47.6</td><td>16.8</td><td>64.4</td></tr>
<tr><td colspan="2">Golf courses</td><td>9.8</td><td>9.8</td></tr>
<tr><td rowspan="2">Farm</td><td>Farmland (abandoned)</td><td>15</td><td>15</td></tr>
<tr><td>Farmland (agrivoltaic)</td><td>15</td><td>15</td></tr>
<tr><td colspan="2">Other</td><td>17</td><td>17</td></tr>
<tr><td colspan="2">Total ground-mounted PV</td><td>47.6</td><td>73.6</td><td>121.2</td></tr>
</table>

Source) Created by REI

To sum up the above, as of 2035, a total of 280 GW of solar PV power generation capacity will be installed: 159 GW on buildings and 121 GW on land.

Based on the average rate of new capacity development, in FY2030, it will be necessary to have a total of 208.4 GW of capacity in place: 113.5 GW on buildings and 95.0 GW on land. Under the current Strategic Energy Plan, the ambitious level for 2030 is 117 GW_{AC}, corresponding to roughly 164 GW on a DC basis (calculated using an overload factor of 140%). The plan assumes the installation of about 10 GW of new capacity per year, a pace that would result in a total capacity of 214 GW by 2035. This leads to a significantly smaller gap with our present estimate, suggesting that it is vital to raise the 2030 target.

Quantity of generated electricity

Since all power generation capacities are expressed on a DC basis, we applied a uniform capacity factor of 14.0 before taking into account the overload factor. Based on this calculation, the total amount of electricity generated comes to 343.7 TWh.

Table 2-3 Projected annual PV-generated electricity in FY2035 (summary)

		Installed capacity (GW)	Capacity factor (%)	Generated electricity (TWh)
Building rooftop	Houses	45.8	14.0	56.1
	Non-residential	113.3	14.0	138.9
Ground-mounted		121.2	14.0	148.6
Total		280.2	—	343.7

Source) Created by REI

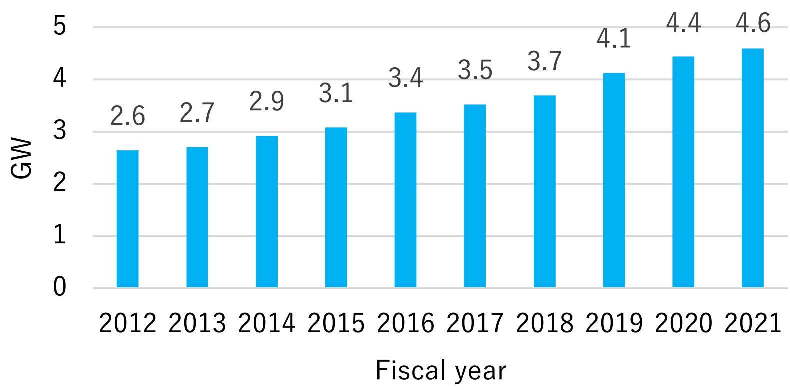
Chapter 3　Wind power development potential

1. Wind power development status

Current development status

According to the Japan Wind Power Association (JWPA), a wind power industry body, the total installed wind power generation capacity in Japan as of the end of 2021 was 4.6 GW, including 135 MW of offshore wind power. The total electricity supplied by wind power (FY2021) was 9.43 TWh according to the Comprehensive Energy Statistics.

Fig. 3-1 Cumulative installed wind power capacity in Japan



Source) Created by REI based on JWPA data

The deployment of wind power generation in Japan began in the late 1990s, with 2.5 GW of capacity already in operation before the launch of the FIT scheme. As of the end of September 2022, business plans had been approved for a total of 13.8 GW of projects under the FIT scheme, but only 2.4 GW of these had begun operation. It is reported that a variety of issues such as connections to power grids and prolonged environmental assessment procedures tend to drive up the time and costs of projects.

While wind power generators have been developed mainly on land up to now, offshore wind has attracted growing interest in recent years. Given that it is surrounded by sea on all sides, Japan's potential for offshore wind power development is particularly high. As offshore wind turbines become larger and larger, they can take advantage of strong offshore winds more efficiently (Fig. 3-2). As a power source that can be scaled up to very high levels, wind power is helping to accelerate the deployment of renewable energy throughout the world.

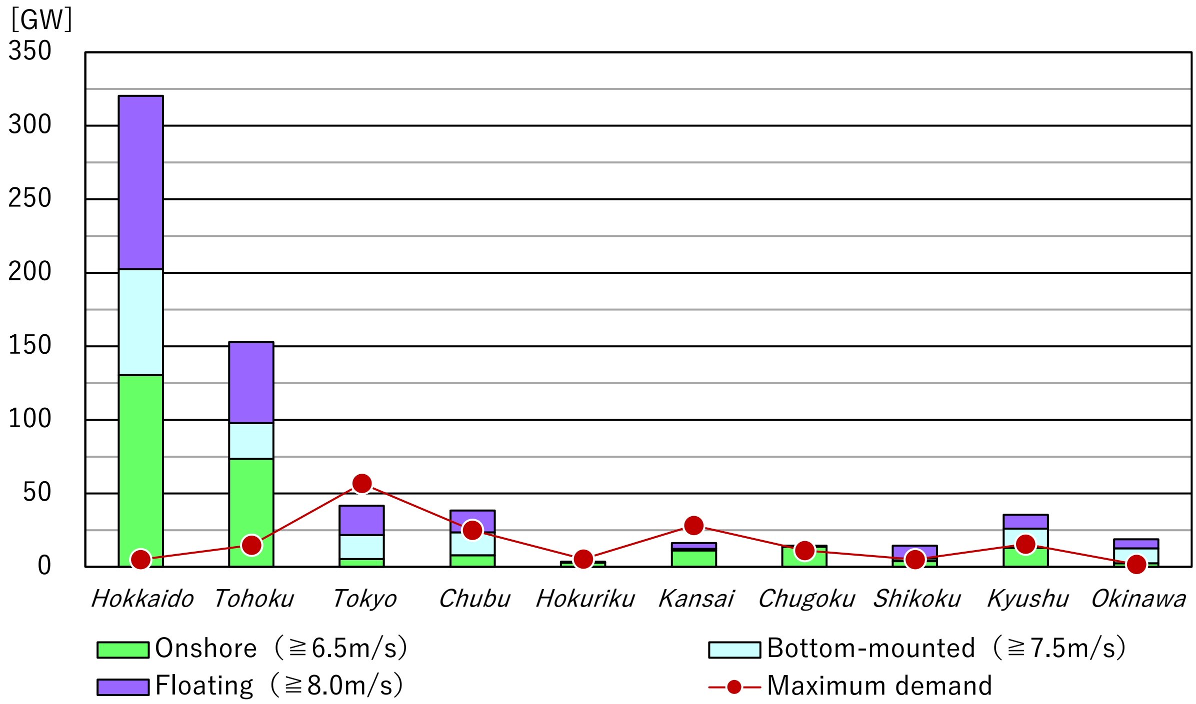
Floating offshore wind technology (Fig. 3-3) has also made it possible to harness the potential of Japan's deep coastal waters.

Offshore wind power development in Japan started to take off seriously in 2019 with the passing of the Act on Promoting the Utilization of Sea Areas for the Development of Marine Renewable Energy Power Generation Facilities, which applies to general sea areas, following the amendment of the Port and Harbour Act (effective in 2016) to facilitate the development of port districts. A total of 3.5 GW of wind power projects have so far been developed (Fig. 3-4).

Development potential

Based on a report published by the Ministry of the Environment in May 2022, Japan's total potential for wind power generation is 264 GW for onshore wind (assuming wind speeds of at least 6.5 m/s) and 392 GW for offshore wind (assuming wind speeds of at least 7.5 m/s for fixed-support systems and at least 8.0 m/s for floating systems), for a total potential of 656 GW. A breakdown of offshore wind power shows that the potential of floating wind power is greater than that of fixed-support systems; 236 GW compared to 156 GW. However, development potential is unevenly distributed geographically through the nattion with 49% of development potential in Hokkaido and 23% in the Tohoku region, where power generation capacity would far exceed peak power demand (Fig. 3-5).

Fig. 3-5 Wind power potential and real peak power demand in FY2021



Source) Created by REI based on a report commissioned by the Ministry of the Environment in FY2019 on the development and publication of basic zoning information on renewable energy

Prospects for development by government and industry bodies*

2. Current and future costs of power generation

The cost of wind power generation in Japan is currently high compared with the rest of the world. For example, according to the Agency for Natural Resources and Energy (ANRE), the global cost of onshore wind power in the first half of 2022 was ¥5.2/kWh, while the cost in Japan was nearly 2.5 to 3 times higher, as described below. Leaving aside wind conditions and other natural environment factors, high capital costs and operation and maintenance costs are considered the biggest contributing factors to the high cost. In any case, offshore wind power systems are only just starting to get off the ground seriously, so there are still few examples of them in Japan.

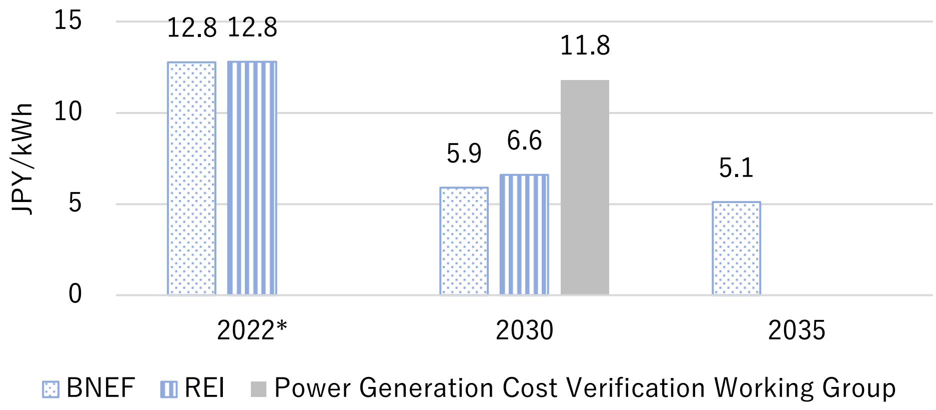
On the other hand, the mass deployment of wind power generation will naturally be accompanied by cost reductions. Growing market scale and installed capacity, as well as technological advances, are expected to be major factors in reducing costs.

Onshore wind power generation

Onshore wind power generation has not enjoyed any significant cost reductions in the past few years. The most recent estimates of power generation cost are ¥12.8/kWh (2021) by REI, ¥12.8/kWh (2022) by Bloomberg NEF (BNEF), and ¥14.9/kWh (first half of 2022) by ANRE. We can therefore roughly assume the cost to be ¥13 to ¥15/kWh. Nevertheless, costs are expected to decrease significantly between now and 2030, with cost projections of ¥6.6/kWh by REI and ¥5.9/kWh by BNEF.

Behind this anticipated cost reduction is the increasing size of wind turbines. This reduction is considered to be due not only to the higher output per unit, but also to the contributions that higher hub height and longer blades make to increasing power generation (resulting in higher capacity factor). However, the government's Power Cost Verification Working Group (hereafter "PGCV WG") is conservative in its forecast of generation costs in 2030, emphasizing a decline in suitable sites and failing to taking into account the above technical improvements. Only BNEF has projected the cost of wind power in 2035, expecting to see it further drop to ¥5.1/kWh.

Fig. 3-7 Onshore wind power generation cost (forecast) (25-year operating life)



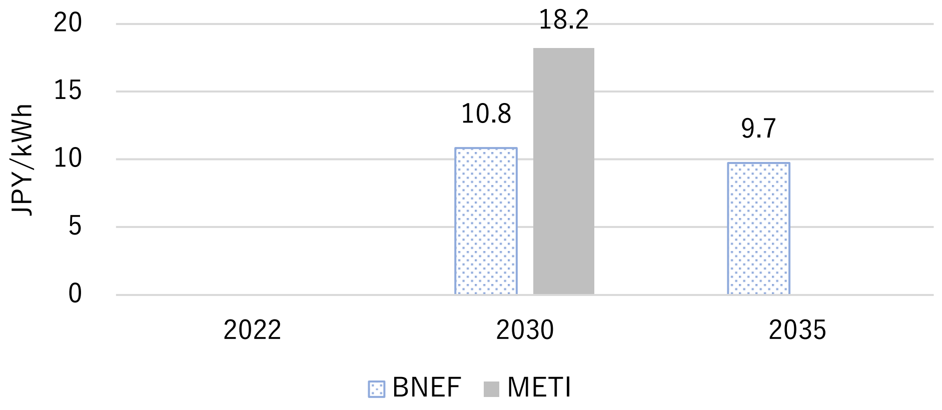
Note) REI's 2022 figures are actually 2021 values. Estimates are based on survey data. Operating life: All estimated are based on 25 years. Discount rate: BNEF calculates the discount rate as 3.3% plus inflation, while the PGCV WG and REI assume 3%, without taking inflation into account. Grid connection costs are not included in any of the estimates. Since BNEF calculations were made in 2021 USD prices, they were converted to JPY using the average exchange rate in 2021 (¥110/$).

Source) Created by REI based on "Cost and Technology Trends for Onshore Wind Power in Japan" (REI, March 2022), Bloomberg NEF (2H 2022 LCOE Update, 2022), and "Summary (draft) of Power Cost Verification" (PGCV WG, 2021)

Offshore wind power generation

Offshore wind power is expected to be deployed at full-scale in Japan in the near future. The government's PGCV WG cost forecast for 2030 (25-year operating life) is ¥18.2/kWh. In addition, the Vision for Offshore Wind Power Industry (1st), issued in December 2020, sets a reduced power generation cost target of ¥8 to ¥9/kWh by 2030–2035 for fixed-support wind power. Bloomberg NEF's cost projections for 2030 and 2035 are ¥10.8/kWh and ¥9.7/kWh, respectively. Note that an offshore wind farm (819 MW) off the coast of Yurihonjo, Akita Prefecture, scheduled to begin operation in 2030, was contracted for a 20-year purchase period at a price of ¥11.99/kWh. Bloomberg NEF expects the cost of power generation to fall below ¥10/kWh by 2035.

Fig. 3-8 Offshore wind power generation cost (forecast) (25-year operating life)



Note) Discount rate: BNEF calculates the discount rate as 3.3% plus the inflation rate, but the government estimate is 3%, without taking inflation into account. Grid connection costs are not included in any of the calculations. Since the BNEF calculations are made in 2021 USD prices, they were converted to JPY using the average exchange rate in 2021 (¥110/$).

Source) Created by REI based on Bloomberg NEF (2H 2022 LCOE Update, 2022) and "Summary (draft) of Power Cost Verification" (PGCV WG, 2021).

3. Trends in wind power development*

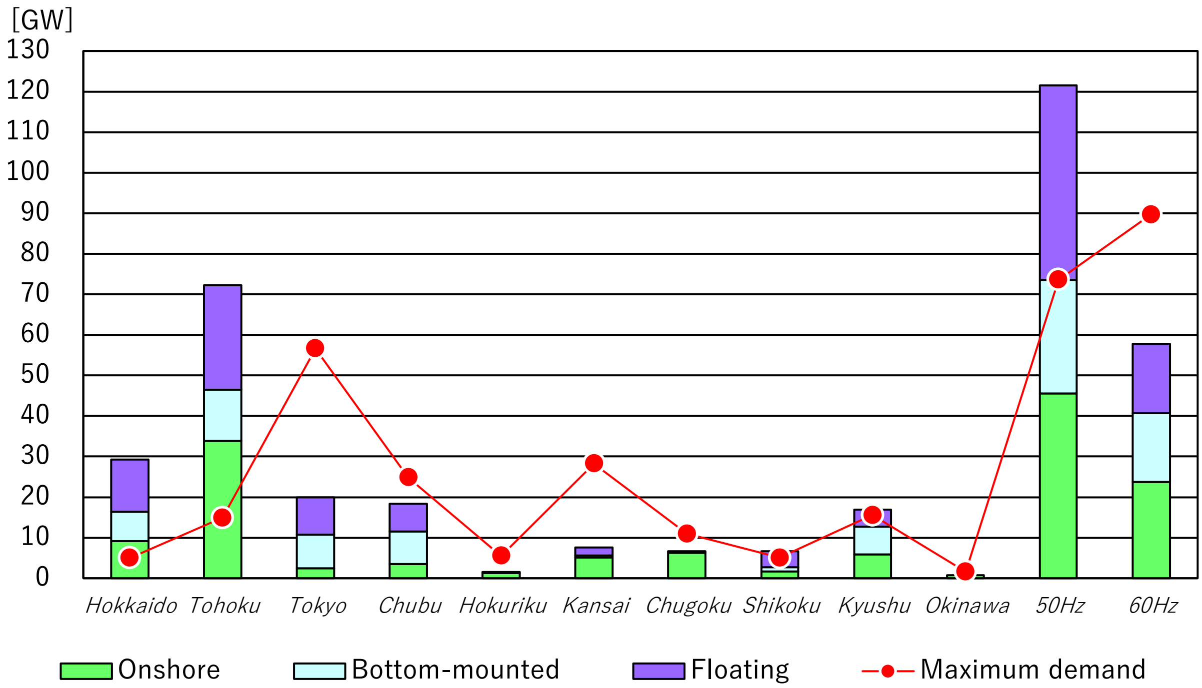
4. Estimating developed capacity by 2035

To estimate the quantity of wind power capacity that needs to be developed by 2035, we determined the amount required to achieve 100% renewable energy by 2050. We also verified the possibility of reaching this assumed capacity (by 2035) by accelerating wind power policy in terms of the environmental assessment and applications for connection to the power grid, as mentioned earlier.

As mentioned above, the potential for wind power deployment is enormous, estimated at 656 GW. However, the Hokkaido region accounts for 49% of this total, or 320 GW (64 times local peak power demand), while the Tohoku region accounts for another 23%, or 153 GW (10 times local peak power demand). Therefore, to dramatically boost the supply of electricity from wind power generation, it is essential to ensure stable supply by taking advantage of the smoothing effect of drawing power output from widely distributed wind power systems. Deployment potential may also increase or decrease subject to the results of detailed field surveys.

If examinte wind power development potential in light of these circumstances, we can expect a total of 180 GW (552.8 TWh) of capacity across Japan, consisting of 70 GW of onshore wind power and 110 GW of offshore wind power (45 GW fixed-support and 65 GW floating), assuming that systems are developed to supply six times the peak power demand in 2021 or up to around 50% of the wind power development potential of each area. At this level of development, the Hokkaido region would have 29.3 GW of capacity (5.8 times local peak power demand), or about 10% of its full potential, while the Tohoku region would have 72.2 GW (4.8 times local peak power demand) (Fig. 3-12).

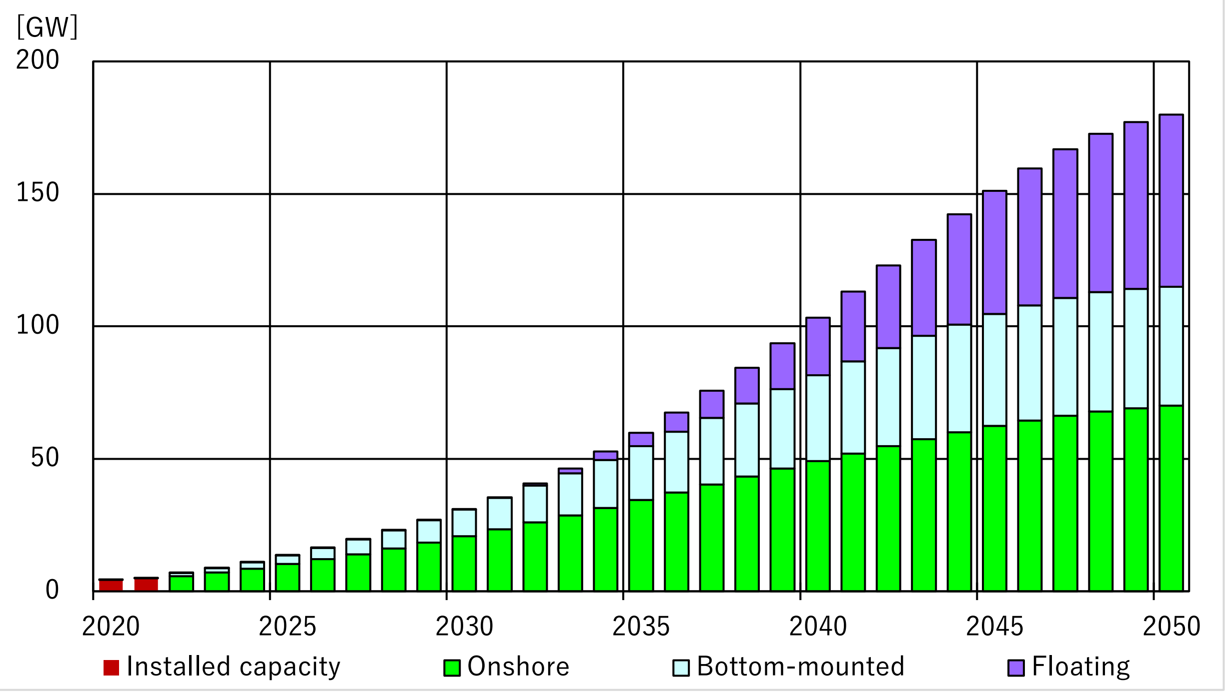
Fig. 3-12 2050 Wind power development targets and actual FY2021 peak power demand by area



Source) Created by REI

By plotting growth curves for each of onshore wind, offshore wind (fixed-support), and offshore wind (floating) to achieve this 180 GW of installed capacity by 2050, we found that the total installed wind power capacity in 2035 is expected to be 59.8 GW, made up of 34.4 GW from onshore wind and 25.4 GW from offshore wind (20.5 GW from fixed-support and 5 GW from floating) (Fig. 3-13, Table 3-2). Figure 3-14 shows the amount of new capacity to be added each year.

Fig. 3-13 Roadmap for wind power development up to 2050



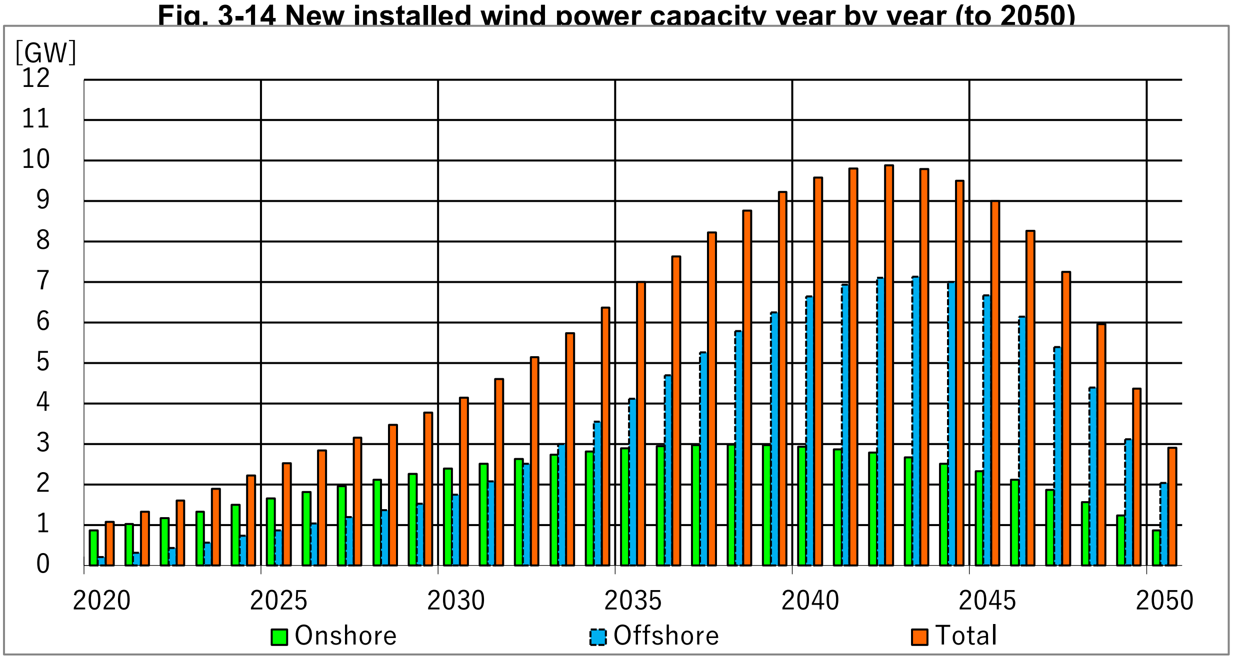
Source) Created by REI

Table 3-2 Actual and projected wind power development

Year (FY)	Actual and projected capacity (GW)				
	Onshore	Offshore (fixed)	Offshore (floating)	Offshore total	Total wind power
2020 (actual)	4.2	0	0	0.1	4.3
2030	20.8	10.1	0.1	10.2	30.9
2035	34.4	20.5	5	25.4	59.8
2040	49.2	32.4	21.6	54.1	103.2
2045	62.3	42.3	46.6	88.9	151.3
2050	70	45	65	110	180

Source) Created by REI

Fig. 3-14 New installed wind power capacity year by year (to 2050)



Source) Created by REI

We checked the feasibility of realizing the potential outlined above and achieving a stable power supply, based on current conditions relating to environmental assessment and applications for grid connections. From the time a project is decided, the construction of wind power generation facilities take about four years to complete in the case of onshore wind power and six years for offshore wind. As mentioned, environmental assessment and grid access procedures account for a significant component of this time frame.

In the case of onshore wind power, we assume that of all the projects currently undergoing environmental assessment, 100% of those in the preparatory documentation and assessment documentation stages, 80% of those in the scoping documentation stage, and 20% of those in the consideration documentation stage will be in operation by 2030. (This low figure of 20% is due in part to the fact that many such projects are still in the early planning stages.) As a result, the total capacity of projects undergoing environmental assessment is expected to reach 18.5 GW by 2030. Adding the actual installed capacities in 2021 (4.6 GW) to this figure brings the total to 23.1 GW, which is more than the projected development in 2030 (20.8 GW).

On the other hand, the average annual increase in the number of projects under environmental assessment during the last three years, from February 2020 to February 2023, has been 0.9 GW for projects in preparatory and assessment documentation stages, 1.0 GW for projects in scoping documentation stages, and 1.3 GW for projects in the consideration documentation stages. Assuming that these will all continue beyond 2023 and start operation at the same rate as above, the average increase in capacity will be 2.0 GW per year (0.9 + 1.0 × 0.8 + 1.3 × 0.2), adding up to 14 GW of capacity in operation by 2035 due to new environmental assessments in the seven years from now to 2030. Adding this to the 23.1 GW of capacity projected by 2030 brings the total to 37.1 GW, which is close to the 34.4 GW of estimated development potential.

The cumulative total of offshore wind power capacity will be 4.3 GW when the Round 2 projects, which are currently subject to public tender, begin operation, and 6.4 GW when capacity in “promising areas” with development potential begins operation. On top of this, in “areas that have progressed to a certain stage of readiness,” the average capacity of projects currently undergoing environmental assessments (if multiple environmental assessments are conducted in the same area of sea, the average capacity for the relevant area) will cumulatively amount to 11.8 GW when the facilities begin operation. In addition, in areas of sea that have not yet reached the preparatory stage, the cumulative total capacity will only be 14.3 GW, even if the operation is assumed to start at the average installation capacity during environmental assessment.

As discussed in Chapter 6, to accelerate the development of offshore wind power generation projects in particular, it is necessary to shorten the project development period by means of regulatory reform. Through these efforts, it will be possible to achieve deployment of 25.4 GW of capacity by 2035 by continuing to designate project promotion zones until 2030, at a rate of about 2 GW/year for fixed-support wind power and 1 GW/year for floating wind power.

If we check against grid connection applications and assume that 80% of projects now at the stage of application for grid connection agreement and 10% of projects now at the stage of application for gird connection considerationwill be connected to the grid by 2030, taking into account areas of overlap for offshore wind, we can expect 29.1 GW of capacity to be be installed. If we add the actual capacity installed as of 2020 (4.2 GW) to this figure, we get 34.3 GW, which shows that the projected total installed capacity of onshore and offshore wind power in 2030 (30.9 GW) will be achieved. In addition, the average annual increase in connection applications over the past three years (2019 to 2022) was 3.0 GW at the stage of application for grid connection agreement and 3.0 GW at the stage of application for grid connection consideration, so assuming that this rate of increase persists, we can expect an average annual increase in capacity of 2.7 GW (3.0 × 0.8 + 3.0 × 0.1). Furthermore, if the offshore wind power promotion zones mentioned earlier (total of 3 GW/year for fixed-support and floating systems) are added to the grid-connected capacity as part of the government's grid stabilization scheme, total grid-connected capacity will reach 59.8 GW by 2035. To realize this goal, however, new intra-regional backbone transmission lines and inter-regional interconnection lines will also neeed to be constructed.

As mentioned above, speeding up the project development process is a prerequisite for achieving this level of wind power deployment by 2035. It is vital to work on accelerating and streamlining environmental assessment and grid connection processes (including deregulation), and other relevant procedures.

Wind power generation capacity

We calculated wind power output based on the power curve for low wind speed specifications from wind conditions at ground level (sea level), assuming a hub height of 90 m for 4 MW and larger turbines in the case of onshore wind power and a hub height of 140 m for 10 MW and larger turbines in the case of offshore wind power. As for wind conditions, we assumed that development will be advanced at the same potential rate in unit of 0.5 m/s with the minimum annual average wind speed (6.5 m/s for onshore, 7.5 m/s for offshore fixed-support, 8.0 m/s for offshore floating). In doing this, we referenced the potential data according to grid area, also taking into account differences in wind conditions by region. Considering the growing size of wind power generation equipment and wind conditions, capacity factor will increase significantly, especially in Hokkaido and Tohoku regions, where wind conditions are good.

The total quantity of energy generated by onshore and offshore wind power systems in Japan in 2035 is estimated to be 174.0 TWh.

Summary

Summing up the above, the total wind power capacity that can be installed is shown in Table 3-3.

Table 3-3 Installed wind power capacity and wind-generated energy in 2035

	Capacity (GW)	Generated energy (TWh)	Effective capacity factor
Onshore wind	34.4	92.2	30.60%
Offshore wind (fixed-support)	20.5	64.8	36.20%
Offshore wind (floating)	5	17	39.10%
Total	59.8	174	33.20%

Note) Effective capacity factor is determined from the theoretical capacity factor after considering differences in wind speed distribution and availability factor. Totals may not add up exactly due rounding.

Source) Created by REI

Chapter 4 Potential for non-variable renewables

In 2035, solar PV and wind power will serve as the main sources of electric power in Japan in quantitative terms. However, power generation using other kinds of renewables, such as biomass, hydropower, and geothermal energy, which each offer their own unique characteristics, can be expected to supplement variable solar and wind power generation and contribute to the stabilization of power supply systems. Given their importance, this chapter offers an outline of the deployment potential of each of these sources.

Section 1 Bioenergy power development potential

1. Current state of bioenergy power development

Current state of development

Bioenergy power started to develop significantly after the introduction of the FIT scheme. As of the end of FY2021, 5.6 GW of biomass power projects were operational, including projects authorized under the RPS Act (Act on Special Measures Concerning New Energy Use by Electricity Providers) before the FIT scheme came into effect. Approved capacity amounts to approximately 11 GW, mainly under the category of “general woody materials and agricultural residue”, but many projects are expected to lapse when the deadline for commencement of operation passes in November 2024.

On top of this, some biomass projects are run independently of the FIT scheme, for industrial on-site power generation, mainly in the paper industry. Many of these are so-called combined heat and power (cogeneration) systems can also supply high-temperature steam. They are estimated to generate around 9.0 TWh of total energy per year.

Table 4-1 Current state of biomass power generation (FIT scheme only, as of end of FY2021)

	Operating capacity (GW)	Approved capacity (including transition certification) (GW)	METI long-term projection
Methane fermentation gas	0.1	0.15	0.18
Unutilized wood	0.48	0.69	4.34
General wood and agricultural residues	2.54	7.1	
Construction waste, general waste, RPS, etc.	2.52	2.7	3.5
Total	5.64	10.6	8.02

Note) In some projects, fuels other than biomass (fossil fuels or non-biomass waste) may also be used, so capacity figures refer only to power generated from biomass.

Source) Created by REI based on FIT scheme statistics from the Agency for Natural Resources and Energy

Potential

To assess the potential of biomass resources, we can make use of data compiled by the Ministry of Agriculture, Forestry and Fisheries (MAFF) on the quantities of biomass generated and used, and rate of utilization. However, due to the inclusion of data on compost utilization, it is difficult to determine the amount of energy available from biomass.

For forest biomass, such as thinned wood and other woody biomass, targets consistent with the Strategic Energy Plan are specified in the Basic Plan for Forest and Forestry formulated by the Forestry Agency. The target volume for 2030 is 9 million m^3. Since the biomass volume used in 2021 exceeded 8 million m^3, it is considered difficult to significantly increase the quantity utilized.

There is also a steady rise in the consumption of imported biomass. In addition, while the three types of fuel that could be used under the FIT scheme were woody biomass (chips and pellets), PKS (palm kernel shells), and OPT (oil palm trunks), in April 2023 fuel options were expanded with the addition of non-edible agricultural residues/by-products such as EFB (empty fruit bunch) and coconut shells. There is therefore a significant amount of sustainable usability, but given the growing need for heat supply (in addition to power generation) and for sustainable aviation fuel (SAF) feedstock, careful consideration is required.

2. Estimating capacity development by 2035

Biomass generation for sale of electricity (mainly FIT)

In light of the above situation, the outlook for biomass power generation for sale of electricity, mainly with the support of the FIT is as follows.

- Methane fermentation
  - Though only moderately, the amount of approved capacity is certainly growing, and we assumed that the deployment of methane fermentation electricity generation will continue to increase up to 0.16 GW, the same level as forecast for 2030 in the Strategic Energy Plan. This is backed by the expected increase of use of the liquid fertilizer obtained as a result of methane fermentation (owning to the “agriculture and livestock collaboration”) and increase of use of sewage sludge as energy and fertilizer.
- Woody biomass (unutilized woody biomass = domestic wood)
  - Based on the limited availability of domestic wood supply, we assume that capacity will grow up to the 2030 target in the Strategic Energy Plan and then remain steady until 2035. In 2035, some projects, in which the FIT purchase price will no longer be paid, will begin to appear, but we expect that these projects will continue to operate.
- Woody biomass (general woody biomass and agricultural residues = imported wood)
  - We assume that the industrial association’s projection (5 GW), which excludes unused material, will be achieved, but that capacity will then level off.
  - The prices of fuels are rising and there have been delays in procurement. Given these changes in the business environment, it is assumed that some plants will switch from FIT to FIP. For this reason, the capacity factor of facilties will need to be revised downward.
  -
- Construction waste, general waste (including former RPS)
  - The quantities of generated scrap and waste matter are not expected to increase due to factors such as population decline, so we assume that capacity will increase

up to the 2030 target of the Strategic Energy Plan but then remain steady until 2035.

Conversion from coal-fired power independent of FIT (including on-site bioenergy generation)

It is assumed that under the framework of the Energy Conservation Act and other mechanisms, in-house power generation for industrial use and fuel conversion of existing coal-fired power plants to biomass will progress to a significant degree. In addition to conventional wood pellets, the development of black pellets, formed by heat-treating biomass, are also developing as an alternative fuel to coal. Since black pellets can be made from a wide variety of agricultural residues as well as from woody biomass, they will potentially expand the available fuel supply. Although commercial production has not yet started, Idemitsu Kosan aims to produce the equivalent of 10% of its current coal sales by heat value by 2030. Other companies are making similar moves, as seen in an announcement of plans to purchase a coal-fired power plant and convert them to biomass use.

For this reason, we assume that the current level of biomass electricity production (9.0 TWh) will be maintained until 2030, but also that 10% of Japan's current total coal power generation (approximately 30 TWh) will be converted to biomass fuel by 2035. It is assumed that by 2035 this biomass fuel will be used in plants that are 100% converted to biomass, mainly for industrial on-site power generation facilities, rather than for extending the life of coal-fired power plants.

Summary

Based on the above, the quantity of biomass generation capacity in 2035 is estimated to be 85.7 TWh. Capacity factors were set for each category with reference to the latest data reported by the Procurement Price Calculation Committee. Note that as of 2030, while FIT projects will have typically reached their caps, the quantity of generated electricity is expected to be 59.6 TWh, since the conversion from coal-fired power generation is not expected to be in full swing yet.

If we compare this figure to the ambitious level of 47 TWh in the 6th Strategic Energy Plan, it seems high. The difference is principally due to the current use of on-site power generation (9.0 TWh) and the expected increase in future conversion from existing coal-fired power generation (30 TWh).

Note that when using bioenergy, it is important to give due consideration to its sustainability, regardless of whether the bimoass fuel is produced domestically or imported. The FIT scheme also incorporates sustainability standards that cover environmental and social criteria for agricultural residue biomass, and it supports third-party certification of biomass fuels. Under the framework of the Energy Conservation Act and the Long-term Decarbonization Auctions, which are expected to increase in the coming years, it is also necessary to require compliance with sustainability standards as well as under the FIT scheme.

Table 4-3 Projected annual biomass power generation in 2035 (summary)

	Installed capacity (GW)	Capacity factor	Electricity production (TWh)
Methane fermentation gas	0.16	0.6	0.8
Unutilized wood	0.55	0.75	3.6
General woody and agricultural residues	5	0.65	28.5
Construction waste, general waste, RPS, etc.	3.5	0.45	13.8
In-house power + conversion from existing coal-fired power	-	-	39
Total	9.2	-	85.7

Source) Created by REI

Section 2 Hydroelectric power development potential

1. Current state of hydropower development

Current state of development

The total installed capacity of hydropower (excluding pumped storage) at the end of FY2021 was 22.5 GW according to the status of 10 kW power connections. According to the government's Comprehensive Energy Statistics, the total quantity of electricity generated from hydropower in FY2021 was 77.8 TWh.

Of this, small and medium-scale hydropower systems (below 30 MW) installed before the end of FY2021 under the FIT scheme accounted for 0.83 GW. Although 9.6 GW of capacity had already been developed before the launch of the FIT scheme, some of these systems have been replaced, resulting in a current total installed capacity of 9.8 GW. There is also 1.6 GW worth of approved facilities that are not yet operational. On top of this, there is 12.8 GW in large-scale hydropower capacity, consisting of systems of 30 MW or more.

Development potential

According to the Potential Hydropower Survey, Japan's total undeveloped hydropower capacity amounts to 11.7 GW (44.1 TWh), suggesting that capacity can be expanded to approximately 1.5 times the current level. The untapped potential is particularly high in the category of small- and medium-scale hydropower systems, but reportedly due to the remote location of development sites and the small magnitude of power output, the development of this potential is subject to economic, natural and social constraints, as well as grid connection issues.

On the other hand, the Ministry of Environment's Renewable Energy Potential System (REPOS) estimates that there is an additional 3.21 to 4.21 GW (17.4 to 22.6 TWh) of development potential for small and medium-scale hydropower when business viability is taken into account.

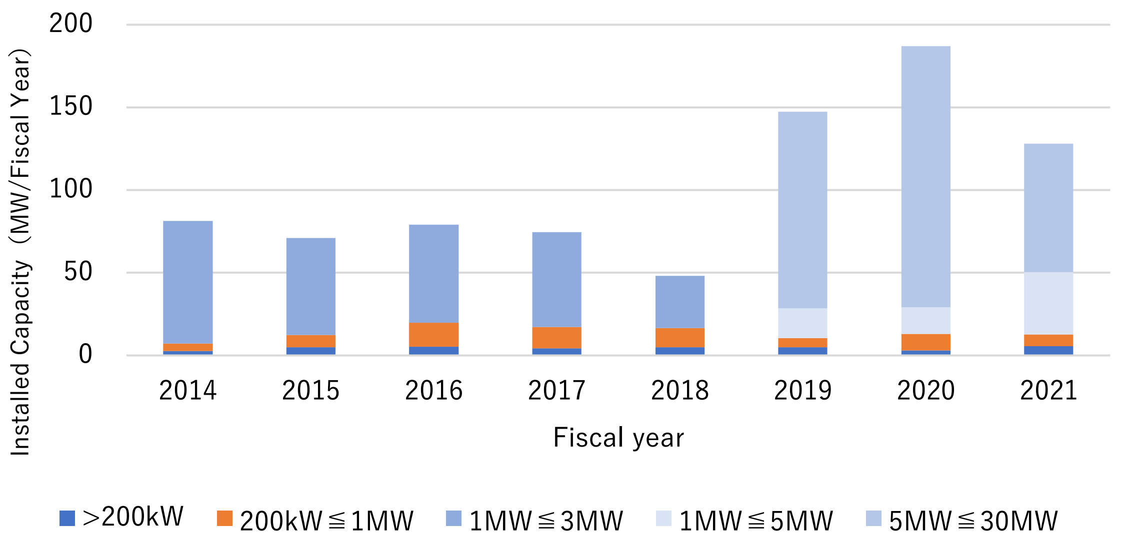
2. Estimating develpment by 2035

In using hydropower for energy, it is essential to design the use of local water resources to ensure a balance between local flood control, irrigation, and other forms of water utilization, especially in light of the recent rise in flooding and landslide disasters.

Small and medium-scale hydropower

Firstly, for FIT-approved projects, the lead time is about two years for projects up to 1 MW and four years for projects up to 3 MW. Such approved projects tend to operate reliably. Up to now, the average annual installed capacity has been 102 MW, but over the past three years it has risen to 154 MW (Fig. 4-1). The quantity of FIT-approved capacity has also grown in recent years, amounting to 267 MW in FY2020 and 855 MW in FY2021, suggesting that further growth is likely over the coming years.

Fig. 4-1 Trend in annual development of small and medium-scale hydropower under FIT



Source) Created by REI from FIT statistics of the Agency for Natural Resources and Energy

This estimate therefore forecasts an increase in capacity of 2.0 GW, including 1.6 GW of unutilized capacity as of the end of March 2022, with the deployment of approximately 140 MW of new capacity each year. This figure is higher than the 100 MW per year assumed in the Strategic Energy Plan, but slightly lower than the actual capacity installed over the past three years. Our figure also takes into account the overlap due to FIT approval as a result of the renewal of existing facilities. Furthermore, although the quantity of approved capacity has been high in recent years, development sites are becoming increasingly remote, thereby necessitating increasingly delicate construction work (with water conduit tunnels for example). For this reason, a downward trend in approved capacity is also expected. As a result of all these considerations, we estimate the total capacity of small and medium-scale hydropower at the end of FY2035 to be 11.8 GW.

Large-scale hydropower

As mentioned above, under the leadership of the Headquarters for Water Cycle Policy of the Cabinet Office, measures to maximize hydropower generation will be promoted at dams and other facilities under the authority of various administrative bodies, including the Ministry of Land, Infrastructure, Transport and Tourism (MLIT), Ministry of Agriculture, Forestry, and Fisheries (MAFF), and prefectures. Although this will not lead to an increase in power generating capacity, it is expected to boost total electricity production to 7.5 TWh. (This includes non-FIT small- and medium-scale hydropower.)

Summary

From the above, we can conclude that the quantity of electric power generated by small- and medium-scale hydropower and pursеched through the FIT schme will increase in proportion to the projected increase in capacity. In the case of large-scale hydropower, an increase of 7.5 TWh of electricity is projected, as outlined above.

To summarize the above, annual hydropower generation is projected to produce 99.6 TWh of electricty in 2035. Assuming a uniform rate of growth up to 2035, expected electricity production from hydropower in 2030 will be 93.1 TWh.

Table 4-4 Projected annual hydropower generation up to 2035 (summary)

	Type	FY2021	FY2030	FY2035
Installed capacity (GW)	Small- and medium-scale hydropower	9.8	11.1	11.8
	Large-scale hydropower	12.8	12.8	12.8
	Total	22.6	23.9	24.6
Generated electricity (TWh)	Small- and medium-scale hydropower (FIT only)	4.5	11.4	15.3
	General hydropower (incl. non-FIT S&M-scale hydro)	76.8	81.7	84.3
	Total	81.3	93.1	99.6

Note) Total hydropower generation is the 10-year average for FY2012 to FY2021. The quantity of electricity generated by small and medium-scale hydropower is assumed to be the quantity of electricity purchased under the FIT scheme in FY2021, with the remainder assumed to be "general hydropower."

Source) Created by REI

Section 3 Geothermal power development potential

1. Current state of geothermal power development

Current state of development

As of the end of FY2021, the total installed geothermal power generation capacity in Japan was 0.54 GW (with the connection by the 10 major power companies), corresponding to a total electricity production ofs 2.4 TWh (Comprehensive Energy Statistics). By the end of FY2021, 220 MW worth of geothermal power projects had been approved under the FIT scheme, of which 90 MW were operational. Of these geothermal power systems with an installed capacity of 10 MW or more, approximately 449 MW of capacity was in operation by the end of FY2011, with another 46 MW in operation from 2012. Due to the long lead time of geothermal projects, typically seven to 10 years, geothermal power capacity has increased only slightly since 2012, when the FIT scheme was launched.

Development potential

Japan is said to boast the world's third largest geothermal power generation potential, amounting to about 23 GW. However, as mentioned above, the total installed geothermal power capacity currently in operation is only 0.54 GW, corresponding to just 2.3% or so of total estimated geothermal potential.

According to a survey by the Ministry of the Environment's Renewable Energy Potential System (REPOS), total geothermal power potential is estimated to be 14.4 GW (100.6 TWh). If business viability is taken into account, geothermal power potential is estimated to be 9 to 11.4 GW (63.0 to 79.6 TWh of electricity), indicating that geothermal capacity can be expanded to approximately 26 times the current level.

2. Estimating development up to 2035

At present, there are five large-scale geothermal power projects in Japan currently undergoing environmental assessment, with a total capacity of 70 MW. These geothermal power plants are expected to become operational between 2023 and 2029. Since the purchase price for geothermal power of 15 MW or more is set at the low level of ¥26/kWh under the FIT scheme, many of the geothermal developments currently in progress are smaller than 15 MW, to take advantage of the higher purchase price of ¥40/kWh.

Like this, a look at the progress of environmental impact assessments shows that Japan is far away from meeting its goal of deploying an additional 1 GW of geothermal power, as projected in the Strategic Energy Plan. To achieve this target and make best use of Japan's geothermal power potential, the following issues with the geothermal power development process need to be resolved.

The development of geothermal power necessitates a variety of processes, including a survey on the utilization of geothermal resources, grid connection to the area where power plants are located, and a consensus building process with hot spring operators close to the planned power plant site. In many cases, however, the necessary geothermal resource survey, involving drilling, never eventuates, due to a failure to secure the consensus of the local community.

Table 4-6 Expected capacity of operational large-scale geothermal power plants (currently undergoing environmental assessment)

	Prefecture	Municipality	Power plant	Output (MW)	Expected operation start	Environmental assessment
1	Hokkaido	Hakodate City	Esan Geothermal Power Plant (tentative name)	9.9	2028	Scoping documentation
2	Iwate	Hachimantai City	Matsukawa Geothermal Power Plant (updated)	14.9	2025	Assessment documentation
3	Akita	Yuzawa City	Kijiyama Geothermal Power Plant (tentative name)	14.9	2029	Scoping documentation
4	Akita	Yuzawa City	Katatsumuri Yama Geothermal Power Plant (tentative name)	14.9	2027	Assessment documentation
5	Iwate	Hachimantai City	Appi Geothermal Power Plant	14.9	2024	Assessment documentation

Source) Created by REI based on the Ministry of the Environment's Environmental Impact Assessment Information Support Network (http://assess.env.go.jp/)

This is conditioned by the fact that drilling permits for geothermal development, even for research purposes, are decided by advisory councils or other collegial body composed of local hot spring operators, academics, and other parties, in accordance with the Hot Springs Act. Since these councils, which are set up in each prefecture, deliberate on drilling permits on a project-by-project basis, it takes considerable time to obtain a permit. In addition, because the councils primarily deliberate on the use of hot springs, they do not have specific criteria for assessing geothermal projects. One particular problem is that when an advisory council considers a permit for geothermal development, before any deliberation it needs to decide whether the scale of geothermal development is appropriate and to determine the quantity of geothermal resources in the area through a drilling survey. However, approval is required to conduct drilling for research purposes. Strangely, there is no clear distinction between drilling approval for geothermal resource research and drilling approval for geothermal project development. Or in other words, it is just as difficult to acquire approval to drill for research as it is for project construction. For this reason, projects in many promising geothermal resource areas have come to a standstill at the stage of obtaining approval to conduct a drilling survey, which is essential for determining the quantity of geothermal resources.

Furthermore, there are no clear rules or processes established for geothermal development in Japan, which means that developers and other involved parties are forced to pursue projects on their own. One of the fears of hot spring operators is that developers will end up failing to comply with agreements reached with local residents. If the agreement is not bound by any local government ordinance or law, there will not be any penalties for failure to comply with an agreement. On top of this, it is difficult to scientifically prove influences of geothermal development, including depletion of a hot springs source. Local residents are concerned that project developers may dodge their commitment to the terms of agreement. This current failure to establish clear rules and transparency in geothermal development has fueled a sense of distrust and uncertainty among existing users of geothermal resources (e.g., hot springs operators), giving rise to a situation in which it is difficult to obtain approval for permits from the advisory councils mentioned above.

To increase installed capacity under these circumstances, it is necessary to take advantage of the original geothermal power potential by establishing a system to promote the development of geothermal power plants and improving the business environment. One essential step that needs to be taken is to institute a “Geothermal Law” to set rules for the geothermal power business environment, which should include the following matters.

Implementation of drilling surveys for government-led, nationwide geothermal resource surveys: Based on data obtained from government-led surveys conducted in the 1980s, the national government will lead the initiative to conduct nationwide geothermal resource surveys (drilling surveys for research purposes), without requiring the approval of any prefectural advisory council, to ascertain the quantity of geothermal resources in each region of the country. By obtaining a more precise understanding of the geothermal resources of each region, the government can set an appropriate scale of geothermal power development for each region. This information can then be used by the advisory councils in each prefecture to inform their decisions about drilling approvals.

Geothermal zoning: Based on government-led drilling survey and environmental assessments, zoning will be conducted to designate areas in which the environment should be protected and areas in which geothermal development is possible, with the aim of opening up the benefits of geothermal development to both developers and local communities. In this process, the appropriate scale of power generation is decided based on the data obtained from the geothermal resource survey performed before the area was classified as viable for geothermal development. After approval for drilling for geothermal development purposes and for the scale of power generation is obtained from the advisory council of the relevant prefecture, the project will be ready to progress to the selection of project operator once the zoning has been determined. In addition, the contents of the agreement concluded in advance with local residents as conditions for development will be verified by the national government or other third-party body, to verify compliance. It may be a good idea for the national government to establish the terms of agreements as common rules for all projects across the country.

Central method for geothermal development: Based on geothermal resource survey data, geothermal developers/operators are selected through a public tender process in the areas designated as viable for geothermal development by the geothermal zoning process. By selecting developers/operators in this way, it will be possible to maintain a scale of geothermal development appropriate to the quantity of geothermal resources in each area. Furthermore, preventing multiple developers from competing to develop projects in the same geothermal area can help to create an environment that facilitates geothermal development in harmony with local communities.

If these measures improve the business environment for geothermal power, they can also be expected to promote the development of geothermal power in a way that ensures a harmonious coexistence between companies that want to participate in geothermal power development and local stakeholders that are open to the benefits of geothermal power. Ensuring the predictability of the growth in geothermal development projects would also make it easier to train specialists and professionals for geothermal power-related work, which are currently in short supply.

Summary

The above institutional reforms are vital for expanding the development of geothermal power generation. Even if these institutional reforms were initiated immediately, no significant increase in capacity could be expected until around 2030 due to the long lead time of projects. However, it is possible to realize the development of a total of approximately 1 GW by 2035, at the rate of 200 MW per year over the five years from 2031 to 2035. As a result, we can project geothermal power generation capacity and annual geothermal electricity production to reach 1,651 MW and 11.5 TWh, respectively, by 2035.

Chapter 5 Electricity supply mix in 2035

Section 1 Electricity demand outlook in 2035

1. Ambition required for energy (electricity) demand in 2035

According to the IPCC AR6 Synthesis Report, released on March 20, 2023, the level of global greenhouse gas (GHG) emissions by 2030, based on the current Nationally Determined Contributions (NDCs) submitted by the countries of the world are likely to lead to a mean global temperature rise of more than 1.5°C by the end of this century. The report therefore states that global GHG emissions need to be cut by 43% by 2030 and by 60% by 2035 relative to the 2019 level.

In the 6th Strategic Energy Plan, energy and electricity demand in 2030 is assumed to be as shown in Table 5-1. These figures were determined to meet Japan's NDC goal of reducing GHG emissions by 46% by 2030 relative to the 2013 level. They were formulated by making downward revisions to the macroframes of previous plans (e.g., economic growth rates, production volumes in major industries, and transportaiton demand), as well as by a series of energy-saving measures.

Table 5-1 Projected final energy consumption and electricity demand in the 6th Strategic Energy Plan

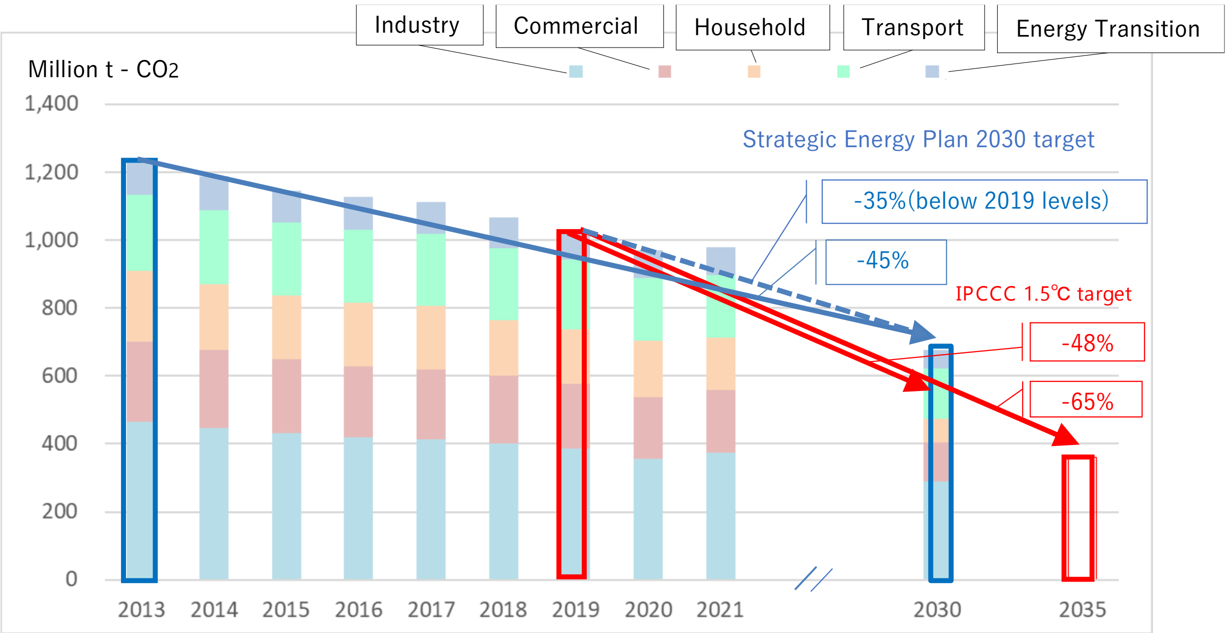
	Final energy consumption (GI crude oil equiv.)				Electricity demand (TWh)			
	FY2013	FY2019	FY2030 (BAU)	FY2030 (after energy-saving)	FY2013	FY2019	FY2030 (BAU)	FY2030 (after energy-saving)
Industrial	168	156	150	140	365	342	387	331
Commercial	59	54	70	50	324	316	399	300
Household	53	47	50	30	283	252	288	211
Transport	83	77	80	60	17	17	19	23
Total	363	335	350	280	990	927	1,092	864

Source) Agency for Natural Resources and Energy, "Energy Supply and Demand Outlook for 2030 (Related Data)" (September 2021) and Comprehensive Energy Statistics (FY2019)

Note) Totals may not add up exactly due rounding.

However, the CO_2 emission reductions required by the IPCC (relative to 2019 levels) are 48% by 2030 and 65% by 2035. As shown in Fig. 5-1, energy-derived CO_2 emissions in the Strategic Energy Plan can only be reduced by 35% from the 2019 level. For 2035, it is vital to try and reduce CO_2 emissions at least to the level required by the IPCC, i.e., to 65% below the 2019 level, or to 360 million tons. It is essential to try and realize this goal.

Fig. 5-1 2030 Targets in the Strategic Energy Plan and CO2 emission reduction levels required by the IPCC



Source) Created by REI from Agency for Natural Resources and Energy (ANRE) "Comprehensive Energy Statistics Time Series Tables" and "Energy Supply and Demand Outlook for 2030 (Related Data)"

2. Approach to demand reduction measures up to 2035

Basic approach to estimating activity levels

The estimates of demand in the current Strategic Energy Plan are different to those in previous Strategic Energy Plans in that many of the economic activity indicators in specific sectors, such as economic growth, production volume in major industries, growth in total floor area of commercial buildings, and passenger and freight traffic, have been revised downward. Given that various statistics showed a gradual decline or diminishing rates of growth up to 2019 and considering the impact of the COVID-19 pandemic in 2020 and subsequent years, these are reasonable assumptions.

However, in estimating demand in 2035, it is necessary to think even further ahead. It is especially important to keep in mind the shift to a circular economy. In the 2020s, it will be increasingly necessary to try and reduce the consumption of resource materials, not just through recycling, but also by stepping up efforts to improve design, change materials, increase strength, reduce weight, and extend operating life, as well as by transitioning to a recycling-oriented business models. As a result, it will be important to start replacing new production with recycling by 2035, at least for domestic demand in the materials industry, as well as to reduce production. Reducing the overall level of energy consumption by transitioning to a circular economy offers huge potential for future emission reductions.

On the basis of this approach, in this report REI assumes that the macro indicators that reflect the level of activity in each sector of the economy will exhibit a stronger downward trend than is assumed in the Strategic Energy Plan. In the steel industry, which emits more CO_2 that any other industrial sector, a shift from blast furnaces to electric furnaces that utilize recycled iron is expected, representing a major step forward to a circular economy.

Need for further promotion of electrification*

The need to strive for electrification in industrial sectors*

Promotion of electric vehicles (EVs) in the transportation sector*

2. Estimating electricity demand in 2035

Based on the above points, we estimated the level of electricity demand in 2035. While focusing primarily on electricity demand in this projection, we note that to achieve the emission reductions required by the IPCC, total energy demand needs to be reduced. The results of our estimation are shown in Table 5-3.

We estimate that final energy demand in 2035 will be 254 million kl of crude oil equivalent, 24% below the 2019 baseline. Reductions are steadily being made in the household, transport, and industrial sectors. Compared to the 2030 target of the Strategic Energy Plan (SEP), this estimate anticipates greater energy cuts in the industrial and commercial sectors.

We estimate total electrical energy demand to be 850 TWh, which is 8% below the 2019 level. Reductions will be made in the industrial, commercial, and household sectors by promoting power reductions through energy-saving. Although electricity consumption in the transport sector has always been low, given the plans to promote EVs up to 2050, the reduction in electricity demand will be less than the reduction in final energy consumption.

Table 5-3 Estimated energy and electricity demand in 2035

Sector	Final energy consumption (Gl of crude oil equiv.)					Electricity demand (TWh)				
	FY2013	FY2019	FY2030 (SEP)	FY2035	FY2019	FY2013	FY2019	FY2030 (SEP)	FY2035	FY2019
Industrial	168	156	140	113	-28%	365	342	331	299	-13%
Commercial	59	54	50	42	-23%	324	316	300	266	-16%
Household	53	47	30	31	-34%	283	252	211	219	-13%
Transport	83	77	60	55	-29%	18	17	23	66	286%
Total	363	335	280	254	-24%	990	927	864	850	-8%

Source) Created by REI

The following is an outline of our calculations for each sector.

Industrial sector

We estimated final energy consumption in the industrial sector to be 28% lower than in 2019. This figure is 20% lower than the 2030 target in the Strategic Energy Plan. We assumed electricity demand to be 299 TWh, 13% below the 2019 level.

We assumed that the decreasing trend of level of activity, which serves as the basis for our calculations, will intensify after 2030, based on population forecasts and the assumptions about production volume in major industries in the Stategic Energy Plan, as well as our expectation of an increasingly circular economy. We estimated BAU (business-as-usual) energy in 2035 by multiplying the current energy consumption by the predicted activity reduction rate, and then we took into account energy-saving and electrification as reduction measures. One energy reduction measure that has been very effective is the promotion of higher energy efficiency through the installation of industrial heat pumps. The rise in electricity demand is more than offset by the magnitude of the energy saving.

The steel industry, which accounts for nearly half of total industrial emissions, is shifting away from blast furnaces to electric furnaces as an emissions reduction measure. 15% of blast furnaces that will reach the end of their operating life by 2035 (equivalent to approx. 7.5 million tons of production capacity). are being converted to electric furnaces.

Commercial sector

We assumed the final energy consumption in the commercial sector to be reduced to 23% below the 2019 level. This figure is 16% lower than the 2030 target in the Strategic Energy Plan. Total electricity demand was calculated at 266 TWh, which is 16% below the 2019 level.

We used the total floor area of commercial buildings as an indicator for the amount of activity, and followed the 2030 estimate in the Strategic Energy Plan, and we assumed that the actual floor area utilized after 2030 will start decreasing, based on the anticipated population decline between 2030 and 2035.

To calculate the BAU energy consumption, we used the consumption per unit floor area for different energy sources, multiplying by the projected commercial floor area in 2035, after which we cumulatively calculated and subtracted the reductions achieved by measures for different uses and energy types. The main energy-saving measures we assumed were increasing the efficiency of equipment and electrification, along with upgrading equipment for heating, hot water, lighting, and cooking. In addition to the extensive conversion to LED lighting, the conversion to electric heat pumps for air conditioning and hot water supply yields significant benefits, in terms of both electrification and efficiency. We also assumed that energy and electricity demand reductions will be achieved by reducing energy loads by upgrading thermal insulation and heat shielding performance when constructing and renovating buildings. For our calculations, we assumed a cycle of 50 years for new construction and 25 years for renovation of existing buildings.

Household sector

We estimated final energy consumption in the household sector to be 34% lower than in 2019. This estimate is 3% higher than the 2030 target in the Strategic Energy Plan. Electricity demand is assumed to be 219 TWh, a 13% reduction relative to 2019.

As our activity level indicator, we used the estimated number of households, expecting it be 3% below the 2019 level in 2035. We calculated our BAU estimate by taking the energy consumption per household for different uses and multiplying by the projected number of households in 2035, after which we cumulatively subtracted the reductions for each kind of energy use. As in the commercial sector, the main energy reduction measures are efficiency improvements and electrification of equipment, along with equipment upgrades for heating and cooling, hot water, cooking, and lighting. In the household sector, replacement of fuel-based heating equipment with electric heat pump air conditioners and the replacement of water heaters with electric heat pump water heaters are making a very substantial impact. We also anticipate that energy and electricity demand will be lowered by reducing energy loads by upgrading insulation and heat shielding performance in new and renovated buildings. For our calculations, we assumed a cycle of 40 years for new construction and 25 years for renovation of existing homes.

Transport

We estimated final energy consumption in the transport sector to fall to 29% below the 2019 level. This figure is 8% lower than the 2030 target in the Strategic Energy Plan. Total electricity demand is expected to increase to 66 TWh, which is 286% higher than in 2019.

Using passenger and freight traffic as indicators, we estimate that activity in this sector will gradually diminish in line with falling population after 2035, based on the 2030 estimates in the Strategic Energy Plan, with expected drops of 9% in passenger demand and 1% in freight demand. We calculated energy consumption based on per-unit energy consumption for different transport modes and sectors in 2019 both for passenger and freight (private vehicles, taxis, buses, trucks, trains, ships, and aircraft), by determining the expected improvement in fuel consumption through regression calculations and multiplying by the projections of traffic volume in 2035. Although energy consumption (per unit) has been improving for private passenger vehicles, the rate of improvement for truck freight is low. In the case of trains, there has been almost no change. Thus, each mode of transport has its own characteristics.

The measure is the electrification of motor vehicles. By 2035, EVs and PEVs (pure EVs) will account for 30% of the total energy consumption of passenger vehicles, and a 15% share of buses and trucks too. There will be also be a modal shift to some degree, with transitions from passenger vehicles to buses and from freight vehicles to trains.

Section 2 Projected supply potential of each power sources

1. Renewable power generation

Table 5-4 summarizes the potential development of each of the renewable energy sources examined so far. We assume that if regulatory reforms are instituted to accelerate the deployment of solar power, wind power, and other forms of renewable energy, and if the policies to promote these technologies are put in place, the total amount of electricity generated from renewable sources in 2035 can be expanded to 714.5 TWh.

Table 5-4 Projected renewable power generation capacity in 2035

		FY2021	"FY2030 (SEP)"	FY2030 (REI estimate)	FY2035 (REI estimate)
Installed capacity (GW)	Solar PV	79.2	164	208	280.2
	Wind	4.6	23.6	30.9	59.8
	Bioenergy	5.6	8	9.2	9.2
	Hydro	22	23.2	23.9	24.6
	Geothermal	0.5	1.5	0.7	1.6
	Total	111.9	220.3	269.7	375.4
Total electricity (TWh)	Solar PV	86.1	146	255.1	343.7
	Wind	9.4	51	87.9	174
	Bioenergy	33.2	47	59.6	85.7
	Hydro	77.8	98	93.1	99.6
	Geothermal	3	11	4.5	11.5
	Total	209.5	353	500.2	714.5

Note) The government's ambitious goal for solar PV in its Strategic Energy Plan (SEP) is 117.6 GW (AC-based). For comparison, we converted this figure to DC by multiplying by an overload factor of 140%.

Source) Created by REI

* The figures in this table are calculated based on the data in this report.

The figure of 714.5 TWh of energy from renewables alone amounts to more than three times the total current level of power generation, and more than double the government's target of 353 TWh for 2030. Renewable power will need to be deployed far beyond the current level and even the level the government is aiming at, so this goal will clearly not be easy to achieve. However, as discussed in Chapter 1, most of the developed nations of the G7 are aiming to decarbonize all power sources by 2035, focusing principally on renewables. This includes the U.S., which currently has a similar level of renewable energy deployment to Japan.

The current scenario for Japan assumes that by 2035 solar PV systems will be grow to 3.5 times the current level. This is comparable to the ambition of Europe's REPowerEU Plan, which aims at a four-fold increase by 2030. For wind power, the commitment is to increase capacity 13-fold by 2035, a goal that requires a more rapid expansion than solar power. However, this is necessitated by Japan's current backwardness in wind power, with only 4.6 GW of total wind power capacity, including just 135 MW of offshore wind power. The goal of the UK, whose electricity market is one-third the size of Japan's, is to increase total capacity of offshore wind power by a factor of five by 2030, from the current 10 GW to 50 GW. Numerous projects aimed at realizing this goal are already underway.

Japan is not alone in needing to rapidly expand its renewable energy capacity. Many countries around the world, including some G7 nations, are taking up the same challenge. The world is giving such a high priority to the expansion of renewable energy because the cost of generating electricity, both by solar PV and by onshore/offshore wind power, has dropped dramatically in recent years, with costs expected to continue dropping. Although the quantity of renewable energy that needs to be developed under this scenario is large compared to the government's previous goals, the goal for 2050 needs to be even higher. We believe that even by 2035 it may be possible to deploy more renewable energy than called for in this scenario, depending on cost reductions, technological developments, and progress in regulatory reform.

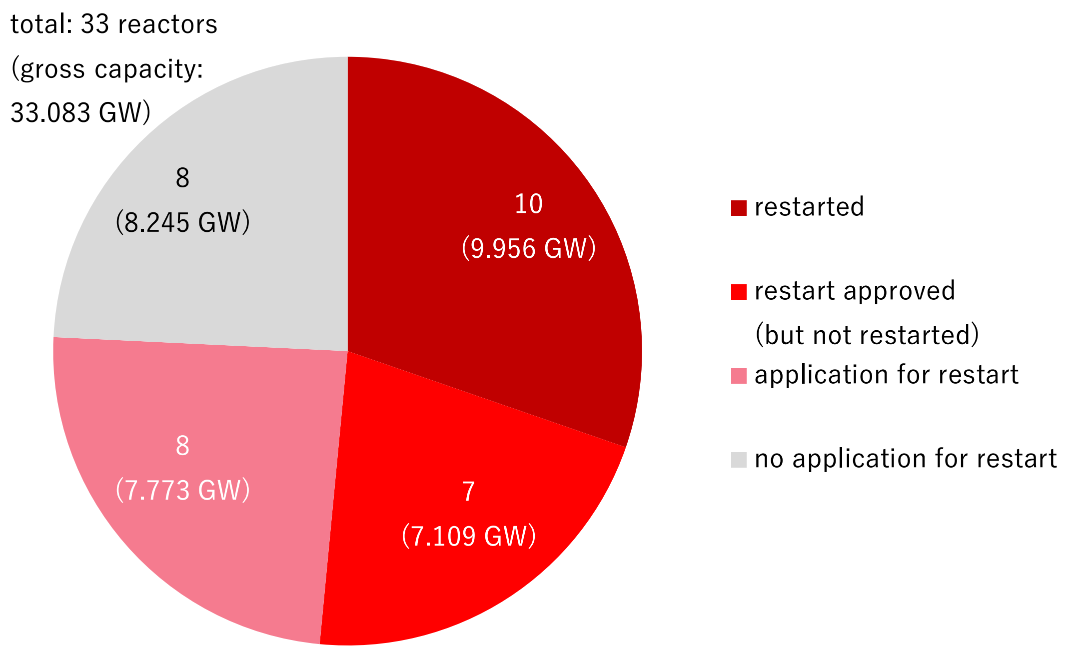
2. Nuclear power

As pointed out in Chapter 1, in its GX Basic Policy the Kishida administration appears to be putting more emphasis on restoring nuclear power generation than on other measures. It states its rationale for promoting nuclear power as promptly securing power supplies and promoting climate change action. However, as we have pointed out, nuclear power is not capable of delivering a stable supply of power; nor is it capable of playing any significant role as a decarbonized power source in the future. As for the construction of new nuclear power capacity, the roadmap of the GX Basic Policy does not anticipate the operation of any new reactors by 2035. Even the government's Cost Verification Committee states that nuclear power will take 20 years from planning to start of operation. Accordingly, in the following analysis, only the quantity of electricity generated by existing nuclear power plants is considered.

Current operational status

As of March 2023, only 10 (10 GW) of Japan's 33 reactors (33 GW) were in operation. A further seven reactors (7.1 GW) have passed the new regulatory standards, but have not been restarted yet

Fig. 5-2 Operational status of nuclear power plants in Japan (as of March 2023)



Source) Created by REI from "Japan's Nuclear Power Reactors (as of March 7, 2023)," Japan Atomic Industrial Forum, Inc.

There are also three nuclear reactors currently under construction, but in the case of Shimane- 3 (Chugoku Electric Power Co., Ltd.: 1.37 GW), the inspection that was suspended in anticipation of the reactor's completion in 2024 has just resumed. The construction of the Oma Nuclear Power Plant (1.38 GW by Electric Power Development Co., Ltd. (J-Power) is scheduled for completion in 2029, but its operation has already been postponed five times due to the protracted inspection process. Construction of TEPCO's Higashidori Nuclear Power Plant (1.38 GW) remains suspended, with no prospect that it will ever be completed.

Government estimates of power generation

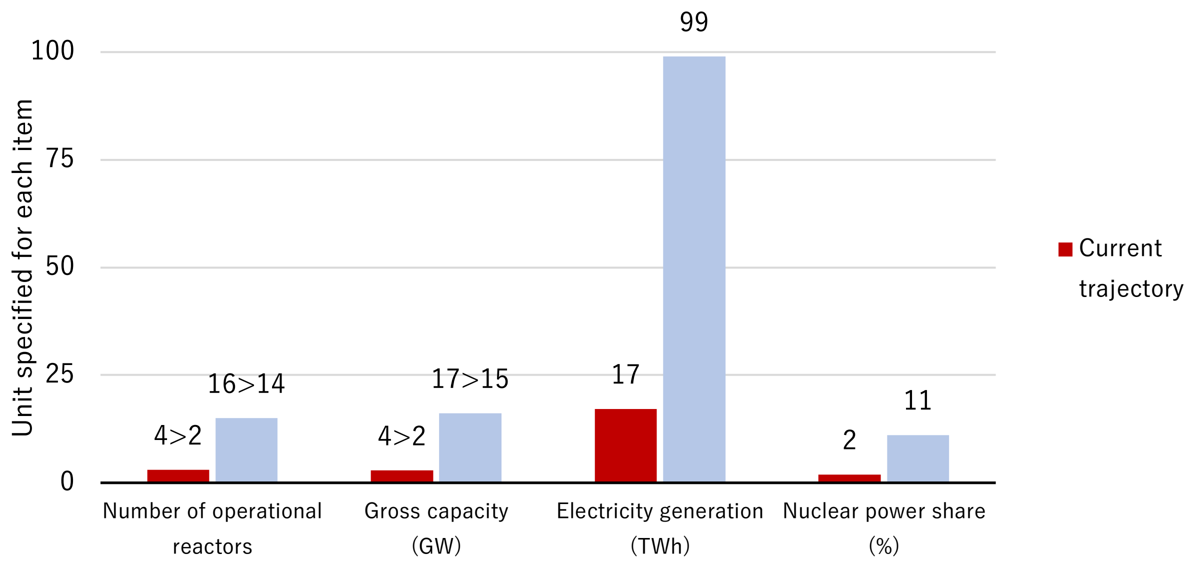
The 6th Strategic Energy Plan calls for nuclear power to account for 20–22% (186.8–205.5 TWh) of electric power production in FY2030. Considering that the share of nuclear power was only 6.9% in 2021, this represents a remarkable increase to approximately three times the current level. This 2030 target is undeniably unrealistic and overly ambitious, however. Even supposing that all the currently restarted reactors, all the reactors that have passed the new regulatory requirements but are not yet operational, and all the reactors that are currently under regulatory review will be operational, and that two of the three new reactors (not Higashidori) will also be operational, the maximum possible share of nuclear power will only be 15.7%. Yet, given that delays in restarting and constructing reactors are already evident, it will be extremely difficult to achieve even this level of capacity share.

Projected electric power production in 2035

Of the 10 reactors that are now in operation, only two are currently scheduled to be operational in 2035, Kyushu Electric Power Company's Genkai-4 (1.18 GW) and Kansai Electric Power Company's Mihama-3 (0.8 GW), which has been approved for 60-year operation. A further two reactors, Onagawa-2 and Takahama-2, are not currently operational, but they have passed the new regulatory standards and have scheduled operation dates. If these two reactors are restarted, they will also be in operation by 2035. Nevertheless, these four reactors can only generate a total of about 17 TWh, or about 2% of total power generation. In addition, two of these four reactors will reach the end of their operational life within FY2035, with the other two reaching their end in 2036 and 2037.

On the other hand, what if we assume that (1) all the reactors currently under inspection pass inspection and are restarted; (2) that all reactors that have applied for 60-year operation are permitted to extend their operating life; and (3) Shimane-3 and Oma start operation, the maximum number of reactors in operation in 2035 would then be 16: 14 existing reactors and two new reactors. In this case, a total of 99 TWh of nuclear energy would be supplied, accounting for about 11% of total electricity production. This scenario is extremely difficult to achieve, however. No nuclear reactors anywhere in the world have ever been in operation for more than 60 years. In addition, although this estimate assumes a capacity factor of 70%, existing nuclear power plants are not immune to the effects of aging, so their capacity factor is likely to decline as problems become more frequent over time. And in any case, half (seven) of the 14 existing reactors will cease operation by 2038.

Fig. 5-3 Projected nuclear power generation in 2035



Note) Status quo: Reactors that have been restarted (excluding those with a pending application for operating life extension) and reactors with a confirmed (scheduled) restart date. Maximum/difficult to achieve: Reactors that have been restarted (including those with a pending application for operating life extension), reactors approved for restart or with a pending application for restart (excluding those whose allowed operating life has expired), including Shimane-3 and Oama, which are under construction.

Source) Created by REI

It is clear from the above discussion that nuclear power generation, which the government is advocating to play a major role in delivering a stable supply of electricity and combating climate change, will in reality be unable to play a signficant part in either supplying electricity or in reducing carbon emissions in 2035. As described in the section "Comparing the costs of decarbonized power sources" at the end of this report, new nuclear reactors are massively expensive, so from an economic standpoint alone, they do not offer a rational choice.

3. Fossil fuel power generation

Current state of development and plans for new construction

To limit the increase in global mean temperature since industrialization to 1.5°C, in line with the Paris Agreement, it is necessary to phase out the use of fossil fuels for power generation as soon as possible. However, fossil fuels still account for the majority of Japan's electricity supply.

As of the end of FY2021, the biggest contributions to Japan's fossil fuel-generated power were 50.4 GW from coal-fired plants, 79.1 GW from natural gas-fired plants, and 22.7 GW from oil-fired plants. In terms of share, coal-fired power accounted for 31%, natural gas-fired power for 34.4%, and oil and waste-fired power for 7.4% of total electric power production, with fossil fuels collectively accounting for 72.8% of total electricity in FY2021.

Coal-fired power

The phase-out of coal-fired power generation, which is responsible for more CO_2 emissions than any other kind of fossil fuel-fired power generation, as soon as possible is one of the most urgent challenges for climate change and energy policy. This is explicitly stated in the IEA's "Net Zero by 2050" report. The 1.5°C scenario of the Paris Agreement also requires developed countries to totally phase out coal-fired power generation by 2030.

In accordance with the scientific findings of these decarbonization scenarios of the IEA, IPCC, and other bodies, more than three-quarters of all the coal-fired power plants in OECD countries and Europe are already scheduled for closure by 2030. In the UK, carbon pricing has driven a dramatic reduction in coal-fired power production, from 38% of annual electricity in 2012 to just 2% in 2019.

In line with these scientific findings and trends in OECD countries, this report also assumes that coal-fired power generation will be totally phased out by FY2030. However, on top of the fact that coal still acounts for a large slice of Japan's electricity, there are also plans to construct 2.3 GW worth of new coal-fired power facilities. In February 2023, Kobe Steel started operation of a 650 MW coal-fired power plant, a move that runs counter to the logic of battling climate change. Furthermore, the government remains committed to the continued use of coal-fired power generation, combining it with ammonia co-firing and CCS. As pointed out in Chapter 1 and described in the section "Comparing the costs of decarbonized power sources" at the end of this report, trying to reduce emissions from thermal power generation using these methods is neither feasible nor cost-effective. The incompatibility of such attempts with the decarbonization goals of the Paris Agreement has been clearly and repeatedly demonstrated in previous reports and presentations by REI. All coal-fired power generation need to be shut down by 2030, not 2035.

Natural gas-fired thermal power

Although natural gas is a type of fossil fuel, natural gas-fired power generation emits less CO_2 than other types of thermal power generation. By simply increasing the capacity factor of natural gas-fired power plants to replace coal-fired power generation capacity, the CO2 emissions from that amount of coal-fired power generation can be halved. Natural gas-fired power is also superior to nuclear in the sense that its power output can be flexibly adjusted, making it useful when combined with variable renewable power sources. Since it will be necessary to achieve 100% renewable energy as soon as possible after 2035, natural gas-fired power will need to be phased out. Until then, however, gas-fired power can be used to supply the power requirements that cannot be met by renewables. From this perspective, we examined whether it would be possible to meet the electricity demand that cannot be satisfied by renewables in 2035 using only existing natural gas-fired power plants.

Assuming that the 79 GW or so of existing natural gas power capacity in 2022 will be shut down after 40 years of operation, and that the 2.3 GW of new facilities that are planned but not yet built will never be built, there will be approximately 58 GW of natural gas-fired power generation capacity in 2035. If we suppose that these facilities operate at 70% capacity, they will be able to supply 356 TWh of electricity. This is equivalent to approximately 40.0% of the electricity demand estimated earlier. Therefore, even if all coal and oil-fired power plants are phased out and no new natural gas-fired power plants are built, it should still be possible to supply all the power needed in 2035 using only existing natural gas-fired power plants and renewable energy.

Section 3 The shape of the 2035 electricity mix toward decarbonization

Table 5-5 shows the decarbonized electricity mix that needs to be established by 2035 and that can be achieved through necessary institutional reforms, based on our examination of electricity demand, renewable energy sources, nuclear power, and fossil fuel power generation in 2035.

Table 5-5 Decarbonized electricity mix in 2035

Type of power source		Total electricity (TWh)	Share (%)
Renewable energy	Solar PV	343.7	38.6
	Wind	174.0	19.6
	Bioenergy	85.7	9.6
	Hydro	99.6	11.2
	Geothermal	11.5	1.3
	Subtotal	714.5	80.3
Fossil fuels	Natural gas	175.5	19.7
Total		890.0	100.0

Source) Created by REI

Renewable energy sources, principally solar and wind power, will supply 714.5 TWh, or 80.3% of the 890 TWh of electricity that is expected to be generated in 2035 (adding supply losses to the electricity demand estimated in Section 1). The remaining 175.5 TWh will be supplied by natural gas-fired power.

To maximize CO_2 emission reductions, it is assumed that coal-fired power generation will not be used at all. Although nuclear power generation has the potential to supply up to 11% of electricity demand in 2035, we assume that it will not be used, for a variety of reasons: because it is difficult to realize such amoung to electricity production by nuclear power plants in practice, because it would not be possible to keep nuclear power plants in beyond 2035 even if they were realized, and because nuclear cannot be considered a sustainable power source since no final disposal site for radioactive waste has yet been secured.

By achieving this decarbonized electricity mix, it will be possible to reduce CO_2 emissions from the power generation sector by 73.2%. Furthermore, compared to current levels, the quantity of fossil fuels required for thermal power generation will be substantially reduced, resulting in a massive saving in fuel costs for power generation, from 5.368 trillion yen in FY2021 to just 1.159 trillion yen, a saving of 4.209 trillion yen. Although natural gas imports will continue, the quantity of electricity generated using natural gas will drop by half, from 355.5 TWh in FY2021 to 175.5 TWh, thereby greatly reducing the degree to which power costs are affected by the volatility of fossil fuel prices. Excluding imports of biomass fuels, approximately 80% of electricity will come from domestic renewable energy resources. This will help to both increase energy self-sufficiency and enhance energy security.

Chapter 6 Proposals for 2035 decarbonization pathway electricity mix

In the previous chapters, we showed that Japan has the potential to increase the share of renewables in its electricity supply mix to about 80% by 2035. In this chapter, we present some of the challenges that need to be tackeld to achieve a decarbonized electricity mix by taking advantage of Japan's abundant renewable energy potential and relying on the vitality of companies, local governments, and communities. We also propose some approaches to these challenges. The seven main pillars of this effort are listed below.

Seven pillars for achieving a decarbonized electricity mix

Pillar 1 Promptly revise the Strategic Energy Plan and set the 2035 renewable electricity target to at least 80%

The IPCC's AR6 Synthesis Report, released on March 20, 2023, expresses with unprecedented directness that the opportunity to achieve the 1.5°C warming target is gradually slipping away.

"Climate change is a threat to human wellbeing and the health of the planet, and any further delay in concerted global action will miss a brief and rapidly closing window to secure a liveable future."

To take advantage of the remaining potential to achieve the 1.5 degree goal, the IPCC also calls for a 48% reduction in global CO_2 emissions by 2030 and a 65% reduction by 2035 relative to the 2019 level. There is little time left. In its current report, the IPCC emphasizes that "the choices and actions implemented in this decade will have impacts now and for thousands of years."

Since the 48% and 65% reduction goals are for the world as a whole, developed countries will be required to achieve even greater reductions. For the electric power sector, where emission reductions are most urgently needed, the U.S., the UK, and Canada (all G7 nations) have voluntarily committed to decarbonizing all their power sources by 2035. Germany has also made a strong commitment to total power decarbonization by moving forward its deadline for the total phase-out of coal-fired power from 2038 to 2030. Meanwhile, France has already produced 88% of its electricity from renewables and nuclear power as of 2022. Italy has set a renewables target of 70-72% by 2030, and is likely to boost this further by 2035. Looking at the 2030 and 2035 targets of other G7 member countries makes Japan's 2030 target of 36 to 38% look remarkably low.

When the government is pressed to raise emission reduction targets in the power sector, it is easy to predict that it will respond by promoting greater use of nuclear power, or else by moving to increase the share of ammonia-coal co-firing power and other forms of thermal power with CCS. However, as already explained, neither of these approaches can viably deliver significant quantities of power by 2035. Furthermore, both nuclear power and "zero-emission thermal power" are expensive to generate. As shown in "Comparing the costs of decarbonized power sources" at the end of this report, these are far from being economically rational choices.

If we are serious about acahieving power source decarbonization by 2035, the only realistic option is to dramatically expand the supply of electricity from renewables. Based on the recommendations of the IPCC, the targets set by other developed countries, and the supply potential of solar, wind, and other energy sources examined in this report, at least 80% of Japan's electricity in 2035 needs to come from renewables.

As a first step toward this goal, the current Strategic Energy Plan needs to be promptly revised, to make a renewable electricity target of at least 80% by 2035 the cornerstone of national energy policy. The countries of the world are required to submit their National Determined Contributions (NDCs) for 2035 by 2025. It is essential to revise the Strategic Energy Plan in time for this.

Along with a renewables deployment target of at least 80%, it is necessary to specify goals and a roadmap for achieving the desired installed capacity for each power source. A roadmap indicating the capacity (GW) of solar PV and onshore/offshore wind power will be installed each year from now until 2035 will make investment more predictable. Setting ambitious targets and presenting a roadmap will faciltate the formation of supply chains for solar PV and wind power, thereby accelerating development and reducing costs. The deployment of renewable energy will accelerate not only in developed countries, but also in China, India, and other emerging economies, as well as in developing countries. If Japan remains the only country with a low target, Japan will find itself unable to attract essential investment or to establish domestic supply chains.

Until the Great East Japan Earthquake and the Fukushima Daiichi Nuclear incident of 2011, the government did little to promote the adoption of renewable energy. Although the government introduced a feed-in tariff (FIT) scheme in 2012, in its 2014 Strategic Energy Plan, the first revision after the disaster, it set the 2030 renewable energy goal to the low level of 22%–24%, which remained unchanged in the 2018 revision of the plan. Under this low renewables target, efforts to deploy offshore wind power have been slow. Neither have there been any significant measures to promote the installation of solar power in buildings. As a resultsof these halfhearted government policies, Japan has fallen far behind Europe, China, and other countries in the deployment of renewable energy. This mistake must not be repeated when it comes to planning for 2035.

Pillar 2 Implement regulatory reforms to significantly accelerate deployment of wind and solar power

In addition to setting higher renewable energy targets in the Strategic Energy Plan and presenting a roadmap for deployment, there is also a need for regulatory reform to significantly accelerate the development of wind and solar power projects, which are fundamental to Japan’s energy and emission reduction strategy.

Challenges in accelerating wind power deployment

Solar power and wind power are the two main forces driving the expansion of renewable energy worldwide. Japan’s fatal weakness has been the very small magnitude and slow pace of its wind power deployment. Offshore wind power development has finally begun, but the level of development is still an order of magnitude smaller than in the pacesetting regions of Europe, the U.S., and China. We therefore believe that the most important challenge for decarbonizing Japan’s power supply by 2035 is to institute regulatory reforms to significantly accelerate wind power development and cut project development time by half. To achieve approximately 60 GW of installed capcity by 2035, as discussed in Chapter 3, it is essential to speed up the project approval process, from planning to operation. It is particularly vital to improve the development environment by expanding the scale of offshore wind projects and accelerating their development adopting the “cnetral method.” At the same time, it is important that wind power projects can coexist harmoniously with local communities. Dialogue and coordination with stakeholders in the areas of land and sea where projects are sited need to be addressed from an early stage within a framework in which the government plays a leading role. (On top of this, power grid development is also urgently needed, as discussed in Pillar 4).

Speeding up the approval process

Even countries that are leaders in deployment of wind power are working on regulatory reforms to accelerate project development. The UK, for example, has pushed a variety of measures aimed at halving the development time of offshore wind power projects, which is currently about 13 years, while the EU has started setting up a system to shorten the approval period (see Box below).

The development process for wind power involves a variety of approvals. If the lengthy procedures for obtaining approvals are not improved, the rate of development cannot be increased. At the same time, an increase in the speed of development is likely to increase the predictability of projects, reduce risk, increase investment by developers, and to get more capacity installed sooner.

Speeding up the environmental assessment process*

Improving the process of establish consensus with local communities*

Challenges to accelerating the deployment of solar PV power*

Given that the quantity of installed capacity as of the end of FY2021 was 79 GW, to achieve our estimated target of 280 GW by 2035, an average of 14.4 GW of capacity per year will need to be added over the 14 years from 2022 to 2035. Although annual installed solar PV capacity has recently dropped to about 7 GW, since the introduction of the FIT scheme, a peak of 13.2 GW was added in FY 2014. The cost of solar PV power has fallen significantly since that time, with futher reductions expected in the years leading up to 2035. Furthermore, most of the capacity to be installed through to 2035 will be in the form of relatively small-scale projects with short construction periods, such as PV systems on building rooftops and farmland. It is therefore possible to increase the pace of development through more productive planning, design, and construction. On the other hand, supply chains for equipment such as PV modules and power conditioners may become bottleneck. For this reason, Japan should set out to enhance domestic production and decentralize and diversify production systems as soon as possible.

To make the most of the potential described above and achieve the target of 280 GW in 2035, or perphaps aim at even higher levels, the following policies and systems will be particulalry needed.

Making the installation of solar PV systems in new buildings mandatory

To ensure accelerated deployment by 2035, it is necessary to implement national measures to make the installation of PV systems compulsory, like the pioneering mandatory requirement imposed on homebuilders by the Tokyo Metropolitan Government and Kawasaki City. At the national level, mandatory installation of solar PV systems was on the agenda for a time during discussions about the Act on the Improvement of Energy Consumption Performance of Buildings, revised in June 2022. However, the idea was pushed aside without being seriously considered. The national government should learn from the innovative schemes adopted by local governments and promote similar measures nationally. It is also essential to reconsider instituting a law that makes installation of solar PV systems mandatory.

Taking the initiative to promote the intallation of lightweight PV systems on public buildings*

Resolving local grid connection issues*

Instituting regulatory reform on land use*

Pillar 3 Reform the electric power system focusing on separation of ownership

The other challenge essential for accelerating the development of renewables and achieving a decarbonized electricity mix is to reform the electric power system. REI has pointed out the need for power system reform repeatedly over the years, stressing concerns about fair access to and upgrading of transmission networks, market trading according to merit order, and wide-area supply-demand balancing. Making these reforms is an essential condition for making renewables a mainstay source of electric power, but the efforts to date have been inadquate. This lack of reform is probably the main reason for the slow pace of solar and wind power deployment in

The dysfunction of electricity system reform

Since last year, a series of scandals associated with system reform involving leading electric power companies have been exposed. There have been allegations of cartels, leaking and unauthorized viewing of the customer information of new electric power companies, and unauthorized viewing of the Ministry of Economy, Trade and Industry’s renewable energy management system. If true, these behaviors would constitute violations of the Anti Monopoly Act and the Electricity Business Act. These scandals are of serious concern, because they undermine confidence in the basic assumptions of a fair and competitive business environment, including the neutrality of power transmission and distribution. As former monopolies, the major electric power companies still enjoy overwhelming market dominance, effectively maintaining their monopolies over power transmission and distribution networks. If they engage in illegal conduct in concert, any electric power system reforms will inevitably be dysfunctional. Unfortunately, it appears that REI was correct in pointing out that reform efforts have been inadequate.

Without neutrality in the transmission and distribution business, it will be difficult for renewable power producers (many of which are new players in the market) to access power grids. It is highly likely that similar factors have played a role in the heavy burden of grid connection, the fact that power output control in Kyushu and other regions is nowhere near as rational as in Europe, and the delay in upgrading transmission and distribution networks. Furthermore, unauthorized viewing and cartel behavior may have led to the unfair exclusion of new power companies. It cannot be denied that the relatively positive trade in renewable energy power by new power companies may have been impeded.

From legal separation to ownership separation

It is now time to reform the electric power system comprehensively from scratch. Now that it is clear that legal separation of the power transmission and distribution businesses has been ineffective, it is necessary to separate their ownership. From the start, legal separation was an inadequate measure from the viewpoint of competition policy, but it was adopted as a compromise solution in combination with strict regulation of conduct. It is now urgently necessary to give priority of transmission and supply to renewable energy, to rationally balance supply and demand over wide areas, and to upgrade transmission networks, under a system of independently owned transmission and distribution businesses.

It is also necessary to separate the power generation and sales divisions of the major electric power companies, to ensure thoroughly non-discriminatory wholesale trading (fair treatment of external wholesales boies by the elecric power comapnies), and to require mandatory participation in the spot market. But the problems have not been limited to the transmission and distribution subsidiaries. There has also been a lack of responsibility for legal compliance in retail and planning divisions. The big electric power companies have not been able to break free from the mindset of a legal monopoly and vertical integration. So, it is not enough just to maintain the neutrality of power transmission and distribution; there is also a need for rigorous policies to ensure competition.

Reviewing the Electricity and Gas Market Surveillance Commission

Pillar 4 Upgrade power grids for decarbonization through renewables

Variable renewables such as solar PV and wind power will play a central role in the decarbonized electricity mix. With the decarbonized electricity mix, approximately 518 TWh of the 890 TWh of electricity generated in 2035 will come from solar PV and wind, a share of approximately 58% of total electricty. Following this report, REI plans to examine the ideal power grid necessary for maintaining a stable power supply with this projected power source mix, featuring a 58% share of variable renewables. We will also make some essential policy recommendations.

Study by the “Power Grid Study Group for decarbonization through Renewable Energy”

In parallel with its study of the power supply mix in 2035, REI has established a study group of academic and other experts to examine the level of transmission capacity needed to achieve decarbonization through renewables. It has also published a report (hereafter “Transmission Network Report”) based on the discussions of the group. According to the results of this study, to achieve a decarbonized electricity mix in which 80% of electricity is supplied by renewables, it is necessary to begin upgrading power transmission networks immediately, as shown below.

In our transmission network report, we examined a scenario released in March 2023 by the Organization for Cross-regional Coordination of Transmission Operators, Japan (OCCTO) that is modeled on the Long-term Policy for Wide-Area Grid Systems (Master Plan for Wide-Area Interconnection Systems). This OCCTO Master Plan Replication Scenarios assumes the deployment of 260 GW of solar PV power, 41 GW of onshore wind power, and 45 GW of offshore wind power. Except for offshore wind power, these assumptions are similar to those of the current decarbonized electricity mix (280 GW of solar PV, 34 GW of onshore wind, and 25 GW of offshore wind).

In the transmission network report, demand and supply are allocated to each transmission system operator (TSO) area based on reference to the quantities specified in September 2022 in the Master Plan for Wide-Area Interconnection Systems, with hourly demand set for 8,760 hours per year. We then analyzed whether the supply of renewable power satisfies the demand by performing a supply and demand simulation. In contrast, to examine the scale of power transmission lines considered necessary to achieve the decarbonized electricity mix in 2035, we conducted a simplified estimate of the capacity deployed in specific areas and compared our results with those of the analysis conducted in the Transmission Network Report (our assumptions for installed capacity in specific areas and comparison with the allocations in the OCCTO Master Plan Replication Scenarios are shown in the Appendix at the end of this report). Although there are some differences, such as the quantities of installed solar PV capacity in the Kansai TSO area, in general there is very little difference between the decarbonized electricity mix and the OCCTO Master Plan Replication Scenarios in terms of the PV capacity installed in each TSO area. On the other hand, the total quantity of wind power installed in each TSO area differs, since the total wind power capacity installed in Japan differs by about 26 GW between the two scenarios. Most notably, the Hokkaido TSO area is assumed to have 6.7 GW of wind power in the decarbonized electricity mix, which is only about half as much in in the OCCTO Master Plan Replication Scenarios (11.8 GW). This difference is expected to be reflected in the difference in transmission line capacity needed in 2035.

With regard to the transmission capacity between Hokkaido and Tohoku TSOs specifically, the base scenario of the Master Plan for Wide-Area Interconnection Systems suggests that an increase in 6 GW of capacity between Hokkaido and Tohoku TSO areas and of 8 GW between Tohoku and Tokyo TSO areas would be effective from a cost-benefit viewpoint. Considering the difference in the wind power capacity that is likely to be installed in the Hokkaido area, an increase of around 4 GW between Hokkaido and Tohoku TSO areas would probably be appropriate for achieving the projected decarbonized electricity mix. On the other hand, it may be necessary to increase the transmission capacity between Tohoku and Tokyo TSOs by about 8 GW, based on the fact that the analyses of the Master Plan for Wide-Area Interconnection Systems and the decarbonized power mix anticipate approximately the same magnitude of solar and wind power capacity for the Tohoku TSO area. However, since the demand assumed in the decarbonized electricity mix is approximately 70% of that in the master plan, the ideal scale of capacity expansion should be carefully discussed after conducting a another simulation analysis using an electricity supply-demand model.

The ideal transmission network for an 100% renewables scenario

Aside from the OCCTO Master Plan Replication Scenarios, based on the Master Plan for Wide-Area Interconnection Systems, our transmission network report also proposes a “100% renewable energy scenario” that aims at supplying all electric power demand with renewable energy, with analyis of the extent to which renewable energy can meet the power demand of different areas subject to exogenous factors. In this case, the electricity demand for the Hokkaido-Tokyo TSO is calculated as follows. In this case, it was concluded that at least 12 GW of additional transmission line capacity would be required between Hokkaido and Tokyo TSO areas. In other words, achieving carbon neutrality in Japan through renewables requires a bigger upgrade in transmission network capacity than indicated in the Master Plan for Wide-Area Interconnection Systems.

Starting the power grid upgrade for 2035 immediately

To implement the Master Plan for Wide-Area Interconnection Systems, the Wide Area Network Development Committee is already studying the expansion of a single-route 2GW line between the Hokkaido and Tokyo TSO areas. Based on this simple study, it is thought that an upgrade of about 4 GW network capacity will be required to utilize the abundant natural energy resources of the Hokkaido and Tohoku regions for achieving an 80% share of renewable power by 2035. To achieve 100% renewable energy by 2050, it would probably be necessary to expand the power transmission network even further, to a scale larger than estimated in the Master Plan for Wide-Area Interconnection Systems. Since it will take a long time to build such a transmission network, it is vital to reach a consensus on the energy mix needed to enable Japan to achieve carbon neutrality in its electricity sector, with goals for 2035 as well as 2050, so that systematic work on developing the network can begin as soon as possible.

Pillar 5 Promptly introduce carbon pricing to attract global decarbonization investment to Japan

One of the most basic tools for achieving a decarbonized electricity mix and significant emission reductions from the use of other forms of energy by 2030 and 2035 is effective carbon pricing.

GX-ETS deviates from global standards

One of the special features of the GX Basic Policy is that it provides for the introduction of an emissions trading scheme, GX-ETS. However, GX-ETS is a purely voluntary scheme, in which companies are free to particpate or not participate, as they wish. In a document it submitted to a working group studying GX-ETS, the Ministry of Economy, Trade and Industry (METI) itself pointed out problems with the scheme, stating that voluntary participation could lead to disparities in burdens between non-participating and participating companies, and that doubts could arise about fairness among participating companies. The transition to mandatory participation and the start of paid auctions of emission quotas will begin in 10 years, in 2033, but participation will be limited to power producers. The GX Basic Policy also states that in addition to emissions trading, a carbon levy will be imposed on fossil fuel importers from 2028. Although this is another kind of carbon pricing, even when combined with the above-mentioned paid auctions, the price of carbon is expected to remain low, at about ¥1,500 per ton. The IEA has set the carbon price required of developed countries at $130 per ton in 2030, so the carbon price under the GX Basic Policy is likely to be some 10 times less than this, a strikingly low level.

Issues with GX economic transition bonds

After the U.S. passed the Inflation Reduction Act, Europe issued its Net Zero Industry Act proposal, reflecting a growing movement to seize policy opportunities. The GX Basic Policy calls for more than ¥150 trillion in public and private investment over the next 10 years, with plans to issue ¥20 trillion in “GX transition bonds” to drive investment. Among the intended uses of the GX transition bonds, the government includes plans to support the expansion of hydrogen and ammonia demand. It is especially problematic here that the government plans to allow the use of gray hydrogen and gray ammonia, at least for the time being. This means that even if ammonia is produced from fossil fuels overseas without any CCS and used for co-firing in Japanese coal-fired power plants (i.e., even if it does nothing to reduce global CO_2 emissions), it can still be financed using GX transition bonds.

It is hard to imagine that global or Japanese investors will purchase GX transition bonds under this uniquely Japanese standard. This is because many of Japan’s (three) megabanks, major life insurance companies, and asset management companies have committed to “net zero” under international standards, including Scope 3 emissions accounting for their investments and loans. Under international standards, the use of gray hydrogen and gray ammonia mentioned earlier would fall under Scope 3 Category 3 (fuel and energy-related activities not included in Scope 1 or 2) emissions of the consuming company, which would run counter to net zero. In other words, investing in the production of gray energy, even if its use is currently permitted by the Japanese government, would increase the quantity of emissions of the investment or loan recipients of a financial institution committed to net zero. Since they do not allow net zero commitments to be met, such technologies are unlikely to attract investments.

Promptly adopting global standard carbon pricing capable of attracting global decarbonization investment

The Japanese government has been considering the introduction of an emissions trading scheme (ETS) for over 20 years, since 2000. At a time when substantial emission reductions are required to respond to the recommendations of IPCC, the carbon pricing concept and GX transition bonds proposed in the GX Basic Policy cannot be considered serious measures for addressing the climate crisis.

For global transition investments in excess of $4 to $5 trillion per year to be directed to Japanese technologies, an effective carbon price that enables bold investments in emission reduction initiatives must be established. This can only be done by putting in place global standard carbon pricing as soon as possible. Emissions trading should be mandatory and not permit the use of offsets by means of voluntary credits from non-ETS participants. As commonly advocated in the recommendations of the High-level Expert Group on the Net-zero Emissions Commitments of Non-State Entities, the Race to Zero requirements of the UNFCCC, and the Science Based Targets initiative (SBTi), reductions under the 1.5°C pathway should be made through expenditures that directly lead to the results. public works expenditures. Voluntary credits should be treated separately from the framework to meet the emission reduction goals under ETS. Instead, they should be actively encouraged as financial contribution by developed countries to developing countries.

GX transition bonds should be directed to investments that help to create an environment that facilitates the achievement of net zero through global-standard operations in Japan. If Japan's deployment of renewable energy fails to advance and funds are allocated to technologies that do not reduce emissions under the SBTs, it will be difficult for companies that are pioneers in climate action and committed to global-standard SBT targets to continue operating in Japan. It is necessary to establish a rule so that any technologies that lead to an increase in global CO_2 emissions cannot be counted as emission reduction measures. To the extent that Japan has to compete in the global economy, it needs to follow the international rules of Race to Zero.

Pillar 6 Accelerate corporate PPAs

Japan's RE100 companies are lagging behind

According to the latest survey by RE100, an international initiative that aims at promoting the goal of 100% procurement of electricity from renewable sources by businesses, 334 reporting member companies generated, on average, 49% of their electricity from renewables in 2021 (Table 6-1). This figure is up from 41% in 2019 and 45% in 2020, corresponding to a growth rate of 4 percent points per year. Throughout the world, companies are playing an increasingly important role in the promotion of decarbonization through the use of renewable electricity. The use of renewables is vital for successful decarbonization. However, a look at the situation in the five countries in which RE100 member companies consume the greatest amount of electricity shows very large differences between countries. In the U.S., which is home to the largest number of RE100 companies, total electricity consumption exceeds 100 TWh, of which 68% is derived from renewable sources. The share in the UK is actually 99% and in Germany 85%, which are higher than in the U.S. In China, which is second only to the U.S. in terms of total electricity consumption, the renewables share is 32%. In Japan, which consumes a similar quantity of electricity to China, renewables account for only 15% of the total. This means that even the most progressive companies in Japan (i.e., RE100 members) are not able to utilize renewable energy to any substantial level.

Table 6-1 Use of renewable electricity by RE100 member companies (based on reports by 334 companies for 2021)

Country	No. of RE100 companies (with head office in country)	No. of RE100 companies (doing business in country)	Total electricity consumption (TWh)	Share of renewable energy
U.S.	94	221	105	68%
UK	46	183	12	99%
Germany	15	165	12	85%
China	6	211	30	32%
Japan	66	173	28	15%
World total	227	334	376	49%

Source) Created by REI based on data from "RE100 2022 Annual Disclosure Report" (January 2023): https://www.there100.org/our-work/press/companies-increasing-consumption

There are two main factors behind this state of affairs. Firstly, renewable energy accounts for only a small proportion of Japan's total power production. According to International Energy Agency (IEA) statistics, the renewables share in 2021 in the UK and Germany was 42%, in China 29%, in Japan 22%, and in the U.S. 21%. (According to Agency for Natural Resources and Energy statistics, Japan's share was 20.3% in FY2021.) Although the share of the U.S. is just as low as Japan's, RE100 companies in the U.S. are able to procure large quantity of electricity from renewable energy sources. This is due to the growing use of corporate Power Purchase Agreements (PPAs), in which companies directly purchase their own renewable electricity under long-term contracts. Japan lags behind in the use of PPAs. This is the second factor behind the low share of renewable power use by RE100 companies in Japan.

Accelerating the use of corporate PPAs

According to the results of a worldwide survey by Bloomberg NEF on corporate PPAs, a total of 20.4 GW worth of corporate PPAs were concluded in 2021 in North and South America, mostly in the U.S. Furthermore, in 2022, a total of 24.1 GW worth of PPAs were concluded, a significant rise over the previous year (not including on-site PPAs covering power generation facilities constructed on the company's premises). In Europe, the Middle East, and Africa, corporate PPAs in 2022 totaled 8.1 GW, while in the Asia Pacific region they more than doubled from the previous year to 4.6 GW, with the bulk of agreements in India and Australia. In Japan, after government subsidies for corporate PPAs were initiated in FY2021, 70 agreements had been concluded by the end of 2022 (excluding on-site PPAs). Still, the size of agreements tends to be much smaller than in other countries, averaging just a few MW. In total, corporate PPAs in Japan account for less than 1% of total worldwide contracted capacity (36.7 MW in 2022). To dramatically increase the value of agreements in the future, it is necessary to institute support measures that are applicable to a wider range of companies, as opposed to subsidies for specific projects.

To help companies promote decarbonization, considerable importance is being placed on "additionality," in the sense of constructing (adding) new renewable power generation facilities. This is due to the obvious benefits of cutting CO_2 emissions by replacing thermal power facilities. The fact is that purchasing electricity from existing renewable power facilities does not change national or global CO_2 emissions. Increasingly, companies that use electricity are being required to expand new renewable power facilities through corporate PPAs and in-house power generation. It would therefore be effective to put in place policies that offer incentives for the deployment of such "additional" renewable electricity capacity.

Pillar 7 Increase the obligations and powers of municipalities in renewable energy development

A new era of municipal energy policy*

New obligations of municipalities in electricity supply

Climate change is not a problem of the future; it is an ongoing crisis that is evident here and now. The most fundamental obligation of local governments is to protect the safety, lives, and property of their residents. Given that the climate crisis is threatening these things, the responsibility of cutting greenhouse gas emissions should lie with local governments as well as the national government. It follows, therefore, that local governments should also bear some responsibility for expanding renewable energy capacity, which along with increasing energy efficiency is the most important means for reducing emissions.

Solar PV systems installed on the rooftops of homes and other buildings can also enable the use of electricity when power supply grids are disrupted due to disasters, thereby enhancing local resilience. Thus, they offer great value as a way of tackling the climate crisis.

There is a shift going on in the supply of electricity. We are moving from an era in which most electricity was generated in large fossil fuel-fired thermal power plants and nuclear power plants to an era in which most electricity will come from inexpensive renewable energy sources that are dispersed throughout local communities. This shift opens up the opportunity for local governments to play a much bigger role in supplying electricity.

In an era when accelerated development of renewable energy is needed to protect human life and safety from the threats of the climate crisis, local governments are increasingly expected to promote the development of renewable energy in environmentally harmonious ways, in addition to restricting environmentally insensitive development. Many of the solar PV power projects that will be developed in the years ahead will make use of building rooftops, as well as abandoned farmland, which means the land that has already been developed (therefore no need to cut down forests or clear natural fields). Offshore wind power, which is likely to be the main focus of wind power development in the near future, will be able to coexist with local fishing industries due to its minimal impact on the natural environment. Since it is fully possible to develop renewable energy in harmony with local communities, local governments have a responsibility to promote this type of development.

The clearest indication that local governments are entering into a new era of energy policy is that the Tokyo Metropolitan Government in December 2022 and Kawasaki City in March 2023 enacted ordinances making it mandatory for homebuilders to install solar PV power systems in all the new homes they build. The efforts of these two municipal governments are a good example of the role that local governments need to play in response to the climate and energy crises. At the same time, these movements show that, with the declining cost of solar PV power, these kinds of pioneering initiatives can now be introduced as systems that offer economic benefits.

Germany, the most aggressive G7 country in terms of expanding renewable energy, instituted the Act to Increase and Accelerate the Expansion of Onshore Wind Energy Installations (commonly known as the Onshore Wind Energy Act (Wind-an-Land-Gesetz: “WaLG”) in 2022, with the aim of accelerating onshore wind power generation. The core of the Onshore Wind Energy Act, the “Wind Energy Area Act (“WindBG”) imposes binding targets (so-called “area contribution values”) on each state of the country, effectively allocating 2% of Germany’s total land area to onshore wind power generation.

The relationship between the central government and local governments differs from country to country, and the German case cannot be mechanically applied to Japan. However, given the urgent need for measures to avert a climate crisis, it is essential to discuss the obligations and systems necessary for enabling local governments to play a more active role in renewable energy development, with a readiness to go beyond the usual constraints.

Increasing the power of local governments*

Conclusion

Our report, “Proposal for the 2035 Energy Mix (First Edition),” advises that at least 80% of Japan’s electricity supply in 2035 be generated from renewables, outling both the possibilities and challenges of achieving this goal. To achieve this goal of 80% renewable energy, it is vital to increase the amount of solar PV capacity by 3.5 times and wind power capacity by 13 times. We also showed that the capacity of the wide-area power grid connecting Hokkaido and Honshu may need to be expanded to about 4 GW, though this is only a tentative initial estimate.

These goals go far beyond the 2030 targets enshrined in the government’s current Strategic Energy Plan. From a conventional Japanese perspective, these goals may seem unrealistic. However, as discussed in this report, the electricity supply mix that REI is proposing for 2035 is very much in line with what other G7 countries are aiming for. From an international perspective, therefore, it is an absolutely unexceptional proposal.

More importantly, in light of the IPCC’s goal of reducing CO_2 emissions by 65% relative to the 2019 level by 2035 (as stated in its AR6 Synthesis Report), this proposal is the minimum that Japan must aim for. Japan’s current greenhouse gas emissions reduction target is 46% below the 2013 level by 2030. The IPCC’s recommendation for 2030 is a 60% reduction relative to 2019, which corresponds to a 66% reduction relative to 2013. Accordingly, if the current 2030 target is maintained, a further 20% reduction will be required over the five years from 2030 to 2035. The IPCC’s recommended 2035 target indicates that Japan needs to step up the pace of its emission reduction efforts before 2030. In the case of electricity, the target share for the deployment of renewables needs to be much higher than the current 36–38%.

The goal of achieving 80% renewable electricity by 2035 is not an easy challenge, but neither is it an impossible one. If 80% of Japan’s electricity can be supplied from domestic renewable energy sources, the country’s dependence on fossil fuels would be greatly reduced. Furthermore, if large numbers of Japanese homes and buildings were equipped with solar PV power systems, people could have access to electricity even when grid power is cut off in the event of a disaster, greatly enhancing resilience. And the deployment of offshore wind power generation can also contribute to the revitalization of local economies.

What we need now is to make a clean break from the stereotype that Japan must forever remain dependent on fossil fuels and nuclear power. Japan needs to step forward and embrace the transformation to a new energy system that is compatible with the new, decarbonized and sustainable world that is emerging, in which the bulk of electric power and energy is generated from domestically produced renewable energy sources.

In contrast to the backwardness of the national government, many companies and local governments in Japan have already begun to openly express their intention to secure the majority of their electricity from renewables by 2035. REI is committed to working exhaustively with many of these non-state actors to help transform Japan’s national energy policy.

Proposal for the 2035 Energy Mix (First Edition)

Toward Decarbonizing Electricity with Renewable Energy

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