Urgent Recommendations for the Revitalization of Nuclear Energy in Japan

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Study Group on Next-Generation Nuclear Energy Utilization

Contents

A. Introduction

In October 2022, the Study Group on Next-Generation Nuclear Power released interim recommendations titled "Facilitating Revitalization of Nuclear Energy in Japan" under the chairmanship of Nobuo TANAKA[1]. Since then, however, the global situation has changed dramatically, including the prolonged Russian invasion of Ukraine, instability in the Middle East, and changes in the global balance of power such as the rise of the Global South in the international community. At the same time, the rapid evolution of digital technology in information and telecommunications has led to an increase in the demand for electricity, which has had a significant impact on the energy sector[2]. Innovative digital technologies, such as artificial intelligence (AI), IoT, cloud computing, big data, biotechnology, and blockchain, are being put to practical use one after another in many related fields, transcending the boundaries of each technology and transforming not only the economy and industry but also society and daily life. Amidst these major changes, the business environment for the use of nuclear energy has also changed significantly from the past with the discharge of treated water from the Fukushima Daiichi Nuclear Power Plant and the progress of deregulation of the electric power industry.

These recommendations consider issues that had not been fully discussed at the time of the interim recommendations in 2022, such as the financing of nuclear power plant construction and expansion, include the progress of discussions in the study group since then, and also take into account changes in the trends in the use of nuclear energy in Japan and abroad during this period.

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[1] The Canon Institute for Global Studies, Interim Recommendations of "Study Group on Next-Generation Nuclear Energy Utilization," "Facilitating Revitalization of Nuclear Energy in Japan," October 2022, https://cigs.canon/uploads/2022/11/To_Revive_Japan%27s_Nuclear_Power_Plant_Yoshikawa_202210.pdf (Japanese), last viewed on February 20, 2025

[2] Agency for Natural Resources and Energy, "Situation Surrounding Energy," May 2024, https://www.enecho.meti.go.jp/committee/council/basic_policy_subcommittee/2024/055/055_004.pdf (Japanese), last viewed on February 20,2025

As with the interim recommendations, these recommendations are basically intended for those who are involved in nuclear energy policy in the government, the Diet, etc. At the same time, we express our opinions through these recommendations to the Japanese public to stimulate discussion on the use of nuclear energy at the grassroots level in Japan and to help more people understand and take an interest in issues related to nuclear energy.

The reason for presenting the urgent recommendations at this time is based on the recognition that this may be the last chance to examine how to address the issues concerning the use of nuclear energy as an important national policy. In other words, looking around the world, amid the trend toward decarbonization and the changes described above, we find that the necessity and importance of the use of nuclear power are once again being strongly recognized[3], and that there are concrete moves toward nuclear power plant construction and expansion not only in China and India, but also in some developed countries. Also in Japan, the Cabinet has approved the Basic Policy for the Realization of GX[4], which calls for the maximum utilization of nuclear power generation, and the development of the business environment is being discussed. The Seventh Strategic Energy Plan[5] has also been released, reaffirming the importance of nuclear power for the future. In reality, however, there is a raft of challenges for the future use of nuclear power that cannot be easily overcome, as evidenced by the fact that not only nuclear power plant construction and expansion but also the completion of the nuclear fuel cycle are not in sight. In addition, it is difficult to say that the medium- to long-term direction of nuclear energy policy, as well as solutions to the challenges we face, have been adequately defined.

A look back at the situation surrounding the use of nuclear energy in Japan reveals that the nuclear industry has stagnated, the supply chain has been in decline, and the nuclear workforce has been aging since the Great East Japan Earthquake in 2011, with the future remaining uncertain. In order to rebuild Japan's nuclear industry and revitalize the use of nuclear energy for sustainable growth in the future, we must now embark on specific measures with a clearly stated firm will based on a long-term strategy, or it will be too late. It is precisely because of this sense of crisis that we are presenting these urgent recommendations at this time, so as not to miss our last chance.

B. Analysis

1. Global Situation Surrounding Decarbonization and Energy

(1) Overview

Russia's invasion of Ukraine as well as the Middle East being in an increasingly tense situation have made global energy supplies, especially oil and natural gas supplies, even more uncertain. As a result, the importance of energy security in energy policy has been reaffirmed in many countries. In addition, the global decarbonization trend is taking root,

[3] IEA, "The Path to a New Era for Nuclear Energy," January 2025

[4] Agency for Natural Resources and Energy, "Basic Policy for the Realization of GX—A roadmap for the next 10 years—," February 2023, https://www.meti.go.jp/press/2022/02/20230210002/20230210002_1.pdf (Japanese), last viewed on February 20, 2025

[5] Agency for Natural Resources and Energy, "Strategic Energy Plan," February 2025, https://www.enecho.meti.go.jp/category/others/basic_plan/pdf/20250218_01.pdf (Japanese), last viewed on February 20, 2025

with many countries declaring themselves carbon neutral, especially since the Paris Agreement[6]. Meanwhile, the demand for electricity is expected to increase owing to the growing importance of electricity in the energy mix and the advancement of information and communication technologies. On the back of these major global trends, nuclear power is once again gaining importance and attracting renewed attention from the two perspectives of stable power supply and decarbonization.

(2) Corporate Moves

Major global corporations are striving to reduce CO_2 emissions from their own corporate activities. Also, in an effort to reduce Scope 3 emissions, they are encouraging companies upstream and downstream in their supply chain to use clean, carbon-free electricity wherever possible, by including relevant provisions in their purchasing contracts with them[7]. A typical example of this is a group of global information and communications technology (ICT) companies called GAFA. Furthermore, since digital technologies such as AI and blockchain, which are forecast to develop further, consume large amounts of electricity in data centers, ICT companies are actively supporting the development of not only renewable energy but also nuclear power generation as a power source for such technologies. Google, for example, has announced a plan to receive power from small modular reactors (SMRs) and to operate its first SMR by 2030.

If Japan is to attract digital industries such as data centers going forward, it is necessary to secure a power source that can stably supply clean, large-capacity power into the future. Electricity demand in Japan has not fluctuated so far, but rather has tended to decline, but it will become necessary for the country to provide clean and stable power to meet the increasing demand for power from data centers and other facilities.

(3) Political Moves

In the US, Mr. Trump returned to the presidency in the presidential election. On January 20, his first day in office, he signed a series of executive orders[8], including actions to pull the US out of the Paris Climate Agreement, ignoring the Biden administration's commitment to climate change and decarbonization. However, since the review of existing rules and policies enacted under the Biden administration, such as the Inflation Reduction Act (IRA), requires congressional deliberation and are likely to be challenged in court in some cases, future developments need to be closely watched.

In Europe, the EU parliamentary elections were held last July, and right-wing parties made big gains. Some of these right-wing parties oppose the strict environmental regulations of the European Green Deal, which may affect future progress on decarbonization and policymaking in the European Commission (EC). The governments in France and Germany, which support the EU, are also facing major difficulties.

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[6] Climate Ambition Alliance, "Net Zero 2050," https://climateaction.unfccc.int/Initiatives?id=48, last viewed on February 20, 2025

[7] RE100, https://www.there100.org/, last viewed on February 20, 2025

[8] The White House, "Unleashing American Energy Executive Order," "Unleashing Alaska's Extraordinary Potential Executive Order," "Declaring A National Energy Emergency Executive Order," January 20, 2025

2. Global Situation Surrounding Nuclear Energy Use

(1) Overview

With the use of nuclear energy attracting worldwide attention, the conventional light water reactor (LWR) market is stagnant in major developed countries, mainly owing to longer construction periods and higher costs caused by tighter regulations, but construction and expansion of LWRs are being carried out steadily in the UK and France, among others. It can be said, meanwhile, that the conventional LWR market is booming in China and India[9].

As for SMRs, the US sees signs that companies consuming a large amount of energy, such as GAFA and petrochemical companies, are considering introducing SMRs for their own use, but basically, as with the conventional LWR market, the SMR market remains lackluster at present owing to the outlook for commercialization costs of the new technology and regulatory uncertainties.

Nuclear fusion, a technology that offers bright hopes for the future in the field of nuclear energy, is gaining a great deal of momentum worldwide as witnessed by promoted international cooperation and an increasing number of ventures. Successful commercialization in the future will require the establishment of a technological foundation and a clear corporate strategy, and above all, it is important that investments are made at the right time. However, it is thought to take a considerable amount of time before this technology is put to practical use.

(2) Nuclear Energy Policy in the UK

In January 2024, the UK Conservative government led by Prime Minister Rishi Sunak published a policy paper, Civil Nuclear: Roadmap to 2050[10], which was intended to address the question of how nuclear power generation can help the UK achieve net zero. The paper states that the UK will expand its nuclear power generation capacity from the current 6 GW to 24 GW by 2050, while at the same time shifting to a policy of direct disposal of the UK's spent fuel, rather than reprocessing it. Like Japan, the UK recognizes that retaining and securing nuclear technology and a nuclear workforce is a major issue, and international cooperation is needed for this purpose. In light of these constraints on human resources and other factors, the UK appears to be working to concentrate on construction and operation expansion of nuclear power facilities as a decarbonized power source by abandoning domestic reprocessing and the development of fast reactors on its own.

(3) Nuclear Energy Policy in France

France has promoted diversification of its power source mix and reduced its dependence on nuclear power since the Fukushima Daiichi Nuclear Power Plant accident. However, against the backdrop of the growing importance of low-carbon energy, energy security, and economic security due to changes in the global situation, President Macron called on February 10, 2022 for a "renaissance" for the French nuclear industry with a plan to build up to 14 new nuclear reactors in France, shifting back to an expansion of nuclear power

[9] IEA, "The Path to a New Era for Nuclear Energy," January 2025

[10] Department for Energy Security & Net Zero, "Civil Nuclear: Roadmap to 2050," January 2024

generation[11].

That being said, the environment for nuclear power business is harsh. Electricité de France (EDF), the core electric utility in the nuclear power business, is in financial difficulties with a large amount of debt, and its restructuring is an important step toward the revival of the French nuclear power industry. Meanwhile, the restructuring of the nuclear giant Areva has created Orano, which works in the nuclear fuel cycle that starts with uranium mining. The company not only undertakes reprocessing of nuclear fuel for several countries, including Japan, but also plays an important role in the international nuclear power supply chain, such as considering the construction of enrichment facilities in the US. It is expected to become an even more important base for enrichment and reprocessing from this point onward.

(4) Nuclear Energy Policy in the US

The Biden administration presented at COP29 held in November 2024 a roadmap for tripling US nuclear power generation capacity by 2050[12]. According to this roadmap, the US will increase its nuclear power generation capacity by 200 GW by the middle of this century by building new nuclear power plants, restarting existing plants, and upgrading existing facilities, with a particular goal of putting new facilities with a generation capacity of 35 GW into operation over the next decade. It is highly likely that President Trump will continue this aggressive nuclear policy, as he called for building new nuclear reactors during his election campaign. On January 10, 2025, just prior to Trump's inauguration, the Department of Energy (DOE) released "5 Nuclear Energy Stories to Watch in 2025"[13], in which it mentioned SMRs, domestic production of nuclear fuel, etc.

(5) Nuclear Energy Policy in South Korea

Scrapping the previous administration's policy of phasing out nuclear energy, the Yoon Suk Yeol administration approved in July 2022 its energy policy direction in a cabinet decision. The new policy outlines a vision to realize a next-generation energy system through decarbonization, strengthening energy security, and creating new industries in the energy sector. Among the goals set in the policy are expanding the share of nuclear power generation and reducing dependence on fossil fuel imports. The government plans to increase the share of nuclear power generation to over 30% by 2030 by increasing the number of nuclear power plants to 28 units through the resumption of construction of the Shin Hanul Nuclear Power Plant Units 3 and 4, which had been suspended, and through continued operation of existing plants on the premise that safety is ensured.

In addition, to support the export of nuclear power plants, the government has set a goal of exporting 10 units by 2030. It is also promoting the development of its own SMRs for export.

[11] Vie-publique.fr, "Déclaration de M. Emmanuel Macron, président de la République, sur la politique de l'énergie, à Belfort le 10 février 2022," 10 février 2022

[12] The White House, "Safely and Responsibly Expanding U.S. Nuclear Energy: Development Targets and a Framework for Action," November 2024

[13] DOE, "5 Nuclear Energy Stories to Watch in 2025," January 10, 2025

3. Japan's Situation Surrounding Nuclear Energy Use

(1) Policy

Japan's nuclear energy policy has been in the doldrums since the Great East Japan Earthquake, but signs of progress have gradually emerged in recent years. In February 2022, the Basic Policy for the Realization of GX[14] declared that in addition to restarting existing reactors, Japan will "work on the development and construction of next-generation advanced reactors," thereby positioning nuclear power as one of the main pillars of GX promotion. Moreover, the environment for effective use of existing reactors is being created with the enactment of the GX Decarbonization Electricity Act[15] in May 2023, which provides that the operation period of existing reactors may be extended. The Seventh Strategic Energy Plan announced in February of this year also places emphasis on nuclear energy, which is in alignment with the Basic Policy for the Realization of GX, as the phrase "reduce dependence on nuclear power as much as possible" is no longer mentioned in the latest plan.

Meanwhile, subsidies for electricity, oil, and other energy sources, which are not consistent with decarbonization, are continued with support from all political parties, although they are supposed to be abolished in a phased manner.

(2) Industry Interests

A stable supply of clean and appropriately priced electricity is essential as the basis for industry. From this perspective, there is strong support from Japanese industry for restarting existing nuclear power plants that have been shut down[16]. Some industries that require high temperatures, such as chemicals and iron and steel, are also calling for high-temperature gas-cooled reactors (HTGRs), one of the next-generation advanced reactors. Other industries using nuclear power, such as drug discovery, express their hope about the widespread use of nuclear energy in various fields other than power generation.

(3) Current Status of Nuclear Energy Use

Unfortunately, the resumption of operation of existing nuclear reactors is not progressing well. As a result, the share of nuclear power generation in the electricity supply remains low at 8.5% (in FY2023)[17], and it will be very difficult to achieve the 20-22% target for 2030 as indicated in the Sixth Strategic Energy Plan. The nuclear fuel cycle is in an even more difficult situation. Several towns and villages have come forward as potential sites for the disposal of high-level radioactive waste, thanks to the courageous decisions of their leaders. Although literature surveys have been conducted with their results compiled, no decision has yet been made on whether to move forward to the drilling survey phase.

Even with regard to the construction of large innovative LWRs, which was announced

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[14] Agency for Natural Resources and Energy, "Basic Policy for the Realization of GX—A roadmap for the next 10 years—," February 2023, https://www.meti.go.jp/press/2022/02/20230210002/20230210002_1.pdf (Japanese), last viewed on February 20, 2025

[15] Cabinet Secretariat, "Bill for the Act for Partial Revision of the Electricity Business Act and Other Acts for Establishing Electricity Supply Systems for Realizing a Decarbonized Society," February 28, 2023

[16] NHK, "Keidanren Proposes Maximizing Use of Nuclear Power for Revision of Strategic Energy Plan," November 22, 2024, https://www3.nhk.or.jp/news/html/20241122/k10014646921000.html (Japanese), last viewed on February 20, 2025.

[17] Agency for Natural Resources and Energy, "Summary of Energy Supply and Demand Results for FY2023 (Preliminary Report)," November 22, 2024, https://www.meti.go.jp/press/2024/11/20241122001/20241122001.html (Japanese), last viewed on February 20, 2025

under the leadership of former Prime Minister Kishida, it will take some time before the construction is completed and the reactors are put into operation. In this respect, Japan is lagging behind the UK, France, the US, South Korea, and other countries that have already announced plans to build additional nuclear power plants.

(4) Nuclear Energy Use in Time of Crisis

Russia's invasion of Ukraine reminded us once again that similar crises could occur elsewhere in the world. In the Middle East, on which Japan depends for more than 90% of its oil resources, conflicts and tensions are unlikely to subside[18]. As the probability of a Taiwan contingency increases, it is an urgent task for Japan to assess, reduce, and prepare for various risks that may occur if the fossil fuel supply is disrupted. It is certain that the share of renewable energy will increase and become the main source of power in the future. However, there is concern that growing reliance on renewable energy sources, whose generation fluctuates according to natural conditions such as solar radiation and wind conditions, will make the power system as a whole more vulnerable, as it will become difficult to maintain a balance between supply and demand. In addition, if a crisis were to occur while the share of renewable energy is increasing, Japan's society and economy, which currently relies on thermal power generation for 70% of its electricity and imports most of its fuel, would be left dependent on an even more fragile power system. Although the procurement sources of natural gas, the main fuel for thermal power generation, are gradually becoming more diversified in recent years, most of it still comes from the Middle East, and therefore, it is clear that supply would be disrupted in the event of a Taiwan contingency. Since the oil shocks of the 1970s, developed countries, including Japan, have held oil reserves as crisis management, but the role of oil in energy demand is shrinking. On the other hand, there is no stockpiling system for natural gas like there is for oil. From this perspective as well, the role of nuclear energy is even more important, not only as a decarbonized power source, but also as an independent power source in a time of crisis.

(5) Nuclear Human Resources

As has already been pointed out, the problem of the nuclear workforce in Japan is very serious. Since the Fukushima Daiichi Nuclear Power Plant accident, personnel with experience in nuclear power plant design and construction have been aging, with the depletion of next-generation nuclear human resources. Design and construction techniques of nuclear power plants, which require a long period of time for design and construction, can be passed on to the next generation only when they are carried out once every few years, as in the case of the ceremonial relocation of a shrine. In this respect, it is regrettable that even the export of nuclear reactors was halted after the Fukushima disaster. With that being said, as seen in the change in nuclear energy policy in the UK, the depletion of nuclear human resources is not a problem limited to Japan but a common problem in many developed countries. Moreover, from the viewpoint of human resource diversification, the Nuclear Energy Agency (NEA), the nuclear energy policy arm of the OECD, has identified the development of female professionals as one of its priority

[18] Agency for Natural Resources and Energy, "Situation Surrounding Energy," May 2024, https://www.enecho.meti.go.jp/committee/council/basic_policy_subcommittee/2024/055/055_004.pdf (Japanese), last viewed on February 20, 2025

issues[19]. Japan can cooperate in securing and educating international human resources by capitalizing on its technical and crisis management experience.

(6) Treated Water and International Relations

The treatment and ocean discharge of water stored in tanks on the Fukushima Daiichi Nuclear Power Plant site was a major issue. The government authorized Tokyo Electric Power Company Holdings, Incorporated (TEPCO) in April 2021 to discharge treated water, from which radioactive materials had been removed, into the ocean[20], and TEPCO began the ocean discharge of the treated water in 2023. The discharge of this treated water into the ocean was conducted upon consultation with the International Atomic Energy Agency (IAEA), and the levels of radioactive materials, especially tritium, were in full compliance with the standards of the World Health Organization (WHO), etc. However, the discharge was met with strong opposition from neighboring countries, and the effects of this opposition continue to be felt in the form of import bans on Japanese marine products and other restrictions.

Japan states that the entire country, including the government, has been careful to ensure that the discharge is made at a level that fully complies with international standards, while also giving due consideration to information disclosure and explanations[21]. It is regrettable that, despite these efforts, we have been met with strong opposition from even Taiwan, which maintains good relations with Japan and whose people are also on good terms with Japanese people. We must examine the reasons for this to ensure that similar incidents do not occur in the future.

[Column 1] Fukushima Daiichi Nuclear Power Plant Treated Water Problem

1) On April 13, 2021, the Japanese government authorized TEPCO to release ALPS (Advanced Liquid Processing System) treated water into the ocean. The plan is to use ALPS to remove radioactive materials from water stored in tanks at the Fukushima Daiichi Nuclear Power Plant since the Great East Japan Earthquake in 2011, dilute the water more than 100 times with seawater, and discharge it into the ocean. Water containing radioactive materials is called contaminated water, while water from which radioactive materials have been removed by ALPS is called ALPS-treated water, and the two are clearly distinguished. ALPS is a method adopted based on the United Nations Scientific Committee on the Effects of Atomic Radiation's effects assessment methodology.

2) Particular attention was paid to the tritium contained in the ALPS-treated water. The ALPS water discharged contains one-seventh of the drinking water standard set by the WHO. The annual tritium discharge from the Fukushima Daiichi Nuclear Power Plant facility is about 2.2 trillion Bq. This is the smallest amount of tritium discharged

[19] NEA, "Roadmaps to New Nuclear 2024: Brief for Ministers and CEOs," September 2024
[20] The Inter-Ministerial Council for Contaminated Water, Treated Water and Decommissioning Issues, "the Basic Policy on handling of ALPS-treated water stored at the Fukushima Daiichi Nuclear Power Station," April 13, 2021, https://www.kantei.go.jp/jp/singi/hairo_osensui/dai5/siryou1.pdf (Japanese), last viewed on February 20, 2025
[21] METI, "Basic Policy on Handling of the ALPS Treated Water," April 13, 2021, https://www.meti.go.jp/english/earthquake/nuclear/decommissioning/pdf/202104_bp_breifing.pdf, last viewed on February 20, 2025

annually compared with nuclear facilities in other countries. For example, in 2021, the Hongyanhe Nuclear Power Plant in China emitted about 90 trillion Bq of tritium; the Kori Nuclear Power Plant in South Korea, about 49 trillion Bq; and the Maanshan Nuclear Power Plant in Taiwan, about 35 trillion Bq.

3) The discharge of ALPS-treated water into the ocean was not only controversial in Japan but also drew international condemnation. The controversy in Japan may reflect the special feelings toward nuclear power held by the Japanese people as a result of their experience of the atomic bombings. However, if we look at the aspect of international law, the discharge of ALPS-treated water into the ocean is in conformity with international obligations. Japan's ocean discharge from land via a pipeline fulfills its obligations under the United Nations Convention on the Law of the Sea regarding the prevention of marine pollution from land-based sources. Meanwhile, shortly after Japan made the decision to discharge the water into the ocean, the IAEA issued a statement in support of it. IAEA Director General Rafael Marian Grossi stated that Japan's ocean discharge method is technically feasible and in line with international practice, and also noted that it is "critical to the sustainability of the Fukushima Daiichi decommissioning activities." Nevertheless, some countries consider Japan's ocean discharges problematic under the Marine Pollution by Ocean Dumping convention regime, which is irrelevant to discharge from land-based sources.

4) Ocean discharges began as planned in April 2023. The Japanese government is continuing its impact assessment, disclosing information and providing explanations to other countries. It is also maintaining close relations with the IAEA, which has sent experts to inspect the discharge of treated water. At the time of this writing, other countries have largely stopped criticizing Japan, with only a limited number of countries concerned about the issue.

5) In addition, the ocean discharge is a necessary and appropriate method for the safe dismantling of the nuclear facilities, as clearly pointed out by the IAEA Director General as "critical to the sustainability of the Fukushima Daiichi decommissioning activities." Contaminated water in storage tanks at the Fukushima Daiichi Nuclear Power Plant facilities may reach the maximum storage capacity, which would hinder the safe dismantling of the facilities. It was therefore essential at that time to release the ALPS-treated water in a safe manner.

4. Changes and Challenges in Japan's Financing Environment

(1) Decline in Profitability of Electric Power Companies

Electric power companies have traditionally financed themselves backed by their robust profitability, but since the Fukushima Daiichi Nuclear Power Plant accident in 2011, their profitability has plunged owing to the following factors.

i) Increased cost of safety measures

Electric power companies are required to invest in additional measures, i.e., enhanced safety measures against severe accidents caused by tsunamis, earthquakes, eruptions, fires, terrorism, and compounding factors.

ii) Abolition of the fully distributed cost method due to electric power deregulation
Implemented in stages since March 2000, electricity deregulation was extended to the low-voltage market in 2016, including general households, stores, and small offices. This has made the electricity market fully open for competition, and at the same time, fully distributed cost pricing in the electricity industry, which had previously enabled electric power companies to make sufficient capital investments, has been abolished. In other words, electric power companies are no longer guaranteed to recover their costs through the setting of electricity sales prices, as in the past, and are now aiming for more efficient management, which has forced them to be more cautious about new capital investment[22].

iii) Dependence on thermal power plants due to the shutdown of nuclear power plants
The Fukushima Daiichi Nuclear Power Plant accident shut down nuclear power plants of all electric power companies, requiring additional thermal power generation. This has boosted fuel costs.

(2) Financing of Electric Power Companies
Prior to the Fukushima Daiichi Nuclear Power Plant accident, capital investment by electric power companies was funded by electric power bonds issued by them. These were low-interest, long-term bonds issued mainly for the construction of power plants against the backdrop of strong demand for electricity during the period of rapid economic growth. The bonds were characterized as coming "with general security." This meant that all assets owned by the power company were pledged as collateral, allowing creditors to recover their claims from all assets of the power company in the event of default by the debtor power company. In other words, the holders of the electric power bonds were in a very strong position when it came to debt collection.

The handling of this general security became an issue with the separation of power generation and transmission that accompanied the deregulation of the electric power industry. That is to say, since the bond issuer (mainly the power holding company) and the operating company (power generation company or transmission company) which holds the assets pledged as collateral were separated, the bonds could no longer be with general security. Concerns were also raised that this general security would allow holders of electric power bonds to recover their funds preferentially and hinder compensation to victims in the event of a nuclear power plant accident. In response to these, the government abolished the general security for electric power bonds as of April 1, 2020, and a transitional measure was established to allow the issuance of bonds with general security for a five-year period only[23].

[Column 2] Challenges Specific to the Nuclear Power Business Concerning Financing

A nuclear power plant is a very long-term project, which covers everything from planning and operation (up to 60 years for operation alone) to decommissioning, disposal of radioactive waste, and other back-end activities. In terms of funding, in

[22] Agency for Natural Resources and Energy, "How Electricity Rates are Set," https://www.enecho.meti.go.jp/category/electricity_and_gas/electric/fee/stracture/pricing/ (Japanese), last viewed on February 20, 2025
[23] Cabinet Secretariat, "Bill for Partial Revision of the Electricity Business Act, etc.," March 2020

addition to the long construction period and associated construction costs, the project will require various investments, including that for the cost of complying with revised safety standards and other regulations. Therefore, it is extremely difficult to forecast the total cost and recovery prospects for such a long period of time with a certain degree of probability, taking into account changes in the market environment, the situation of electric power companies, and other factors. At the same time, there are still many uncertainties regarding the back end, such as the reprocessing of spent fuel, treatment and disposal of high-level radioactive waste, and decommissioning, as the systems and technologies for these have not yet been fully established. Moreover, the revenues of electric power companies are based on the market price of electricity, and the business risks specific to the nuclear power business, such as those mentioned above, are not reflected in the setting of electricity prices.

Thus, the use of nuclear power has inherent business challenges, and accordingly, the business is very difficult to predict. Stated differently, the deregulated electricity market is not a good match for the construction and expansion of nuclear power plants. Having said that, if the long construction period and associated costs can be successfully managed, risks can be carefully avoided, and safety can be ensured, a nuclear power plant, once in operation, will have a long operating period and a low operating cost, which will contribute not only to the profitability of the electric power company, but also to the relatively low price burden on consumers and other users.

C. Considerations

1. Basic Concept

(1) National Will and Strategies for Energy and Nuclear Energy Use

Throughout the world, new investment in nuclear energy use in general is not necessarily going smoothly, owing to a longer period of time required to start operation and soaring costs coupled with regulatory uncertainty, etc. However, new nuclear power plants are being built in the UK and France, where there is a clear national strategy and a certain level of public support. For example, articulating the need for nuclear energy use in its efforts toward decarbonization, the UK appears to be focusing relevant resources on nuclear power generation, and simultaneously endeavoring to overcome the cost challenge by promoting active international cooperation. Taking decarbonization and the war in Ukraine into consideration, France is launching a nuclear initiative and also trying to overcome the cost challenge by standardizing the new nuclear power plant designs as much as possible based on its extensive experience in the construction and operation of such plants. In addition, China and India, which are very active in the use of nuclear energy, have overcome these challenges with a clearly stated national will, and relevant costs are lower, especially in China[24].

Based on the aforementioned characteristics of nuclear energy use, changes in the environment surrounding it, and the examples of other countries that are actively and smoothly promoting it, the following two points are particularly necessary for Japan to continue the use of nuclear power:

[24] IEA, "The Path to a New Era for Nuclear Energy," January 2025

i) Accelerate and continue its efforts to create systems and an environment that will achieve cost reduction as much as possible and facilitate investment in the use of nuclear energy as smoothly as possible; and
ii) Position the use of nuclear energy as a clear national strategy and clearly express Japan's will to use it in other national activities, such as security and peace diplomacy, as a tool having unique value.

(2) Political Involvement and Leadership
In view of the fact that Japan is the only country in the world to have ever suffered atomic bombings; it experienced the unprecedented accident at the Fukushima Daiichi Nuclear Power Plant; the country's overall resources are more limited than before; and the use of nuclear energy, especially if back-end measures are included, will have a very long-term impact, political involvement and will must be demonstrated in a decisive manner under clear political leadership in order to promote the future use of nuclear energy, including the construction of new nuclear power plants. Especially given that the use of nuclear energy lasts for a very long period of time, we will definitely face difficult times when, for example, costs are too high, and a sufficient return on investment cannot be achieved by leaving the matter to market principles alone. However, it is precisely at such times that we must be prepared to carry through with policies and measures, including the treatment and disposal of high-level radioactive waste.

In addition, as a prerequisite for such national will, it is of course essential to have broad public understanding of and public support for government policy. The government must make a process of such political involvement and a presentation of national will through communication and discussion with the public, while promoting individual policies.

(3) Toward Carbon Neutrality by 2050
For the time being, as stated in the Basic Policy toward the Realization of GX and the Seventh Strategic Energy Plan, in order to meet electricity demand and press ahead with decarbonization, the operation of existing nuclear power plants should be resumed and their operation periods should be extended while ensuring safety in nuclear energy use. In parallel with this, the construction of innovative large-scale LWRs, etc. should be promoted. It is important to steadily implement government nuclear energy policy, thereby demonstrating to the public and the business community confidence in the policy and a clear vision for the future. With that being said, this alone is not enough. Above all, the government must actively disseminate information on the use of nuclear energy, and at the same time, extensive discussion about nuclear energy policy must take place in a transparent manner on the political front.

(4) Beyond 2050
An even longer-term challenge that will last beyond 2050 is the disposal of high-level radioactive waste. High-level radioactive waste will need to be disposed of in geological formations in the future or isolated from the human living environment for hundreds of thousands of years. With regard to the disposal of such waste, although some surveys have been conducted, no decision to move to the next phase has yet been made. Consequently, a final disposal site has not yet been determined. Even if the use of nuclear power were to be halted now, this problem would remain a burden on future generations.

Therefore, now is the time to accelerate our response to it and consider all possible options. One of the most promising options is pyroprocessing and the metal fuel cycle. This is a technology developed by Argonne National Laboratory of the US. It uses slag-like metallic fuel as fast reactor fuel and recovers plutonium and minor actinides simultaneously from spent fuel by pyroprocessing, a type of high-temperature metallurgical process, to achieve a proliferation-free property and cost reduction at the same time[25]. The laboratory has already succeeded in making the disposal of high-level radioactive waste a matter of 300 years, instead of hundreds of thousands of years. Pyroprocessing also has the potential to treat fuel debris, the fuel damaged in the Fukushima Daiichi Nuclear Power Plant accident. We must now accelerate our response to the challenge of high-level radioactive waste disposal, including this pyroprocessing and metal fuel cycle, in a completely different way than in the past. The integral fast reactor (IFR), which is being studied at Argonne National Laboratory, is a nuclear reactor design with a high-level radioactive waste treatment function attached, so to speak, and has no precedent for commercialization in the world. We consider it meaningful for Japan, the only country in the world to have ever suffered atomic bombings and having experienced the Fukushima Daiichi Nuclear Power Plant accident, to lead the next generation of innovation in the nuclear energy field.

[Column 3] Integral Fast Reactor

A plant that combines a metal fuel fast reactor and pyroprocessing was proposed by Argonne National Laboratory in the US. Being economical and having a high proliferation-free property, it is called an integral fast reactor (IFR). A fast reactor uses slag-like metallic fuel as fuel. In pyroprocessing, spent fuel is dissolved using the anode in electrolysis, a type of high-temperature metallurgical process, and the large amount of uranium is first recovered using a solid cathode made of low-carbon steel. The cathode is then replaced with a liquid cadmium cathode, which allows the minor actinides to be recovered simultaneously with the plutonium.

This technology has several features. First, plutonium cannot be recovered in its pure form, making bomb production difficult and preventing the spread of nuclear weapons. Second, by recovering minor actinides, which have a long half-life and are highly radioactive, from spent fuel, the period during which high-level radioactive waste is stored before disposal can be shortened from 100,000 years to about 300 years. Third, minor actinides, which do not react to thermal neutrons, can be used as fuel because they can be transmuted by using fast neutrons. Fourth, cost reduction can be expected since only one electrolyzer containing molten salt is required to dissolve spent fuel, separate fission products, and recover uranium and plutonium separately.

In addition, pyroprocessing technology could be used to treat fuel debris that has accumulated in nuclear reactors as a result of the Fukushima Daiichi Nuclear Power Plant accident. Fuel debris is a composite oxide that is a mixture of uranium and plutonium as well as minor actinides and zirconium, which is used to make cladding tubes, and other substances. It is assumed that pyroprocessing technology can be

[25] Charles E. Till and Yoon IL Chang, "Plentiful Energy," 2011

applied by reducing fuel debris to metal using molten salt electrolysis as a pretreatment method. A test using simulated debris from the Three Mile Island (TMI) accident found that the boiling nitric acid in the PUREX process did not dissolve the debris, but the molten salt electrolysis did[26].

2. Recommendations

In the 2022 interim recommendations, we recommended a more realistic method of high-level radioactive waste treatment, contribution to nuclear non-proliferation, and risk minimization as three conditions for making the post-LWR era sustainable[27]. Since then, the importance of nuclear energy use has increased further in relation to decarbonization, electricity demand, etc. Given the sense of crisis regarding nuclear human resources in Japan, the disposal of high-level radioactive waste in particular has become even more important and urgent, as described above. In addition to the three conditions, we propose below issues that need to be addressed and the direction in which to address them in order for the use of nuclear energy in Japan to progress in a meaningful way under the new circumstances.

(1) Nuclear Energy Vision

With the positioning and environment of electric power and nuclear power utilization different from in the past, now is the time for us to have not only the Basic Policy for the Realization of GX and the Seventh Strategic Energy Plan but also a national nuclear energy vision that places nuclear energy at the center, with a view to the entire life cycle of nuclear power in the future. The process of discussing and examining such a vision on a national scale is an excellent opportunity to demonstrate clear political leadership and to foster political involvement and will. The government's taking the decisive initiative in presenting a long-term vision is expected to contribute to the development and maintenance of the nuclear supply chain and, ultimately, to the creation of a favorable environment for costs. The nuclear energy vision must be discussed and consensus must be reached in an unconventional open process, based on the opinions of a wide range of nuclear experts on everything from power generation to the nuclear fuel cycle, especially back-end experts, as well as the opinions of many stakeholders in society, while ensuring full disclosure and transparency of information on nuclear energy policy. It is important that the vision take into account not only nuclear power generation but also the entire nuclear fuel cycle, including policies on the disposal of radioactive waste. At the same time, we must examine the use of nuclear energy with a firm focus on the world situation, especially the tense situation in Asia and neighboring countries, and with an assumption and analysis of the possible impact of a crisis on Japan's energy policy as a whole. In this way, Japan must present its vision and resolve for the future not only to its citizens but also to domestic stakeholders, including industry and local governments, as well as to foreign governments and industry, including its international cooperation partners.

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[26] Washitani, "Chemical Properties of Debris and Applicability Study of Various Reprocessing Technologies, Understanding of Debris Properties and Study of Treatment Measures," the Atomic Energy Society of Japan "2012 Spring Annual Meeting" Planning Session, the "Next Generation Reprocessing Technology" Research Special Committee Report "Technical Issues of Debris Treatment from the Viewpoint of Next-Generation Reprocessing Technology," 2012

[27] The Canon Institute for Global Studies, Interim Recommendations of "Study Group on Next-Generation Nuclear Energy Utilization," "Facilitating Revitalization of Nuclear Energy in Japan," October 2022, https://cigs.canon/uploads/2022/11/To_Revive_Japan%27s_Nuclear_Power_Plant_Yoshikawa_202210.pdf (Japanese), last viewed on February 20, 2025

(2) Radioactive Waste, Decommissioning, and Fast Reactors

Considering the safety issues associated with conventional large LWRs, the treatment and disposal of high-level radioactive waste contained in spent nuclear fuel, and the issues of economic efficiency, there is an urgent need to switch to fast reactors that can solve these issues. In fact, Russia and China are ahead of Western countries in the development of fast reactors[28]. In light of these circumstances, Japan must establish an international cooperative framework for the commercialization of next-generation fast reactors with the UK, France, the US, South Korea, and other countries so as to avoid duplication of time, cost, and human resources involved in their development and commercialization. It is necessary to design and study international cooperation in nuclear energy for the next generation and build a sustainable nuclear power industry model for the entire Western world, while utilizing Japan's unique knowledge, including its experience in dealing with the Fukushima Daiichi Nuclear Power Plant accident.

As a specific initiative for pyroprocessing and the fast reactor cycle, it is necessary to cooperate with the Idaho National Laboratory (INL) of the US to conduct joint testing of a pyroprocessing technique using debris generated from the TMI accident and stored in the US through a trilateral cooperation among Japan, the US, and South Korea, which has performed an experimental study on pyroprocessing. The three countries' joining hands to lead the development of a different method from the conventional method of reprocessing using the LWR and PUREX process could lead to further promotion of the peaceful use of nuclear energy. Joint testing with Japan would be especially meaningful, as Japan has traditionally provided a model for the peaceful use of nuclear energy internationally. Since it will be quite a long time before actually conducting tests on fuel debris from the Fukushima Daiichi Nuclear Power Plant accident, we will first conduct tests using the molten salt electrolysis method of pyroprocessing on spent fuel stored at the time of the same accident in the fuel pool in the reactor building that cannot be processed at the Rokkasho Reprocessing Plant because it was covered with seawater. This test uses actual fuel to verify that uranium, plutonium, and minor actinides in spent fuel converted to metal by molten salt electrolytic reduction can be recovered simultaneously by first depositing most of the uranium on a solid cathode made of low carbon steel, and then depositing uranium and plutonium simultaneously with minor actinides on a liquid cadmium cathode. This will be a new step toward the pyroprocessing of fuel debris from the Fukushima Daiichi Nuclear Power Plant accident, which will lead to a metal fuel fast reactor cycle.

(3) International Cooperation

Resources, including human resources, for the use of nuclear energy are limited worldwide. Therefore, international cooperation in the use of nuclear power is a matter of urgency. In particular, there will be an increasing need to jointly develop and maintain supply chains among major countries that face similar challenges and at the same time share fundamental values. We need to promote international cooperation from this perspective.

[28] IEA, "The Path to a New Era for Nuclear Energy", January 2025

Meanwhile, in order to make international cooperation meaningful to Japan, we must not totally rely on other nations but engage in strategic negotiations with them based on our current status and future prospects regarding the use of nuclear energy. Making the most of our cooperation: with Argonne National Laboratory of the US for IFR development; with the National Nuclear Laboratory (NNL) in the UK for HTGR commercialization[29]; with the South Korea Atomic Energy Research Institute (KAERI) for SMR development; and with France and the US for uranium fuel enrichment and spent fuel reprocessing, we should rebuild the nuclear power supply chain in Western countries and develop a strategy to make Japan an important part of the supply chain.

(4) Facilitation of Finance

As mentioned earlier, there are risks that are difficult for operators to foresee, such as tighter regulations on nuclear power use and extended construction periods. As a response to these risks, there is room to consider diversifying financing sources and the government assuming a certain level of risk. It is necessary to introduce sources of funding other than financial institutions through the use of project finance (a scheme in which the source of financial reimbursement for a specific project is limited to the cash flow of the project), in addition to financial institutions' loans to power companies (so-called corporate finance). Overseas examples of financial assistance measures involving the government include the Contract for Difference (CfD) and the Regulated Asset Base (RAB) introduced in the UK and other countries[30]. Another scheme in which the government temporarily takes on the construction risk is seen in Europe amid the prolonged construction period due to the COVID-19 pandemic and Russia's invasion of Ukraine, as well as soaring construction costs attributable to the rising costs of materials, fuel, and labor. This is a scheme of attracting private investment when the construction of a power plant is nearing completion and construction costs are decreasing. In order to attract private capital for the construction and expansion of power plants in Japan, measures enabling private investment to avoid construction risks will likely be necessary.

Unlike LWRs with a track record of commercial operation for a long period of time, next-generation reactors, such as fast reactors, HTGRs, and SMRs, are still under development. Thus, it is extremely difficult to provide financing for these next-generation reactors. Insurance for the construction and operation of facilities using new technologies developed in recent years in conjunction with nuclear power utilization and energy transitions overseas will play an important role in facilitating financing for the

[29] JAEA, "Memorandum of co-operation between Japan Atomic Energy Agency and National Nuclear Laboratory limited in the field of High Temperature Gas-cooled reactor technologies," https://www.jaea.go.jp/02/press2023/p23090701/att1.pdf, last viewed on February 20,2025

[30] Both CfD and RAB guarantee a certain degree of cost and investment recovery for the operator. The CfD aims to reduce the investment risk of the operator; setting a period of time from the start of operation (e.g., 20 years), the government compensates for the fluctuating difference between the "strike price," a fixed price for electricity from sources subject to the scheme and the market price, thereby ensuring the operator's investment recovery for several years from the start of electricity sales. However, the CfD scheme only applies to assets that start selling electricity after the start of operation, and financial institutions and other fund providers have the disadvantage of not being able to recover any funds during the construction period, which could be as long as 20 years. The RAB model was designed to solve this problem. Whereas CfD only applies to the period after the start of operation of the nuclear power plant, the RAB model allows developers and investors to recover a certain portion of the cost starting from the construction period. The mechanism of RAB is that the developer or investor receives a license from regulatory authorities to charge a regulated price to electricity users to recover the cost. RAB is said to be particularly effective for financial institutions in improving bankability, as repayment is made from the time of construction.

construction, etc. of facilities using new promising technologies that have not yet been put to practical use.

SMRs, including HTGRs and small sodium-cooled fast reactors, pose different challenges. While large reactors provide electricity to a vast range of local industries and residents as social infrastructure, many SMRs are expected to be utilized not as social infrastructure but as off-grid carbon-free power sources that provide clean electricity, heat, and hydrogen using heat to specific companies, factories, or industrial clusters. Therefore, it is necessary to consider schemes in which the off-taker (electric power company) concludes a long-term power purchase agreement with the operator (electric power company) and the operator uses this as collateral to raise funds, or in which the off-taker directly invests in the operator. In the Mankala model[31] used in Finland, a company that consumes a large amount of electricity becomes an investor in the consortium, which invests in the construction of the nuclear power plant, and financial institutions also provide direct financing with a government guarantee. The investors in the consortium have the right to purchase the electricity generated after the plant is completed and put into operation. This method may be worth considering when envisioning a facility that generates electricity exclusively for specific, high-volume electricity users. In any case, the investment is made in new technology that has no proven track record. If it is difficult to earn a return on investment during the first several years, the use of carbon credits, which are expected to be launched in Japan in the future, should be considered as well.

(5) Public Participation and Interactive Communication

In the interim recommendations, we mentioned this as an "improvement of environment" for the three conditions, but we would like to add it as one of our recommendations. The issue of energy and global warming is of critical importance because it is closely related to civilian life and their economic activities as can be seen in Europe and other countries. With the rapid spread of renewable energy and the focus on "decentralization" of power sources and energy sources, the participation of citizens of the local community in discussions must be ensured at every stage of planning and implementation of energy and climate policies. To this end, the government must also increase the transparency of the policy process and strive for two-way communication with local citizens. At the same time, the government must not forget to persist with explanations based on scientific and objective evidence for possible risks.

Public participation in the formulation and decision-making of nuclear energy policy will further strengthen the foundation of nuclear energy policy. In order to ensure such effective public participation, the government should also pay attention to and provide opportunities for the enhancement of citizen literacy regarding the use of nuclear energy.

3. Conclusion

We mentioned earlier the need for political will and strategy, but if political will is difficult to form, then, in light of the changes in the environment surrounding the use of nuclear energy as seen so far as well as the time constraints, the "second-best solution" should be chosen rather than continuing with the existing policy to go ahead with the use

[31] Borenius, "What is the Mankala model found in Finnish power production?" October 17, 2022

of nuclear energy. Specifically, we should, while nuclear human resources are still available in Japan, make a bold shift in conventional policy; human resources that have been devoted to nuclear power use so far should be funneled into the resumption of the operation of existing nuclear power plants and their cleanup, i.e., decommissioning, Fukushima debris treatment, and spent nuclear fuel management, treatment and disposal, especially high-level radioactive waste disposal.

There is a concern that if we continue nuclear power utilization without a clearly expressed national will, the use of nuclear energy will not progress as much as projected, a final disposal site for radioactive waste will not be determined, and in the meantime, the domestic nuclear power supply chain will be difficult to maintain and the nuclear workforce will dwindle. Unfortunately, this has been the trend to date. The use of nuclear energy is by nature a very long-term issue and an important national project requiring a huge amount of money and involving industry, academia, and government. Meanwhile, the current situation in Japan is dominated by maturity rather than the momentum experienced during the period from the dawn of nuclear energy use to its expansion. Also with tight financing conditions, Japan's standing in the international arena is not as strong as it once was. Given these circumstances and the absence of political will and clear leadership, we recommend that Japan choose the second-best solution as we consider it a great risk to simultaneously pursue many measures for nuclear energy use.

(End)