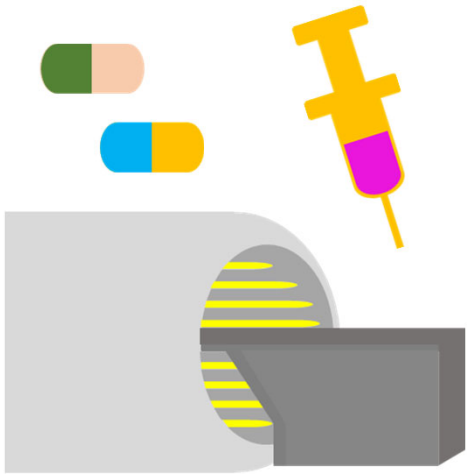
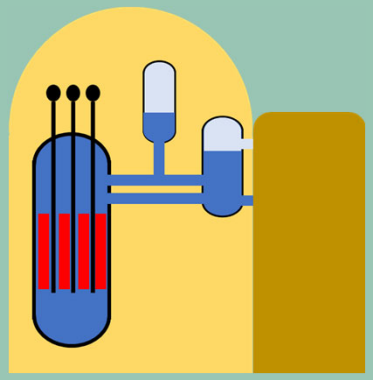


White Paper on Nuclear Energy 2024

published in June 2025

Executive Summary



Japan Atomic Energy Commission (JAEC)

Provisional Translation, August 2023

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Nuclear Technology Supporting Daily Life

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Abbreviations

ALPS	Advanced Liquid Processing System
AZEC	Asia Zero Emission Community
CAO	Cabinet Office, Japan
CEA	French Alternative Energies and Atomic Energy Commission
CT	Computed Tomography
FBR	Fast Breeder Reactor
FMCT	Fissile Material Cut-off Treaty
FNCA	Forum for Nuclear Cooperation in Asia
GVH	GE Vernova Hitachi Nuclear Energy
IAEA	International Atomic Energy Agency
ID	Identification
JAEA	Japan Atomic Energy Agency
JAEC	Japan Atomic Energy Commission
JNFL	Japan Nuclear Fuel Limited
LWR	Light Water Reactor
METI	Ministry of Economy, Trade and Industry, Japan
MEXT	Ministry of Education, Culture, Sports, Science and Technology, Japan
MHI	Mitsubishi Heavy Industries

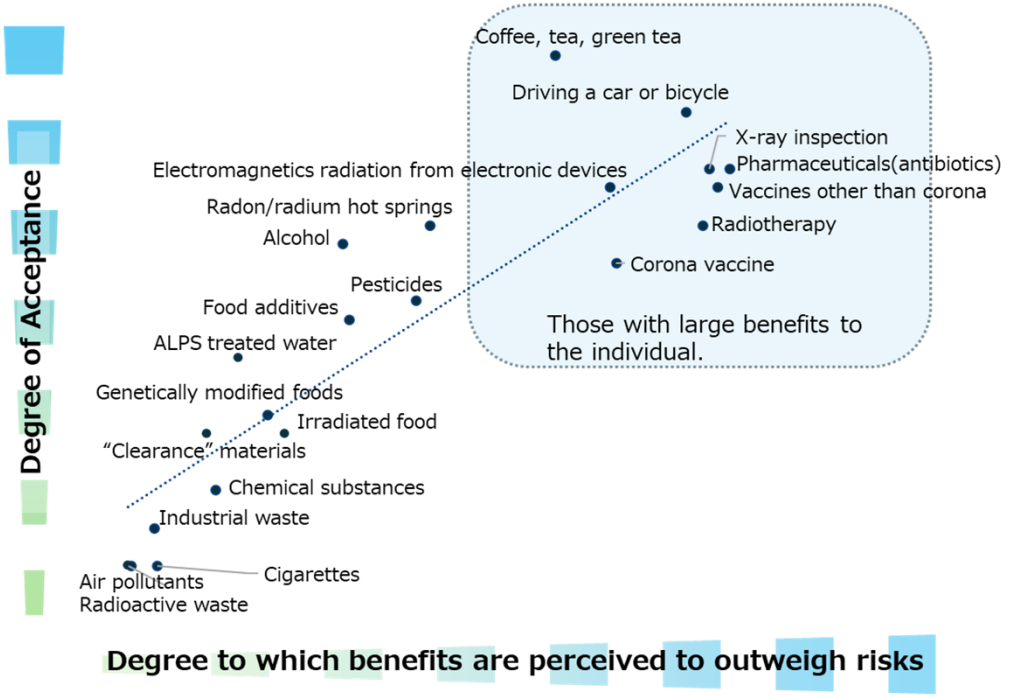
MOFA	Ministry of Foreign Affairs, Japan
MOX	Mixed Oxide Fuel
NDF	Nuclear Damage Compensation and Decommissioning Facilitation Corporation
NEA	Nuclear Energy Agency
NPS	Nuclear Power Station
NRA	Nuclear Regulation Authority, Japan
NUMO	Nuclear Waste Management Organization of Japan
OECD	Organisation for Economic Co-operation and Development
PET	Positron Emission Tomography
QST	National Institutes for Quantum Science and Technology
RI	Radioisotope
RIKEN	Institute of Physical and Chemical Research
SMR	Small Modular Reactor
SPECT	Single Photon Emission Computed Tomography
TEPCO	Tokyo Electric Power Company, Tokyo Electric Power Company Holdings

Special Report: Nuclear Technology Supporting Daily Life (1/5)

Background

- Nuclear technology, including radiation, is applied not only for energy but also in the fields such as medicine, agriculture, and industry, contributing to our daily lives.
- Among these applications, many are not widely known.
- The past survey results suggest that the perception of risks and benefits is a key factor in the social acceptance of nuclear technology.

Relationship between the level of acceptance and perceived benefits at the source of risk (questionnaire conducted by CAO in Feb. 2024)



Source: CAO

Energy	Medicine
・LWR ・Advanced LWR ・SMR	・Diagnostic test ・Radiation therapy ・Radiopharmaceutical

Agriculture	Industry
・Plant breeding ・Food irradiation ・Pest control	・Polymer processing ・Semiconductor processing ・Sterilization and disinfection

- This special feature highlights how nuclear and radiation technologies are already contributing to daily life, and how further benefits are expected as research and development advances.
- Through this feature, it is hoped that public understanding will deepen not only regarding the risks of these technologies, but also their benefits.

Nuclear Technology Supporting Energy Supply

- According to the 7th Strategic Energy Plan issued in February 2025, nuclear energy is designated as a power source that significantly contributes to national energy security, decarbonization, affordability, and exhibits minimal cost volatility.
- Advanced LWRs are being developed based on matured technologies, incorporating cutting-edge innovations to enhance safety and operational performance. Progress is being made toward their practical deployment. Japan is conducting research and development on SMRs, FRs, HTGRs, and fusion energy. Japanese manufacturers are also participating in several overseas SMR projects.
- Efforts are underway to develop nuclear human resources and strengthen the supply chain. Japan also supports human resource development in newcomer countries.

Key Safety Features of Advanced LWR Technologies

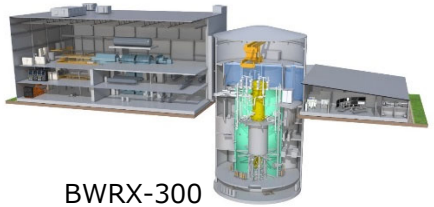
Earthquake and Tsunami Resistance
- Seismic resistance has been improved through structural reinforcement and lowering the center of gravity of reactor buildings.
- Tsunami resilience has been enhanced by implementing waterproofing measures for the buildings.

Core Damage Prevention
- Cooling functions of the reactor core have been strengthened using autonomous mechanisms—such as gravity, pressure differentials, and density gradients—known as passive safety systems, which do not require external power or operator intervention.
- Diversification and redundancy have been achieved through compartmentalization within the reactor building.

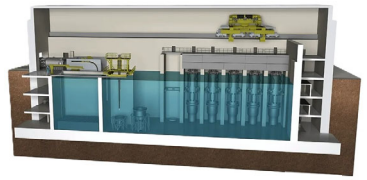
Containment Vessel Failure Prevention
- Containment performance has been improved by installing core catchers, specialized structures that cool molten reactor cores during severe accidents and prevent damage to concrete structures.
- Additional containment of radioactive materials has been ensured through the installation of filtered vent systems.

Aircraft Crash Countermeasures
- Resistance to aircraft crash has been enhanced by reinforcing the outer shield of the containment vessel and the structural integrity of the reactor building.

Source: Hitachi-GE, Technical Features of the High-Economic Efficiency BWRX-300 and Domestic/International Trends, Meeting Material, 4th JAEC's Meeting(2025) ; Toshiba ESS, Toshiba's Initiatives for Innovative Reactors, Meeting Material, 3rd JAEC's Meeting(2025) ; MHI, Initiatives for the Development of Next-Generation Innovative Reactors, Meeting Material, 5th JAEC's Meeting(2025)



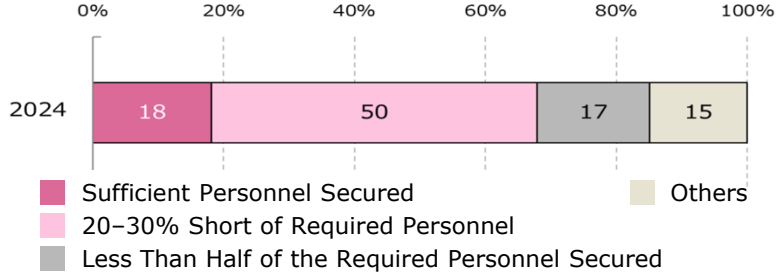
BWRX-300
(Hitachi GE Vernova/GVH)



NuScale Power Module™
(NuScale/JGC/IHI)

Examples of SMR Development

Source: Hitachi GE, Technical Features of the High-Economic Efficiency BWRX-300 and Domestic/International Trends, Meeting Material, 4th JAEC's Meeting(2025) ; IHI, JGC, Initiatives by IHI and JGC on the NuScale SMR, Meeting Material, 11th JAEC's Meeting(2025)

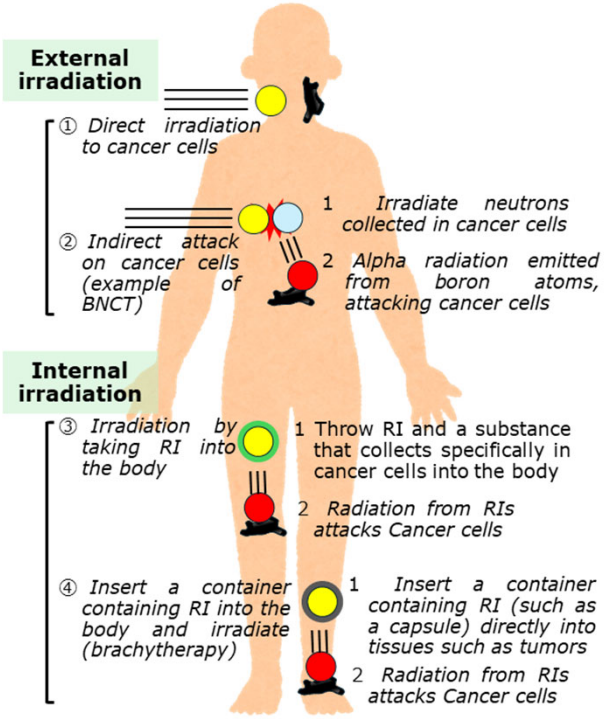


Status of Human Resource Availability in the Nuclear Sector

Source: JAIF, Nuclear Industry Trends Report 2024, JAIF(2024)

Nuclear Technology Supporting Health

- Nuclear medicine diagnostics and therapies have rapidly advanced worldwide in recent years.
- SPECT and PET imaging enable visualization of cerebral blood flow and pathological lesions not detectable by CT, contributing to differential diagnosis of dementia and cancer detection.
- Nuclear medicine therapy involves administering radiopharmaceuticals that emit targeted radiation to selectively destroy cancer cells while minimizing damage to healthy tissue. Several therapies are already in clinical use, and global R&D continues to expand.
- In 2022, the JAEC formulated the *Action Plan for the Promotion of Production and Use of Medical Radioisotopes*. Under this plan, research is underway to domestically produce isotopes such as Actinium-225 and Astatine-211 using research reactors and particle accelerators.
- Hospitals face ongoing challenges, including the need for investment in radiation shielding infrastructure and the safe management of radioactive waste containing used materials.



Model Diagram of Nuclear Medicine Therapy

Source: CAO

Major Radiopharmaceuticals for Nuclear Medicine Therapy Approved in Japan

Radioisotope	Target Disease
I-131	Pheochromocytoma and Paraganglioma, Thyroid Cancer, Hyperthyroidism
Y-90	Malignant Lymphoma
Lu-177	Somatostatin Receptor-Positive Neuroendocrine Tumors
Ra-223	Castration-Resistant Prostate Cancer with Bone Metastases

Source: CAO

Installation of shielding to ensure that the effective dose outside barriers does not exceed 1 mSv/week

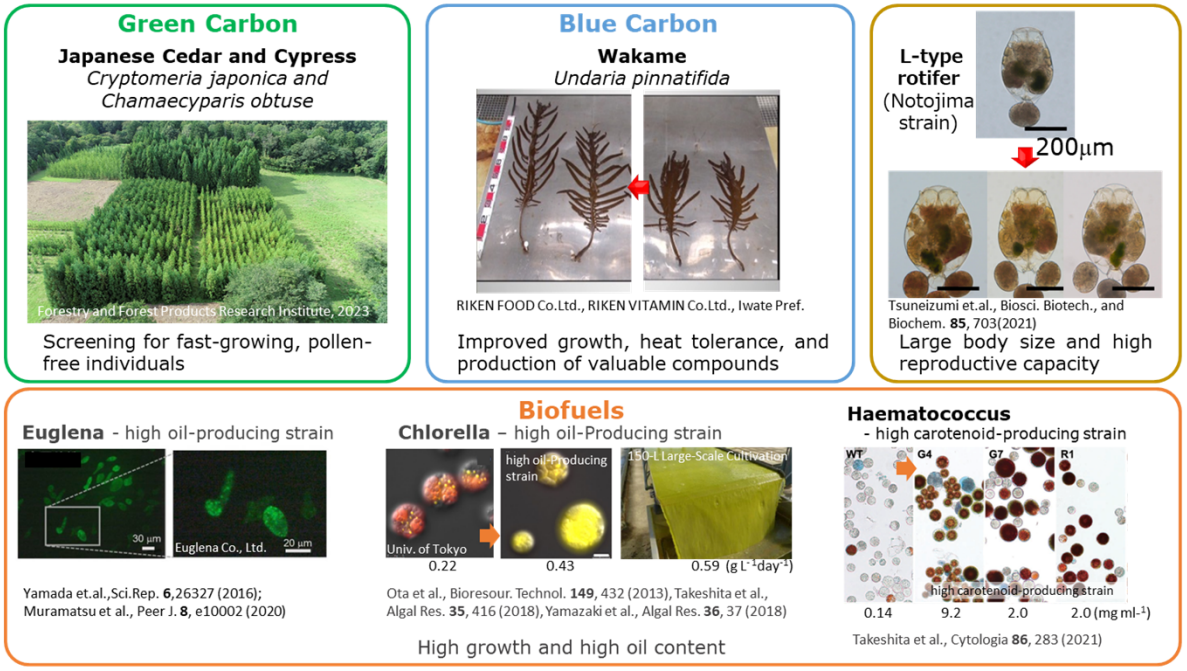
Surfaces such as floors and walls that may be contaminated with RI are covered with materials that facilitate decontamination

Example of Special Measures for a Hospital Room Used in Nuclear Medicine Therapy

Source: S.Takano, Hospital's Initiatives in Theranostics Using Lutetium-177, Doc.1, 3rd JAEC's Meeting(2025)

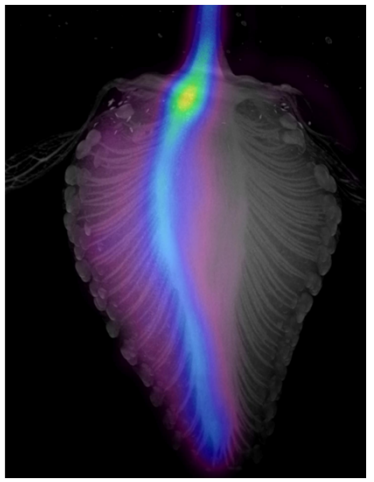
Nuclear Technology Supporting Food Safety and Daily Necessities

- In agriculture, radiation has long been used for mutation breeding. In recent years, ion beam breeding has enabled the development of rice varieties with low cadmium and heavy metal absorption.
- Efforts are also underway to use RI imaging to elucidate the mechanisms by which plants acquire nutrients. These initiatives are expected to contribute to the development of cultivation technologies for crops adapted to global warming.
- In daily life and consumer products, radiation is already being widely utilized: for example, sterilization of medical instruments and PET bottles, processing of polymer materials such as tire rubber and wire insulation, adding deodorizing functions to masks, doping elements in semiconductor manufacturing, and baggage inspection at airports.



Study of Mutants Induced by Ion Beam Irradiation

Source: RIKEN, Research on Breeding Using Radiation" by RIKEN, Doc.1, 2nd JAEC's Meeting (2025)

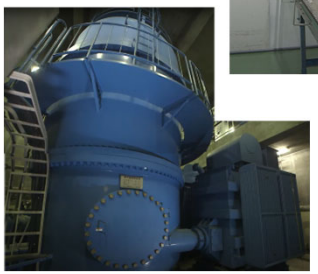


Sugar Transport into Strawberry

Radioisotope Imaging

Source: Ariki Kawachi, The Study of RI Imaging, DOc.1, 12th JAEC,s Meeting (2025)

Gamma Ray Sterilization



Electron Beam Accelerators for Sterilization

Radiation-Based Sterilization

Source: Irradiation Facilities, Radie Industries Co., Ltd. Website (2025)

Understanding Nuclear Technology and Its Role in Our Lives

- The application of nuclear technologies across various fields, like in the energy sector, is fundamentally based on the principle of *Ensuring Safety*, reflecting the lessons learned from the TEPCO Fukushima Daiichi NPS accident.
- The nuclear technologies featured in this report are already contributing to daily life and are expected to further evolve through continued research and development.
- When utilizing such technologies, it is essential to scientifically and comprehensively assess both risks and benefits from a societal perspective, and to share this understanding broadly with the public. For example, in the case of radiopharmaceuticals, it is important to communicate not only the potential side effects but also the medical benefits.
- The JAEC remains committed to promoting the appropriate use of nuclear technologies by continuing to provide clear and proactive communication from a neutral standpoint.

Message from the Japan Atomic Energy Commission (JAEC)

- All entities engaged in the promotion and application of nuclear technologies, including the national government, must ensure that their utilization is firmly grounded in the principle of safety assurance.
- It is essential for these entities to engage in continuous efforts to foster public understanding of nuclear technologies -starting from familiar applications- and to share both the risks and benefits of nuclear utilization with society as a whole.
- To earn public trust in the use of nuclear technologies, it is indispensable to maintain a commitment to disseminating information in a scientific and neutral manner.

Chapter 1: Lessons learned From the TEPCO Fukushima Daiichi Nuclear Power Station Accident and Efforts Toward Reconstruction and Revitalization

1. Efforts Toward the Reconstruction and Revitalization of Fukushima

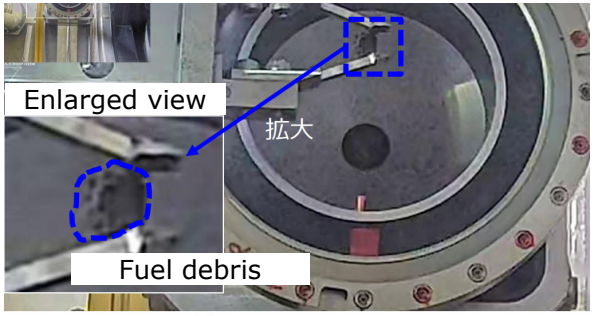
- As of the end of March 2025, approx. 309 Km^2 of land in Fukushima Prefecture remain under evacuation orders. In these areas, decontamination work and infrastructure development efforts are ongoing.
- In March 2025, the government set standards for recycling and landfill disposal of decontamination waste from Fukushima and outlined the plan for final disposal outside the prefecture.

2. Continuous Enhancement of Nuclear Safety and Emergency Preparedness

- The NRA published a report on the operational guidelines for shelter-in-place measures, including the designated geographic areas and the duration of evacuation instructions.
- In February 2025, a comprehensive nuclear emergency preparedness drill was conducted at the Sendai NPS. The exercise was jointly carried out by the national government, local authorities, and nuclear operators.

3. Decommissioning of TEPCO's Fukushima Daiichi NPS

- In November 2024, TEPCO successfully conducted a trial retrieval of fuel debris from Unit 2. The retrieved material is currently undergoing analysis by the JAEA and other institutions.
- The discharge of ALPS-treated water into the sea began in August 2023 and had been carried out a total of 11 times by the end of March 2025.
- By March 2025, the IAEA conducted three reviews and verified that the discharge met international safety standards.
- Under the IAEA framework, additional monitoring was conducted. In April, experts from the IAEA, South Korea, Switzerland, China, and Russia collected pre-discharge samples, which are being analyzed in laboratories across the participating countries



Fuel Debris Retrieved and Placed into Transport Container

Source: Materials from the 132nd Meeting of the Decommissioning, Contaminated Water, and Treated Water Countermeasures Team / Secretariat Meeting(2024)

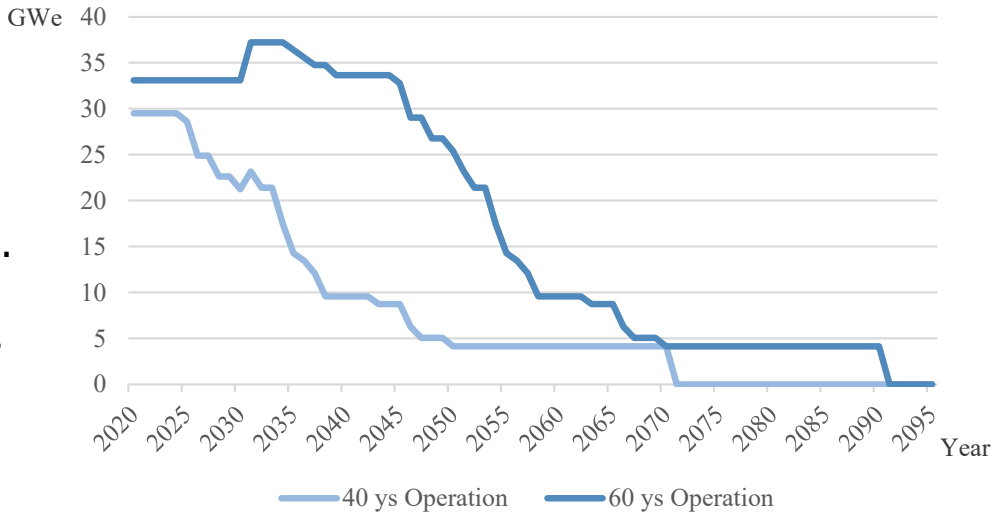
Chapter 2: Safe Utilization of Nuclear Energy for Energy Security and Carbon Neutrality

1. Japan's Energy Utilization Policy

- The 7th Strategic Energy Plan, issued in February 2025, presented a policy to replace existing nuclear reactors with next-generation advanced reactors in order to promote the use of nuclear power as a decarbonized energy source.
- In the energy supply and demand outlook, the electricity mix for fiscal year 2040 is expected to include nuclear power at a proportion of approx. 20%.

2. Status of Nuclear Power Generation

- As of the end of March 2025, fourteen nuclear reactors in Japan have resumed operation.



Nuclear Generating Capacity Projection in Japan

Source: Data from IAEA, Nuclear Power Reactors in the World, Reference Data Series No.2, IAEA(2024)

- In 2024, Onagawa NPS Unit 2 and Shimane NPS Unit 2 resumed commercial operations. These BWRs were the first of their kind to restart following the Fukushima Daiichi accident.

3. Outlook and Current Status of the Nuclear Fuel Cycle

- JNFL has revised its target completion dates for key facilities: the Rokkasho Reprocessing Plant is scheduled for completion within fiscal year 2026, and the MOX Fuel Fabrication Plant within fiscal year 2027.
- The Recyclable Fuel Storage Center, a spent fuel interim storage facility located in Mutsu City, Aomori Prefecture, commenced operations in November 2024.
- Under the Economic Security Promotion Act, the Government of Japan has designated uranium as a specified critical material.

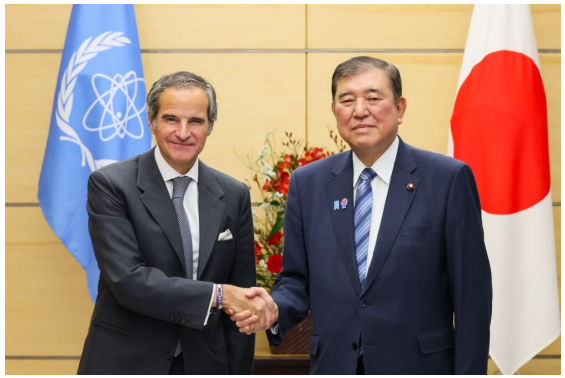
4. Partnership with Host Communities

- In prefectures hosting nuclear facilities, such as Fukui and Aomori, collaborative forums titled "Co-Creation Conferences on the Future Vision of Host Communities" are being held, involving local governments, nuclear operators, experts, and the national government. These initiatives aim to promote regional development through close cooperation with the communities.

Note. Fiscal Year in Japan: April to March (Named by Starting Year)

1. Trends in International Organizations and Major Nuclear Power Countries

- During IAEA Director General Rafael Grossi's visit to Japan in February 2025, he toured Fukushima Prefecture and TEPCO's Kashiwazaki-Kariwa NPS. The visit reaffirmed the strengthening of cooperation between Japan and the IAEA in areas such as the process of reconstruction and revitalization of Fukushima Prefecture, the peaceful use of nuclear energy, and nuclear non-proliferation.
- In the U.S., efforts are underway to extend the operational lifetime of existing reactors to 80 years. In the U.K., plans for the construction of large reactors are progressing, while in Canada, the development of SMRs is moving forward. Russia, China, and South Korea are actively promoting the export of nuclear power plants.



Prime Minister Ishiba Receives a Courtesy Call from IAEA Director General Rafael Grossi

Source: Cabinet Public Relations Office(2024)

2. Promotion of International Collaboration and Cooperation

- At the Japan-U.S. summit held in February 2025, the two leaders expressed their welcome for bilateral cooperation in the development and deployment of advanced technologies related to SMRs and other innovative reactors in both countries.
- In the joint statement issued at the 2nd Asia Zero Emission Community (AZEC) Leaders' Meeting in October 2024, AZEC partner countries reaffirmed their commitment to contributing to global decarbonization efforts.
- The 25th Forum for Nuclear Cooperation in Asia (FNCA) Ministerial Meeting was held in Tokyo in December 2024, featuring a policy dialogue. A Joint Communiqué was adopted, highlighting FNCA's contributions to "food and health," welcoming Singapore's accession, and affirming the need for cooperation on the development of next-generation reactors.

2nd AZEC Leaders' Meeting

Source: METI website(2024)

1. Peaceful Use of Nuclear Energy

- Under the principle of *Not Possessing Plutonium without a Specific Purpose*, Japan ensures transparency in its plutonium utilization. The country annually reports the inventory of all nuclear materials to IAEA.
- Since 2003, Japan has continuously received the IAEA's *Broader Conclusion*, confirming that all nuclear materials remain exclusively in peaceful activities.
- Based on this transparency, Japan promotes a nuclear fuel cycle that includes the reuse of plutonium.

2. Ensuring Nuclear Security

- Following security violations at the Kashiwazaki-Kariwa NPS, including improper ID card use, TEPCO requested an IAEA expert mission in April 2024. The mission confirmed that most corrective actions were completed and provided recommendations for further improvement.

IAEA Expert Mission on Physical Protection the Kashiwazaki-Kariwa NPS

Source: TEPCO, Pr**at**ogress Toward the Vision for the Kashiwazaki-Kariwa NPS(2024)

3. Progress Concerning the Nuclear Disarmament and Non-Proliferation Regime

- In September 2024, Japan confirmed at the high-level launch meeting of the Friends of the Fissile Material Cut-off Treaty (FMCT), an initiative it had announced at the United Nations Security Council ministerial meeting.
- In December 2024, the Japan Confederation of A- and H-Bomb Sufferers Organizations (*Nihon Hidankyo*) was awarded the Nobel Peace Prize.

The High-Level Launch Meeting of the Friends of the FMCT

Source: Cabinet Public Affairs Office(2024)

1. Initiatives for Information Provision and Public Communication

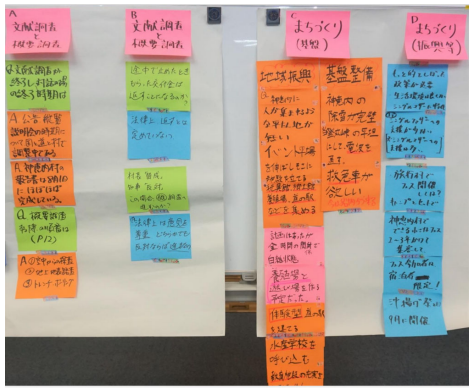
- The government and nuclear-related entities provide public information through energy policy briefings, timely website updates, and video content on platforms such as YouTube.
- The NUMO and the Agency for Natural Resources and Energy, METI conduct interactive briefing sessions nationwide regarding the final disposal of high-level radioactive waste. In areas designated for literature surveys, they also carry out direct dialogue activities with local residents.

2. Information Provision and Public Communication on the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Station

- The NDF provides updates on the progress of the decommissioning of the Fukushima Daiichi NPS within Fukushima Prefecture and organizes *Dialogue Sessions* to address public questions and concerns.
- The Ministry of Foreign Affairs has published English-language videos on its official website explaining the safety of the discharge of ALPS-treated water into the sea. Additionally, informational materials are available in ten languages, including Japanese and English.

Director General of the IAEA Rafael Mariano Grossi's Visit to Fukushima Prefecture

Source: MOFA, Press Releases from Feb. 2025 "Director General of the IAEA Rafael Mariano Grossi's Visit to Fukushima Prefecture", MOFA Website (2025)



Record of Dialogue at the Dialogue Session in Kamoenai Village

Source: NUMO, Record of Dialogue, Literature Survey: 20th Dialogue Session in Kamoenai Village, Hokkaido, NUMO Website (2024)

1. Decommissioning of Nuclear Facilities

- As of March 2025, in addition to the 6 reactors at the Fukushima Daiichi NPS, 18 commercial nuclear power reactors are undergoing decommissioning.

Status of Nuclear Power Plants in Japan

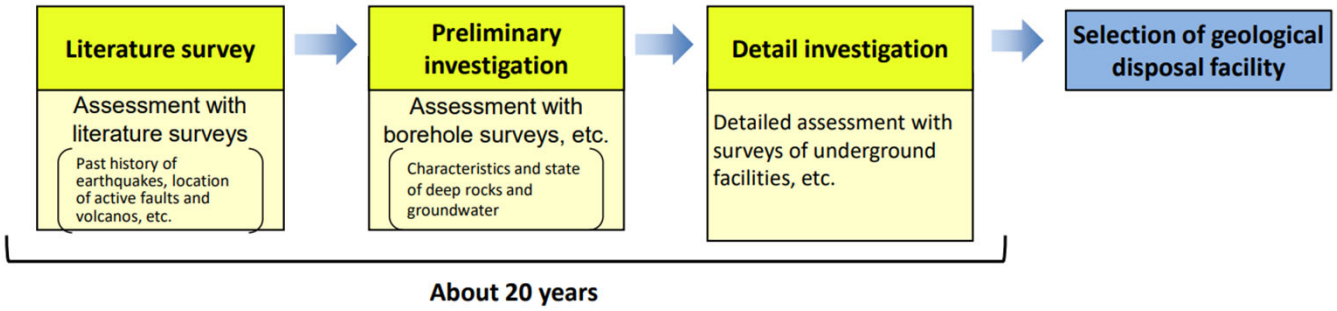
(as of Mar. 2025)

Operational	Suspended Operation	Decommission Process
14	22	24

Source: CAO

2. Radioactive Waste Management

- In November 2024, the NUMO published literature survey reports on high-level radioactive waste for Suttsu Town and Kamoenai Village in Hokkaido. The reports were submitted to the Governor of Hokkaido and local mayors, made available for public review, and accompanied by a comment solicitation. Explanatory sessions were also held across the region.
- In June 2024, a new literature survey was initiated in Genkai Town, Saga Prefecture.
- As low-level radioactive waste is expected to increase due to progress in the decommissioning of nuclear facilities, efforts toward its disposal need to be advanced. Some of low-level waste is already being disposed of or experimental disposed of at private disposal facilities.



The Process for Selecting a Site for the Disposal of High-Level Radioactive Waste

Source: METI, Geological Disposal of High-Level Radioactive Waste in Japan, METI Website(2025)

Note: From left in the photo
— No.1 Disposal Facility, No.2 Disposal Facility

Low-Level Radioactive Waste Disposal Site

Source: Overview of Disposal Projects, JNFL Website (2025)

1. Utilization in the Medical Field

- In Japan, the scope of insurance coverage for proton beam therapy and heavy ion therapy was expanded in fiscal year 2024. There are 26 medical institutions that provide these particle beam therapies.

Synchrotron Accelerator for Heavy Ion Cancer Therapy

Source: Department of Heavy Particle Medical Science, Graduate School of Medical Science, Yamagata University

2. Utilization in Other Fields

- The upgrade of the large-scale synchrotron radiation facility SPring-8 toward SPring-8-II, which will offer more than 100 times the current brightness, has been initiated.
- The 3GeV high-brilliance synchrotron radiation facility NanoTerasu officially began shared use in March 2025, in accordance with relevant legislation. The term "shared use" indicates that the facility is accessible to a wide range of users.

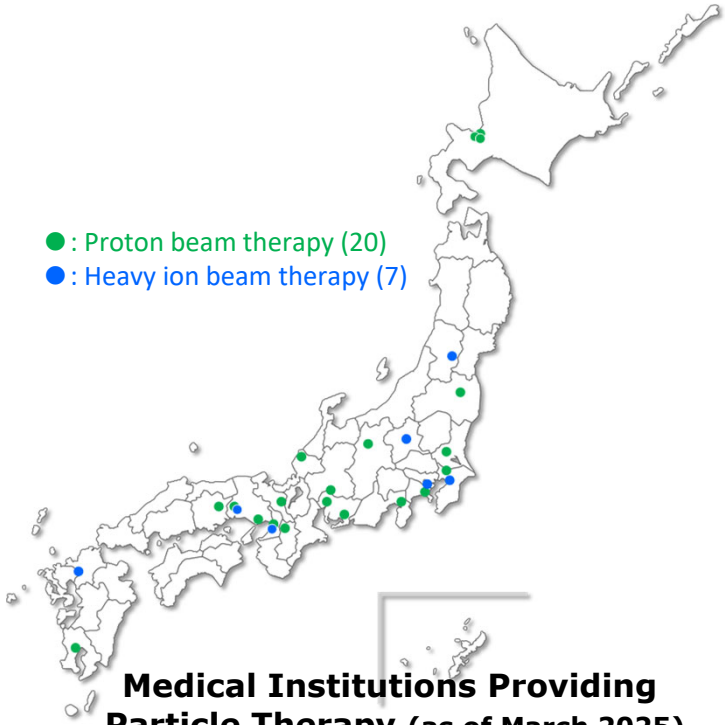
Panoramic View

End Station

Vacuum Chambar

NanoTerasu Synchrotron Light Source

Source: QST



Medical Institutions Providing Particle Therapy (as of March 2025)

Source: List of Medical Institutions Providing Advanced Medical Care, Ministry of Health, Labor and Welfare Website (2025)

1. Advances in Research, Development, and Innovation

- In September 2024, Japan and France updated their cooperation agreement on the development of sodium-cooled fast reactors. The renewed arrangement strengthens joint research in safety assessment, materials performance, and inspection technologies. This collaboration involves JAEA, CEA, and private-sector partners from both countries.
- As part of its contribution to the ITER project, Japan has supplied the gyrotron system used for high-frequency plasma heating.

2. Current Status and Future Prospects of Fundamental Research Facilities

- As of March 2025, only 8 research reactors and critical experiment facilities remained, down from about 20 at their peak.
- The detailed design of a new medium-output research reactor capable of utilizing neutron beams is currently underway. The reactor is planned to be constructed at the site of the prototype fast breeder reactor "Monju," where decommissioning work began in 2016.

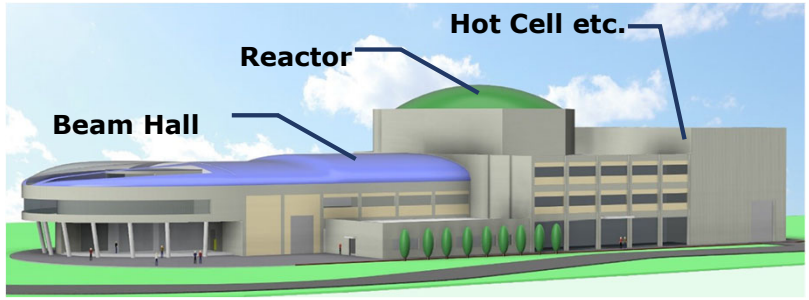
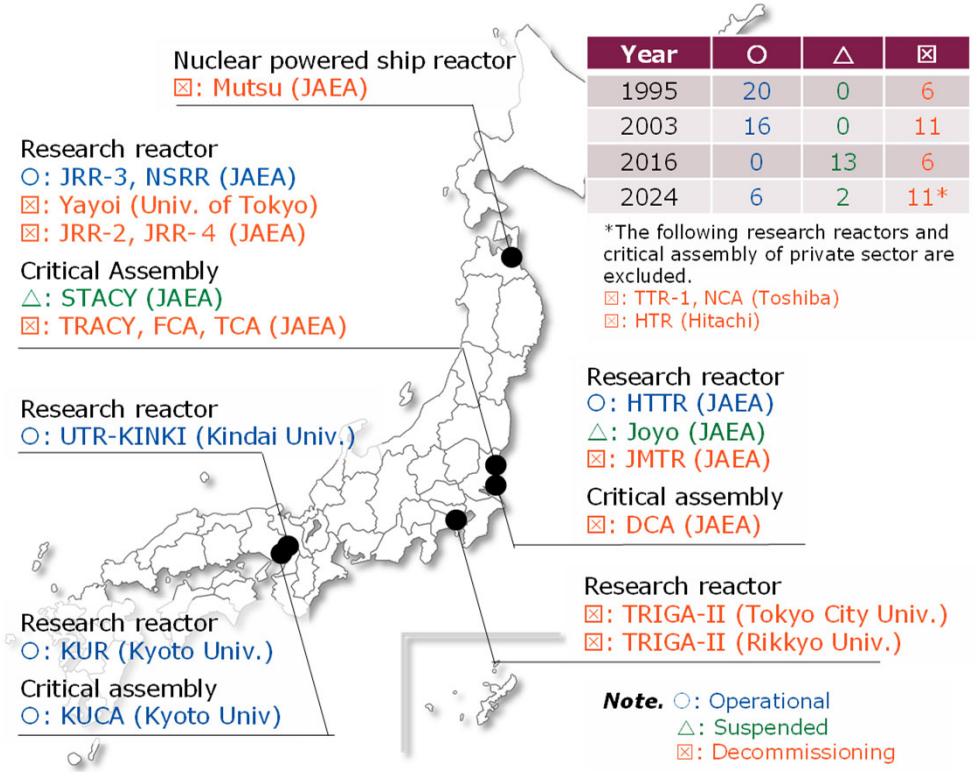


Image of New Research Reactor

Source: New Research Reactor Promotion Office, JAEA(2025)



Year	○	△	☒
1995	20	0	6
2003	16	0	11
2016	0	13	6
2024	6	2	11*

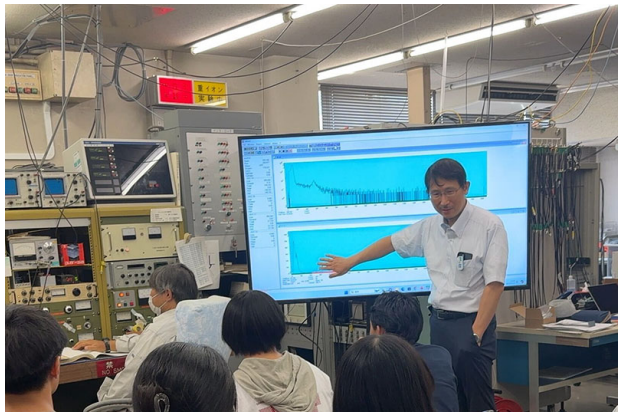
*The following research reactors and critical assembly of private sector are excluded.
☒: TTR-1, NCA (Toshiba)
☒: HTR (Hitachi)

Status of research reactors and critical assemblies

Source: CAO

1. Human Resource Development and Strengthening the Nuclear Supply Chain

- In Japan, fewer university students are entering the nuclear field. To encourage interest, MEXT held a "Nuclear Open Campus" at former Tokyo Institute of Technology for high school students.
- In 2023, METI, in partnership with industry, launched the Nuclear Supply Chain Platform to support nuclear-related businesses. To promote business matching, Japanese suppliers have been dispatched to the U.S. and Canada.



Nuclear Open Campus for High School Students

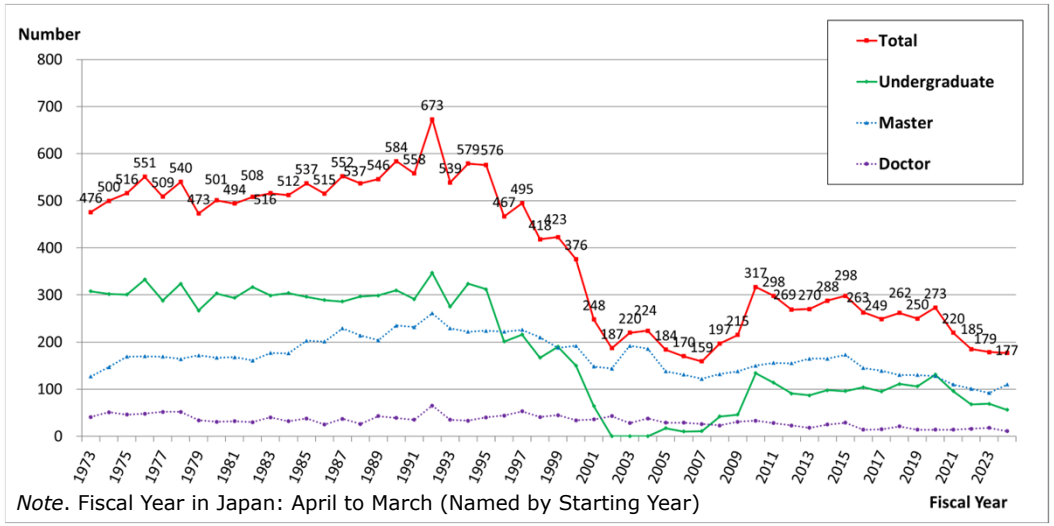
Source: Nuclear Innovator Cultivation Program, Nuclear Open Campus for High School Students held, Institute of Science Tokyo website(2024)

2. Promoting Diversity

- Based on the Recommendation of the Council on Improving the Gender Balance in the Nuclear Sector adopted by the OECD/NEA in 2023, the second meeting was held in September 2024. A commissioner from JAEC participated to discuss ongoing efforts and approaches to improving gender balance.

OECD/NEA 2nd High-Level Group Meeting on Improving the Gender Balance in the Nuclear Sector

Source: JAEC Website(2025)



Trends in the Number of Students Enrolled in Nuclear-related Programs

Source: MEXT (2024)

Japan Atomic Energy Commission (JAEC)

(as of July 2025)

Commissioners

Chairperson
Dr. UESAKA, Mitsuru

Commissioner
Mr. NAOI, Yosuke

Commissioner*
Dr. YOSHIHASHI, Sachiko

*. Term of Dr. OKADA Yukiko ended in June 2025;
Dr. YOSHIHASHI Sachiko appointed thereafter.

JAEC website

https://www.aec.go.jp/en/

Decisions, Statements

White Paper on Nuclear Energy 2024, June 2025
https://www.aec.go.jp/en/kettei/hakusho/

Basic Policy for Nuclear Energy, February 2023
https://www.aec.go.jp/en/kettei/kihon/

Plutonium Utilization in Japan, October 2017
https://www.aec.go.jp/kettei/kettei/20171003_e.pdf