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White Paper on Nuclear Energy 2022
published in 2023 (Summary)

Japan Atomic Energy Commission (JAEC)

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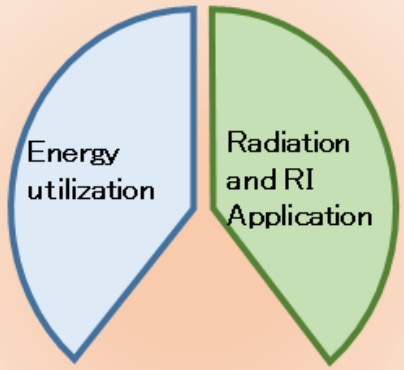
etc



Industrial applications (maintenance of social infrastructure by nondestructive testing, material processing, sterilization, etc) :

・Downsizing of radiation generator (accelerator) for non-destructive testing⇒Topic6
・Upgrading monitoring equipments for non-destructive testing⇒Topic6
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etc

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etc

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etc

Expanding the frontier of knowledge :

・Fusion reactor demonstration ・Lunar resource exploration(water monitoring by neutrons) ・Structural analysis for materials
・Space reactor demonstration ・Theoretical verification(neutron life time measurements, quantum entanglement, etc)・Developing quantum beam technology etc

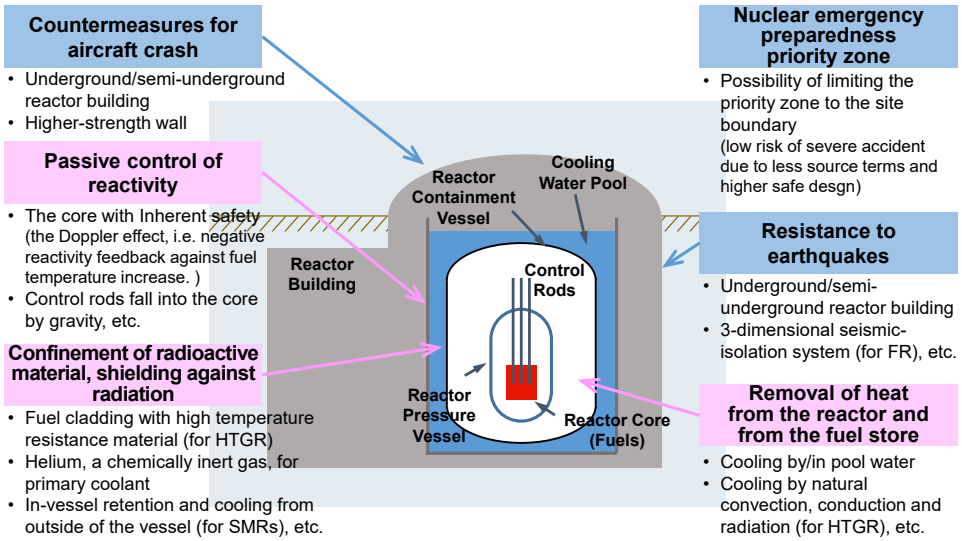
Topic 1 : Development of advanced reactors with improved safety that contribute to decarbonization

○ As the global green transformation(GX) progresses, advanced reactors incorporating innovative safety mechanisms are being developed around the world.

○ Advanced reactors are expected to contribute to the adjustment of the electricity supply-demand imbalance caused by the significant increase in the share of renewable energy sources, and also to be used for the production of carbon-free hydrogen.

○Advanced reactors may also have features that differ from conventional reactors, such as their radioactive waste management. The reactors need to be developed with a comprehensive vision based on the characteristics of their plant life cycle.

Example of innovative safety mechanism of advanced reactors



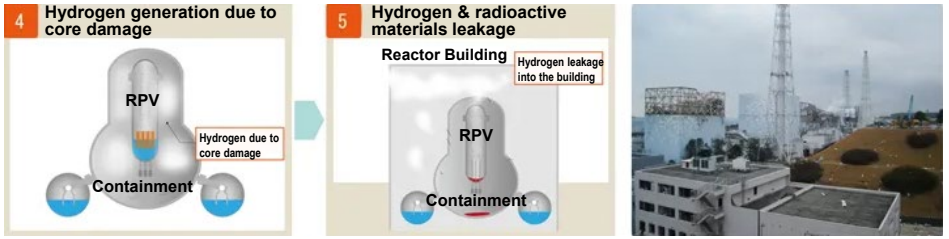
Topic2 : Development of Accident Tolerant Fuels that can suppress hydrogen generation

○In light of the hydrogen explosions that occurred at the Fukushima Daiichi accident, developments of Accident Tolerant Fuel(ATF) that can suppress hydrogen generation and improve accident tolerance are underway.

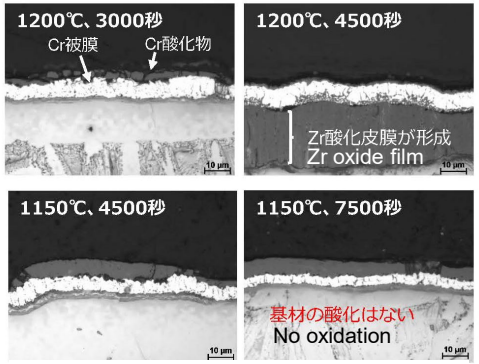
○The ATFs are being developed for implementation in the mid 2030s and beyond, by manufactures with JAEA and also with the U.S., OECD/NEA, and others.

○The use of ATF is one of the requirements for nuclear power to be included in the EU taxonomy (its application is deferred until 2025). In France, the developments of ATF are being hastened on the bases of the findings in the U.S.

Progress of the Fukushima Daiichi Accident

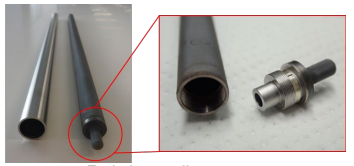


Chromium-coated fuel cladding

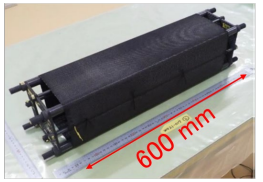


Metallographic pictures after the high-temperature oxidization tests

Silicon carbide composite fuel cladding, channel box, etc.



End plug sealing structure



SiC Channel Box Preform

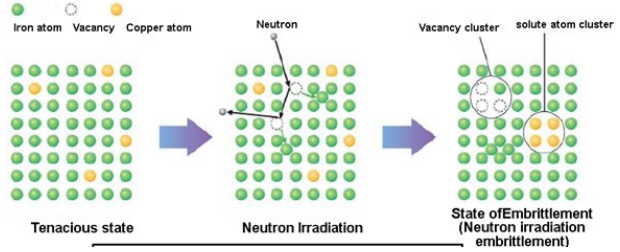
Topic3 : Development of aging degradation evaluation method for highly aged nuclear power reactors

○ The amended law allows for additional extension of the operating period of nuclear reactors, limited to a certain period of shutdown, which has increased interest in the integrity of aged nuclear reactors.

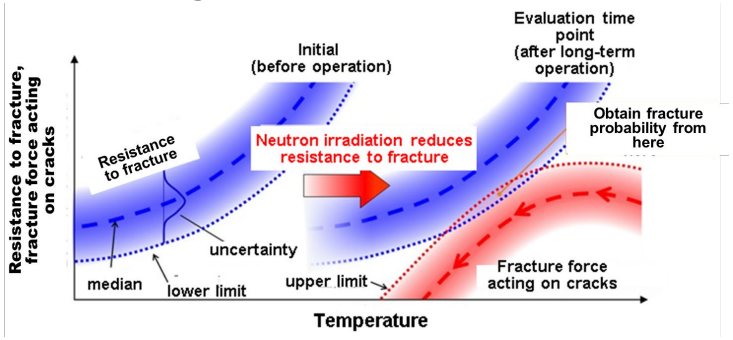
○ While many components of a nuclear facility can be replaced, difficult-to-replace components, such as the reactor pressure vessel, are important in determining the life of a reactor.

○ For neutron irradiation embrittlement, a typical aging degradation event of reactor pressure vessels, improvement of degradation prediction accuracy and development of probabilistic integrity evaluation methods are underway.

Change in atomic structure due to neutron irradiation (image)



Probabilistic analysis of reactor vessel structural integrity considering neutron irradiation embrittlement



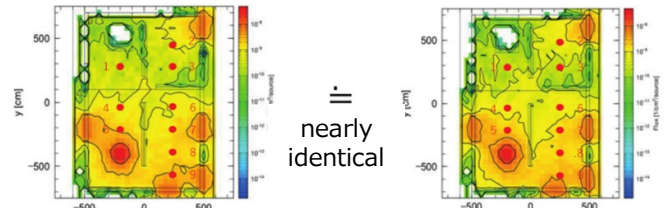
Topic4 : Technology development to cope with high radiation dose for decommissioning

○ The condition of reactors after a severe accident differs from that of normally closed reactors in many ways, including the presence of fuel debris, generation of contaminated water, high radiation dose in the reactor building, and many elements whose conditions are unknown.

○ For the decommissioning of the Fukushima Daiichi NPPs, development of technologies such as identification of the radiation sources and remote handling robots are being implemented in order to reduce the risk of radiation exposure to workers.

○ Sharing these experiences with the international community will contribute to ensuring safety not only in decommissioning but also in the use of nuclear energy, both domestically and internationally.

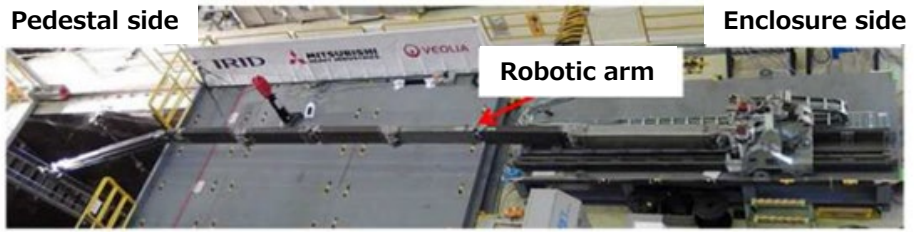
Development of radiation source identification techniques (Comparison of dose rate distributions)



Distribution with Monte Carlo calculation

Distribution with inverse analysis estimation method

The robotic arm for trial retrieval of fuel debris



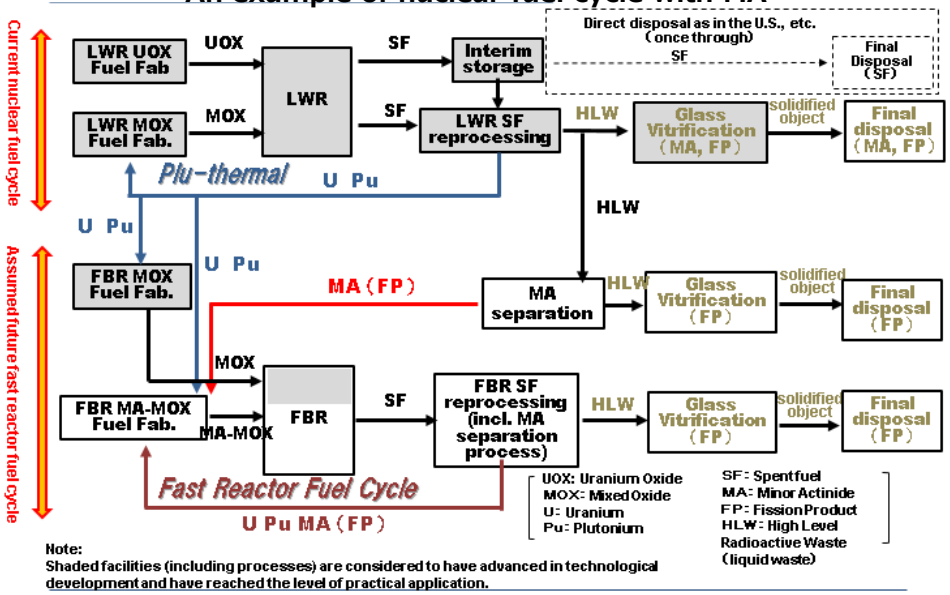
Topic5 : Challenges in reducing hazardousness of spent fuel by separation and transmutation

○ High-Level radioactive waste contains Minor Actinides (MA) with high heat generation and extremely long half-lives. Separation and transmutation of these nuclides is expected to reduce the volume and hazardousness of the waste, and reduce the size of disposal sites.

○ A series of processes is necessary, such as separation and recovery of MA under high radiation dose, fabrication of fuel containing recovered MA, transmutation using fast reactors and so on.

○ Each process can be selected from a variety of methods and technologies, but all are still at the laboratory level, and there is a large gap between the laboratory level and the industrial level. It is important to proceed with verification of the overall scenario while taking into account the maturity of each technology.

An example of nuclear fuel cycle with MA



Note:
Shaded facilities (including processes) are considered to have advanced in technological development and have reached the level of practical application.

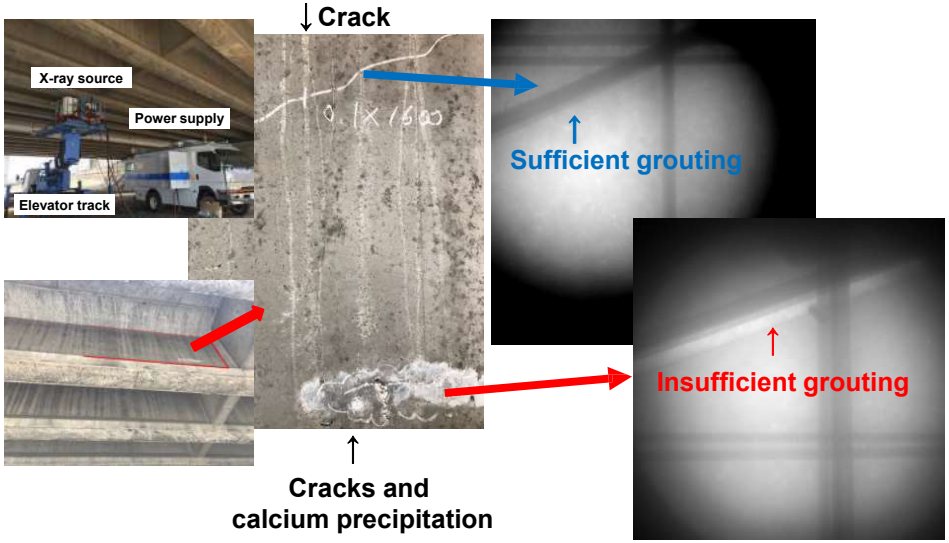
Topic6 : Development of non-destructive testing technology using radiation to support economic and social activities

○ Development is underway to apply the strong penetration power of radiation to non-destructive testing field.

○ For example, the development of a compact and portable X-ray source has made it possible to perform on-site non-destructive inspection of the interior of concrete structures, which is difficult to verify with conventional testing technique.

○ Comprehensive efforts are also essential to address practical issues such as development of regulation and standards and human resources including radiologists.

On-site X-ray inspection results of the pre-stressed concrete structure bridge
(Inspection of the tendon sheaths)



Topic7 : Research on social science aspects of nuclear energy utilization

○ In the use of nuclear energy, which has been the subject of public concern, it is essential that efforts be made to gain the trust of society from the research and development stage, and communication with the public is crucial for this purpose. From this perspective, social science research on the use of nuclear energy is being conducted.

○ Research is being conducted on social decision making and on information reliability. For example, the originator profile technology (*) is being developed, which can easily identify high quality articles, etc. in Web contents by mean of a third-party certification, etc.

(*) Technology that makes it possible to identify trustworthy information senders by providing verifiable information on Internet content creators, digital advertising placement sources, etc.

○ Geologic disposal of high-level radioactive waste involves intergenerational challenges. Discussions and researches are underway on this issue as a problem between the principle of benefit, in which the current generation that benefit from nuclear energy should be mainly responsible, and the principle of capability in which each generation should be also responsible according to its own capabilities.

Message from Japan Atomic Energy Commission : Expectations and Challenges for Innovation through R&D

～Attitude required for R&D～

I. To ensure that R&D do not become “research for research’s sake”, the technology should be verified objectively, including scientific and engineering issues, besides emphasis on its merits for the social implementation.

II. For early realization of social implementation of the technology, the impact on the entire life cycle of the project that uses the developed technology, including radioactive waste management, supply chain at the project stage, regulatory compliance, and economics, should be on the table for discussion from an early stage.

III. In order to promote effective and efficient R&D, it is necessary to actively promote industry-academia collaboration and international collaboration that takes advantage of the initiative of the industries that will use the results of such R&D.

Japan Atomic Energy Commission hopes that all parties concerned will make concerted efforts in R&Ds while recognizing that public trust is a prerequisite, and that innovation through the use of nuclear energy will flourish.

Summary

Chapters 1 to 9

Current status and efforts related to the nuclear utilization in Japan

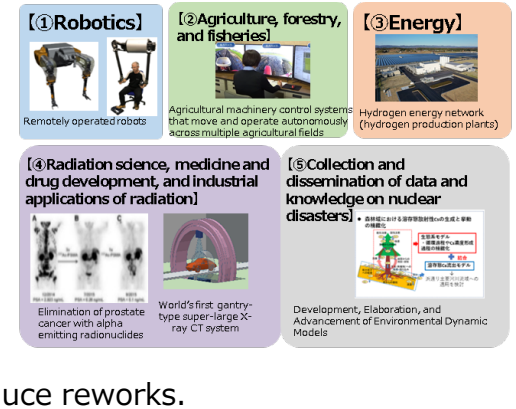
Chapter1: Continue to reflect on the Fukushima Daiichi Accident and learn its lessons

1. Efforts toward the reconstruction and revitalization of Fukushima

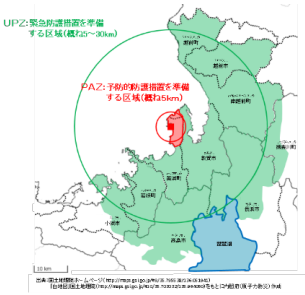
① Lifting of evacuation orders for the “Specified Reconstruction and Revitalization Bases Areas” in Katsurao Village and Okuma Town in June 2022, Futaba Town in August 2022, and Namie Town in March 2023.

② The law was amended in May 2022 and the basic plan was developed in August 2022 for the establishment of the Fukushima Institute for Research, Education and Innovation (F-REI) in April 2023.

Overview of the F-REI researches



The emergency preparedness priority zone in Mihama region



2. Continuous efforts to improve safety and emergency response for nuclear disasters

① Based on the exchange of opinions among the Nuclear Regulation Authority (NRA), operators and others from April 2022, the NRA improved the review process in September 2022, such as holding meetings more frequently to reduce reworks.

② In November 2022, the comprehensive nuclear emergency response exercise was conducted at the Mihama Power Plant.

Chapter2: Use nuclear energy for stable energy supply and carbon neutrality

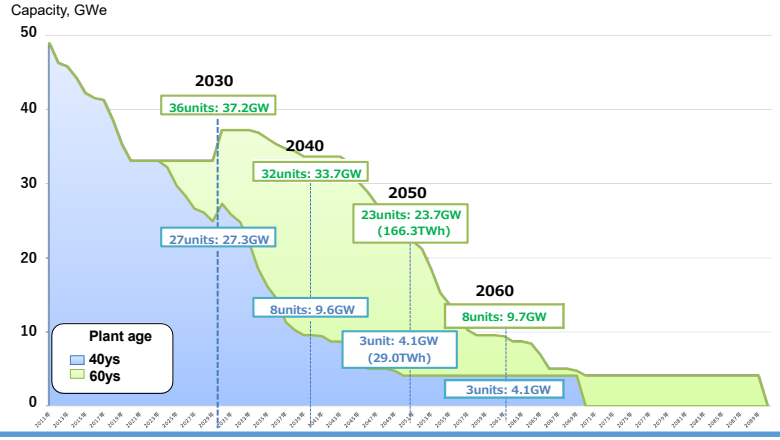
1. Direction of energy supply

① The cabinet decided the Basic Policy for the Realization of GX on February 2023 following discussions at the GX implementation council . The policy initiatives includes measures for use of nuclear energy such as the replacement of decommissioned rector with next-generation advanced reactor and the additional lifetime extensions for existing reactors.

② JAEC revised the “Basic Policy for Nuclear Energy” on February 20th,2023. Under the principle of ensuring safety, the new initiatives are listed: “Restarting existing nuclear power plants”, “Efficient safety reviews”, “Long-term operation of nuclear power plants”,and “Development and construction of innovative nuclear reactors”

Basic Policy for Nuclear Energy

Prospects of the total capacity of NPPs in Japan



2. Status of nuclear power generation

① Sendai Nuclear Power Station unit 1&2 submitted the approval to extent the operation life in October 2022.

※Takahama Power Station Unit3&4 also submitted the approval in April 2023.

3. Status of spent fuel reprocessing

① In December 2022, the Rokkasho Reprocessing Plant has been postponed the completion date to as early as possible in the first half of FY2024.

4. Revision of the Strategic Roadmap for Fast Reactor Development

① The strategic roadmap for fast reactor development was revised at Ministerial meeting on nuclear energy in December 2022. Sodium-cooled fast reactor is evaluated as the most promising.

Chapter3: Domestic and international initiatives in light of global trends

1. Trends in international organizations and leading countries in nuclear power

① IAEA released the first report on safety of planned ALPS treated water discharged from the Fukushima Daiichi site. It was confirmed that the radiation effects on human and environment are significantly less than the levels set by the Japanese regulatory authority.

② In January 2023, the US NRC issued its final rule in the Federal Register to certify NuScale Power's SMR.

③ The EU taxonomy entered into force and applied as of January 1st, 2023, which includes nuclear activities under certain conditions(*).

(*) A nuclear power project must have a construction plans of a disposal facility for HLW with detailed steps for the operation, etc.

2. Engagement in and collaboration with international organizations, and promotion of bilateral and multilateral collaboration

① At the IAEA General Conference held in September 2022, Takaichi Sanae, Minister of State for Science and Technology Policy, Cabinet Office, explained Japan's initiatives in the statement made on behalf of the government including the basic policy on handling of ALPS-treated water.

② At the Forum for Nuclear Cooperation in Asia (FNCA) Ministerial-Level Meeting held in October 2022, participants adopted a joint communiqué including the cooperation for the promotion and the enhancement of radiation cancer treatment.

FNCA the 23rd Ministerial-Level Meeting

Chapter4: Ensure peaceful use of nuclear energy, non-proliferation and nuclear security under international collaboration

1. Promoting the peaceful use of nuclear energy

① JAEC evaluates the plutonium utilization plans and the mid-term implementation plan for spent fuel reprocessing formulated by the operators and other stakeholders from the standpoint of peaceful use and securing plutonium balance.

② The amount of separated plutonium owned by Japan as of the end of 2022 is approximately 45.1 tons in the aggregate both within and outside of Japan.

				As of end of 2022
Total (Japan + Overseas)				approx. 45.1t
Breakdown	**Japan**			approx. 9.3t
	Overseas	**(Subtotal)**		approx. 35.8t
		Breakdown	**U.K.**	approx. 21.8t
			France	approx. 14.1t

Note: The total figures may not agree completely due to rounding.

2. Ensuring nuclear security

① Japan carries out efforts to protect nuclear materials, foster a nuclear security culture, and strengthen nuclear security measures based on the Nuclear Reactor Regulation Act.

② In August 2022, IAEA Director General and the IAEA Support and Assistance Mission to Zaporizhzhya (ISAMZ) visited and investigated the Zaporizhzhya Nuclear Power Plant. Since January 2023, IAEA experts have been stationed at all nuclear facilities in Ukraine.

3. Maintaining and strengthening nuclear disarmament and non-proliferation frameworks

① As the only country to have experienced the use of atomic bombs in war, Japan has engaged actively in efforts toward nuclear disarmament and non-proliferation on the basis of the Nuclear Non-Proliferation Treaty, such as submission of resolution on the elimination of nuclear weapons to the U.N/ General Assembly, while also taking into account the peaceful use of nuclear energy, an inalienable right granted to non-nuclear weapon countries.

② At the tenth review conference of the Parties to the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) held in August 2022, Kishida Fumio, Prime Minister of Japan advocated "Hiroshima Action Plan".

Chapter5: Rebuild public trust and confidence as a precondition for using nuclear energy

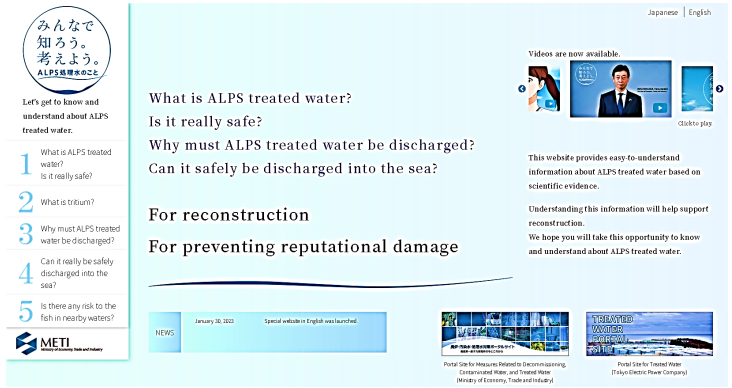
1. Efforts to enhance information sharing and communication by nuclear energy-related organizations

① Information provision initiatives have been taken, including hosting symposiums on energy policies, distributing articles on website and videos on YouTube in a timely manner. *e.g.* Japan Atomic Energy Relations Organization (JAERO) "Atomic Energy General Pamphlet", etc.

② Dialogue-based interactive explanatory meeting across the country on the final disposal of high-level radioactive waste have been held. Dialogue sessions also have been held in Suttsu Town and Kamoenai Village, Hokkaido, in conjunction with the implementation of Literature surveys.

METI Website "Let's get to know and understand about ALPS treated water"

<https://www.meti.go.jp/earthquake/nuclear/hairo_osensui/english/shirou_alps.html>



2. Coexistence with local communities

① In June 2022, the co-creating committee for the future vision for the area around nuclear power plants in Fukui prefecture released "Basic Policy and Initiatives to realize the future vision".

First Report on Safety of Planned Water Discharge from Fukushima Daiichi Site

Chapter6: Decommission of nuclear power stations and the radioactive waste management

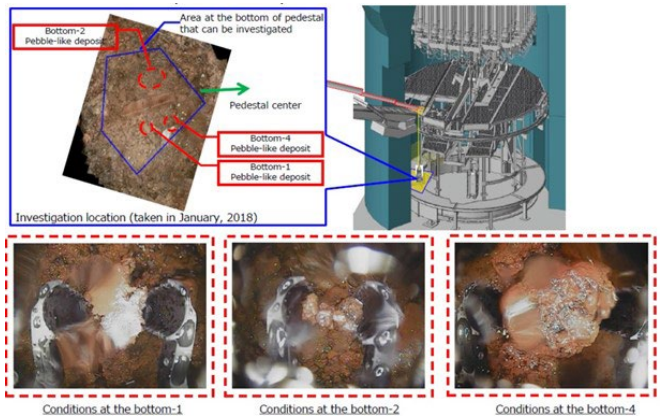
1. Decommissioning of TEPCO's Fukushima Daiichi NPP

① In August 2022 and January 2023, the "Action Plan for the Continuous Implementation of Basic Policy on Handling of ALPS Treated Water" was revised. It indicates to strengthen and expand measures for overcoming reputational damage and that it expected to start discharging the ALPS treated water into the ocean from Spring to Summer of 2023.

② Modification and verification of the control software of the robot arm for the trial retrieval of fuel debris are being progressed, and the trial retrieval is expected to begin in late FY2023.

③ The IAEA conducted its second review on the safety of ALPS treated water in November 2022 and on the regulation of ALPS treated water in January 2023.

Investigation results of the Fukushima Daiichi unit2
(investigated on February 2019)



2. Decommissioning of NPPs and nuclear-related R&D facilities, disposal of radioactive waste

① As of March 31, 2023, 18 commercial power reactors and 18 R&D facilities are under decommissioning.

② At the Ministerial meeting on final disposal of radioactive waste in February 2023, the "Basic Policy on the Final Disposal of Specific Radioactive Waste" was revised to strengthen government-wide efforts to realize the final disposal of high-level radioactive waste.

Chapter7: Promote the utilization of radiation and radioisotopes

1. The use of radiation and radioisotopes (RI) in medical fields

① In May 2022, JAEC formulated the “Action Plan for Promotion of Production and Utilization of Medical Radioisotopes”.

② In April 2022, health insurance coverage expanded to the particle beam radiation therapy (Proton Beam Therapy, Heavy Particle Therapy).

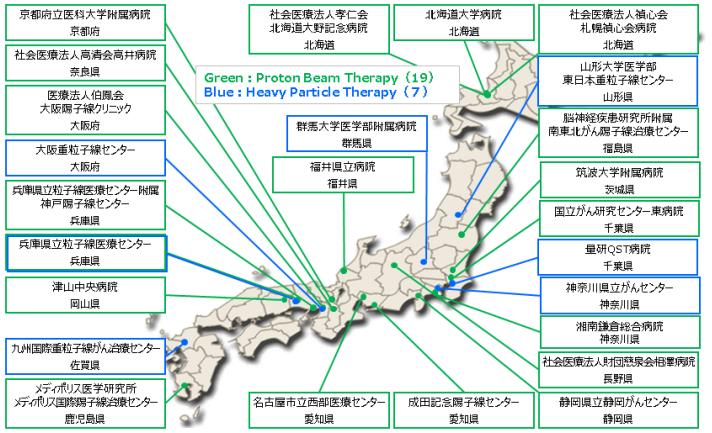
③ In November 2022, the Order for Enforcement of the Act on the Regulation of Radioisotopes, etc. was revised to resolve the dual regulations(*) of some unapproved radiopharmaceuticals used in medical institutions.

*Regulations based on the Medical Care Act and the Act on the Regulation of Radioisotopes, etc.

2. Use of radiation in other fields

① Radiation is used in various sectors, such as industry and agriculture, as an essential technology underpinning society.

Medical institutions offering particle beam radiation therapy (As of March 2023)



Chapter8: Facilitate innovations relevant to nuclear energy utilization

1. Promoting research, development and innovation

① In November 2022, the advanced reactor WG of the nuclear energy subcommittee under the ANRE/METI compiled a technology roadmap on next-generation advanced reactor development to realize carbon neutrality by 2050 and to ensure energy security.

② A study group on the development of R&D infrastructure necessary for the development of next-generation advanced reactors under the MEXT compiled a recommendation on the development of necessary infrastructures and human resources in March 2023.

③ In September 2022, a team consist of JAEA, NNL (UK) and UK company was selected to conduct a feasibility study in the UK Advanced Modular Reactor R&D and Demonstration Program.

2. Strengthening R&D infrastructures

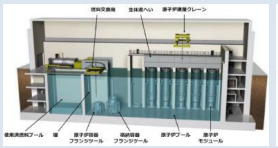
① In December 2022, JAEA was selected as the main contractor to implement the detailed design phase and beyond for the new test reactor to be installed at the “Monju” Site.

Next-generation advanced reactors

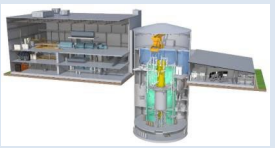
Advanced LWR

◆ Mitsubishi Heavy Industries

SMR (Small Moduler Reactor)



◆ VOYGR, NuScale



◆ BWRX-300, Hitachi-GE

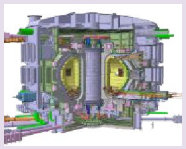
Fast Reactor

◆ Experimental Reactor: Joyo, JAEA

HTGR

◆ Test Reactor: HTGR, JAEA

Fusion Reactor



◆ Experimental device: ITER

Note: ANRE. Agency for Natural Resources and Energy MEXT. Ministry of Education, Culture, Sports, Science and Technology

Strengthening the Supply Chain, and securing and fostering human resources

① The Basic Policy for Nuclear Energy revised by JAEC in February 2023 pointed out the challenges facing Japan's nuclear energy sector include aging of the workforce and the small share of women participation. It also pointed out the need to recruit younger generations to work in the nuclear sector by communicating its attractiveness and the need to improve working environment where all people, regardless of generation, gender, or specialty, can achieve their potential.

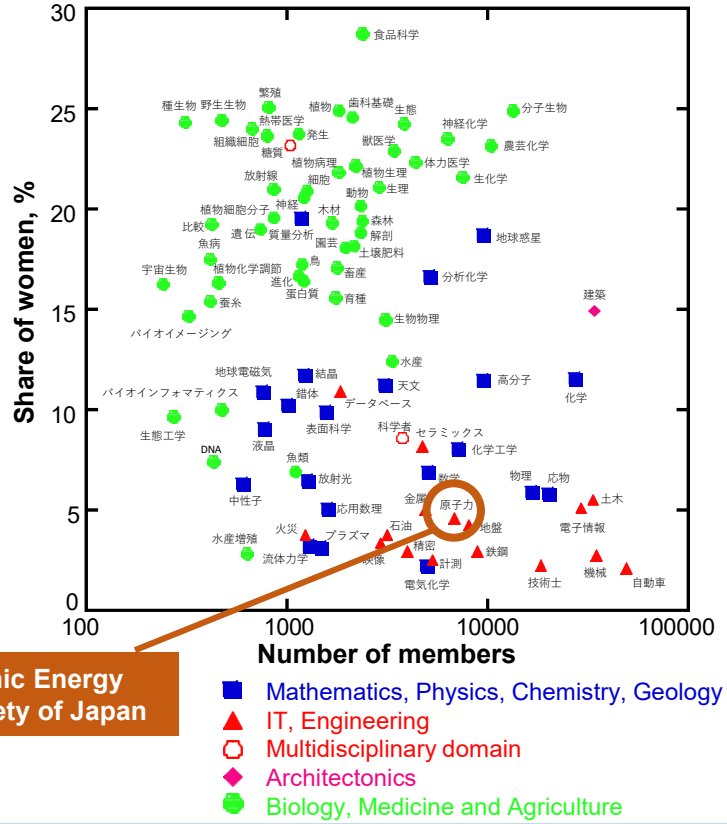
② The action guidelines presented at the Ministerial Meeting on Nuclear Energy in December 2022 indicated the establishment of a support system for the general issue of supply chain, including human resource development and recruitment, disruption of supply chain for parts and materials, and business succession. In March 2023, the ANRE announced the establishment of nuclear supply chain platform as a framework to support nuclear energy-related companies.

③ The Nuclear Human Resource Development Network, which promotes the building of human resources networks domestically and internationally and the planning and organizing cross-organizational activities for human resource development, held a virtual tour of nuclear facilities in August 2022.

④ As a part of next-generation education, the MEXT has prepared supplementary readers on radiation for elementary school students, junior and senior high school students. In addition, the Atomic Energy Society of Japan conducted a survey and made recommendations on the use of radiation, energy resources, and nuclear energy in school textbooks.

Supplementary readers on radiation

Share of women in academic societies



Useful Information
Japan Atomic Energy Commission

Commissioners (as of Aug. 2023)

Dr. UESAKA, Mitsuru
Chairperson

Mr. SANO, Toshio
Commissioner

Dr. OKADA, Yukiko
Commissioner

Website

http://www.aec.go.jp/jicst/NC/eng/index.htm

Decisions, Statements

White Paper on Nuclear Energy 2022, July 2023
http://www.aec.go.jp/jicst/NC/about/hakusho/index_e.htm

Basic Policy for Nuclear Energy, February 2023
http://www.aec.go.jp/jicst/NC/about/kettei/kettei230220_5.pdf

Plutonium Utilization in Japan, October 2017
http://www.aec.go.jp/jicst/NC/about/kettei/kettei171003_e.pdf

Basic Policy for Nuclear Research and Development (R&D), June 2018
http://www.aec.go.jp/jicst/NC/about/kettei/180612_e.pdf