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ARTEMIS REVIEW
OF
JAEA BACK-END ROADMAP:

FINAL REPORT

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DEPARTMENT OF NUCLEAR ENERGY

DEPARTMENT OF NUCLEAR SAFETY AND SECURITY

ARTEMIS REVIEW OF JAEA BACK-END ROADMAP: FINAL REPORT

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INTEGRATED REVIEW SERVICE FOR RADIOACTIVE WASTE AND SPENT FUEL MANAGEMENT, DECOMMISSIONING AND REMEDIATION (ARTEMIS) REVIEW

OF

JAEA BACK-END ROADMAP:

Compiled by: *IAEA, 11 June 2021*

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EXECUTIVE SUMMARY

At the request of the Government of Japan, specifically the Ministry of Education, Culture, Sports, Science and Technology (MEXT), an IAEA ARTEMIS Review of the long-term policy of the Japan Atomic Energy Agency (JAEA) on decommissioning of its installations and processing and disposal of associated radioactive waste was undertaken from 12 April to 22 April 2021. The Review provided an independent international evaluation of JAEA's 'Back-End Roadmap', with the aim of giving guidance on the further development of JAEA's approach to managing its liabilities.

The JAEA's 'Back-End Roadmap' covers 79 facilities, including nuclear reactors, nuclear fuel cycle facilities, and waste management facilities, and it is envisaged that the programme will be implemented over a period of 70 years.

The Review findings should assist MEXT and JAEA in developing the planning and implementation of decommissioning, and the robustness of the decommissioning cost estimates, taking into account IAEA publications (including Safety Standards and Nuclear Energy Series) and good international practice.

The Review focussed on the following specific aspects:

- The overall adequacy of the 70-year programme of decommissioning and waste management
- The methodology of cost estimation, covering all steps from decommissioning to waste disposal
- Ensuring the effective implementation of the programme, including the project management and contracting strategy.

The review was performed by a team of eight senior experts in the fields of decommissioning and radioactive waste and spent fuel management from seven IAEA Member States, with IAEA staff providing coordination and administrative support.

JAEA is currently conducting the decommissioning of several large nuclear facilities and the associated management of nuclear fuel material and radioactive waste. The current programme of decommissioning is concentrated on three main facilities, namely the Tokai Reprocessing Plant, the Prototype Fast Breeder Reactor 'Monju' and the Advanced Thermal Reactor 'Fugen'. These projects, together with associated waste processing and disposal activities, provide the main current management technical challenges, as well as representing the dominant share of cost and other resource needs during the first phase of decommissioning.

The ARTEMIS Review Team acknowledged that the overall decommissioning strategy being implemented by JAEA gives priority to those facilities where greater risk mitigation may be achieved (highest priority) and where significant maintenance-related cost reduction benefits are expected. The ARTEMIS Review Team observed that JAEA has a long record of successful implementation of technology development that could benefit the future decommissioning and waste treatment programme. The ARTEMIS team further observed that the recent changes in organization have facilitated putting in place a centralized management structure which allows consolidation, prioritization and coordination of technology development initiatives in a satisfactory manner.

The ARTEMIS Team noted that, as part of the Fukui Smart Decommissioning Technology Demonstration Base ('Sumadeco'), JAEA invited local industries with no previous experience in decommissioning activities to train on the mock-up facility at Tsuruga. This activity was identified as a Good Practice.

As regards lifecycle management of radioactive waste, JAEA outlined an ambitious overall programme, including siting and construction of concrete vault and trench disposal facilities for low-level waste and very low-level waste within the next decade. This programme presents a significant challenge, including managing the likely shortage of waste storage, especially in the event of delay. In order to support MEXT / JAEA in increasing the effectiveness of the plan and the efficiency of the decommissioning and waste management actions, in terms of risk reduction and time and cost optimization, the ARTEMIS Review Team provided a number of recommendations and suggestions, including:

— JAEA should review a range of options to more clearly separate their organizational and resourcing (people and budget) responsibilities for R&D and decommissioning to strengthen the focus on each mission.

— JAEA should develop an integrated unified resource loaded programme schedule which would enable programme level risk and opportunity analysis and near-term resource allocation and programme management to be conducted.

— JAEA should adopt a clear strategy that aims to align waste storage capacities with the availability of planned disposal facilities for all waste categories, taking account of the possibility of delay in development of disposal facilities.

— JAEA should undertake periodic safety reviews of those facilities under permanent shutdown in order to ensure that safety is maintained over time, and to identify possible actions to further enhance safety, taking into account management of spent fuel and other nuclear fuel material.

— JAEA should ensure that its decommissioning cost assessment methods are further developed in order to provide a comprehensive understanding of total costs of dismantling of facilities, addressing uncertainties and risks.

— JAEA should establish a framework for addressing their skills, capabilities and number of personnel required to implement the programme, developing education and training programmes on decommissioning and waste management.

— JAEA should develop a strategy to promote expansion of the supply chain, implementing a partnering approach with suppliers that aligns with near term work planning activities and communicate with industry a detailed contracting plan, considering options and contracting approaches that ensure balanced sharing of risk and accountability.

— JAEA should conduct extensive characterization of all the main process equipment and cells of the plants, including sampling, in order to build a complete understanding of the nature and quantity of potentially problematic waste.

In summary, the ARTEMIS Review Team considered that JAEA is in a good position to

continue meeting high standards of safe and responsible management of decommissioning, radioactive waste and spent fuel, and identified recommendations and suggestions for further improvements. The ARTEMIS Review Team commends JAEA for the production of a roadmap that establishes the direction of its future programme and highlights the challenges faced.

The ARTEMIS Review Team commended the Japanese organizations and professionalism involved in the design and implementation of the 'Back-End Roadmap', as demonstrated by the deliberate actions taken, the professionalism displayed by all, and the commitment to safety in all its efforts.

I. INTRODUCTION

At the request of the Government of Japan, specifically the Ministry of Education, Culture, Sports, Science and Technology (MEXT), the International Atomic Energy Agency (IAEA) organized an ARTEMIS review of the long-term policy of the Japan Atomic Energy Agency (JAEA) on decommissioning of its installations and processing and disposal of associated radioactive waste, as indicated in the 'Back-End Roadmap' published in December 2018.

The general objective of the ARTEMIS Peer Review Service is to provide independent expert opinion and advice on radioactive waste and spent nuclear fuel management, decommissioning and remediation, based upon the IAEA safety standards and technical guidance, as well as on international good practice. ARTEMIS Peer Reviews are organized jointly by the Department of Nuclear Safety and Security and the Department of Nuclear Energy of the IAEA.

This Review is being performed by a team of eight senior international experts, selected by the IAEA, in the fields of decommissioning and radioactive waste and spent fuel management, with IAEA staff providing coordination and administrative support. After a preparatory meeting in September 2019, and receipt of Advanced Reference Material (ARM) in January/February 2020, the ARTEMIS Review team examined the ARM and identified a number of 'Initial Review Questions (IRQ)', which were sent to the Japanese counterparts on 30 June 2020. The intention of these questions was to assist the counterparts in understanding the interests of the Review Team and so be better able to address the questions during the subsequent Mission.

II. OBJECTIVES AND SCOPE

The objective of the ARTEMIS review was to provide an independent international evaluation of JAEA's 'Back-End Roadmap', with a particular focus on the estimation of future liabilities. The back-end programme covers 79 facilities, including nuclear reactors, nuclear fuel uses facilities, reprocessing facilities, fuel fabrication facilities and waste management facilities.

The Review findings are intended to assist MEXT and JAEA in aligning the planning and implementation of decommissioning, and the robustness of the decommissioning cost estimates, with good international practice.

The review was organized by the Department of Nuclear Energy and the Department of Nuclear Safety and Security of the IAEA. The Back-End Roadmap was evaluated against the relevant IAEA Safety Standards and technical reports, together with proven international practice and experiences by an international peer review team selected by the IAEA.

In accordance with the Terms of Reference for the review agreed between the IAEA and MEXT/JAEA, the review covers three important elements of the back-end programme:

- The overall adequacy of the 70-year programme of decommissioning and waste management
- The methodology of cost estimation, covering all steps from decommissioning to waste disposal
- Ensuring the effective implementation of the programme, including the project management and contracting strategy.

The Review addressed programmatic, technological and safety considerations, organized according to seven specific topical areas:

— Optimization of the Overall Decommissioning Programme
— Waste Management
— Nuclear Fuel Material Management
— Decommissioning Cost Assessment
— Waste Cost Assessment
— Project and Contract Management
— Technology for Decommissioning

III. BASIS FOR THE REVIEW

III.1 PREPARATORY WORK AND IAEA REVIEW TEAM

On 15 May 2019 the Government of Japan, via MEXT, formally requested the IAEA to undertake an ARTEMIS review of the long-term policy of the Japan Atomic Energy Agency (JAEA) on decommissioning of its installations and processing and disposal of associated radioactive waste, as indicated in the 'Back-End Roadmap' published in December 2018.

At the request of the Government of Japan, a preparatory meeting for the ARTEMIS Review was held at the offices of the JAEA on 3-4 September, 2019, in Tokyo, Japan. The preparatory meeting was attended by the ARTEMIS Team Leader, Mr Francesco Troiani, the IAEA Coordinator, Mr Patrick O'Sullivan, Mr Koji Kamitani (IAEA), together with senior personnel from MEXT and from the JAEA.

The preparatory meeting comprised discussions on:

— The Terms of Reference for the ARTEMIS review of the JAEA Back-End Roadmap, in accordance with the request by the Government of Japan; and
— The relevant detailed aspects for organization and conduct of the review.

IAEA staff presented the ARTEMIS principles, process and methodology. This was followed by a discussion of the deatiled planning of the ARTEMIS review mission to Japan, which was originally envisaged to occur in May 2020. As a result of restrictions associated with the Covid-19 pandemic, the Mission was postponed, initially to October 2020 and eventually to April 2021. It was also decided that, as a result of these restrictions, the review could only be undertaken on a virtual basis.

III.2 REFERENCES FOR THE REVIEW

The draft guidelines for the ARTEMIS review service and the Advanced Reference Material and materials presented during the mission and associated discussions. The complete list of IAEA publications used as the basis for this review is provided in Appendix E.

III.3 CONDUCT OF THE REVIEW

The ARTEMIS Entrance Meeting was organized on a virtual basis on Monday, 12 April 2021, with the participation of the ARTEMIS Review Team and senior management and staff from MEXT and JAEA. Opening remarks were made by Mr. Horiuchi Yoshinori, Deputy Director General, MEXT, by Mr Ito Yoichi, Executive Vice President, JAEA, by Mr Christophe Xerri,

Director of the Division of Nuclear Fuel Cycle and Waste Technology, Department of Nuclear Energy, of IAEA, Mr Francesco Troiani, the ARTEMIS Team Leader, and by Mr Patrick O'Sullivan of IAEA.

During the ARTEMIS Review Mission, a review was conducted of all of the topics identified in the Terms of Reference in accordance with the agreed review scope. The overall aim of the review was to provide the Government of Japan and authorities with recommendations and suggestions for improvement and, where appropriate, to identify good practice. The ARTEMIS Review Team performed its review according to the mission programme provided in Appendix B.

The ARTEMIS Exit Meeting took place remotely on Thursday, 22 April 2021. Opening remarks were made by Mr Ito Yoichi of JAEA. A presentation of the results of the Review Mission was given by the ARTEMIS Team Leader, Mr Francesco Troiani. Closing remarks were made on behalf of the IAEA by Mr Christophe Xerri. Closing remarks on behalf of MEXT were made by Mr. Horiuchi Yoshinori.

1. OPTIMIZATION OF THE OVERALL DECOMMISSIONING PROGRAMME

1.1. ORGANIZATIONAL ARRANGEMENTS

MEXT/JAEA Position

JAEA is responsible for 79 nuclear installations and over the next 70 years there will be a range of R&D, operations and decommissioning activities taking place in order to meet the mission of JAEA as required by MEXT and the Government of Japan.

JAEA has conducted an assessment of the nuclear infrastructure under its management, identifying a number of facilities essential to maintain meet its nuclear R&D function, which will remain in continuous use for as needed.

JAEA has identified 46 facilities that will continue to be used over the near to medium term, and 43 facilities which require to be dismantled. For risk mitigation, priority is given to;

1) Facilities that have a large inventory of radioactive materials
2) Facilities that have considerably aged
3) Facilities that have unstable contaminated equipment.

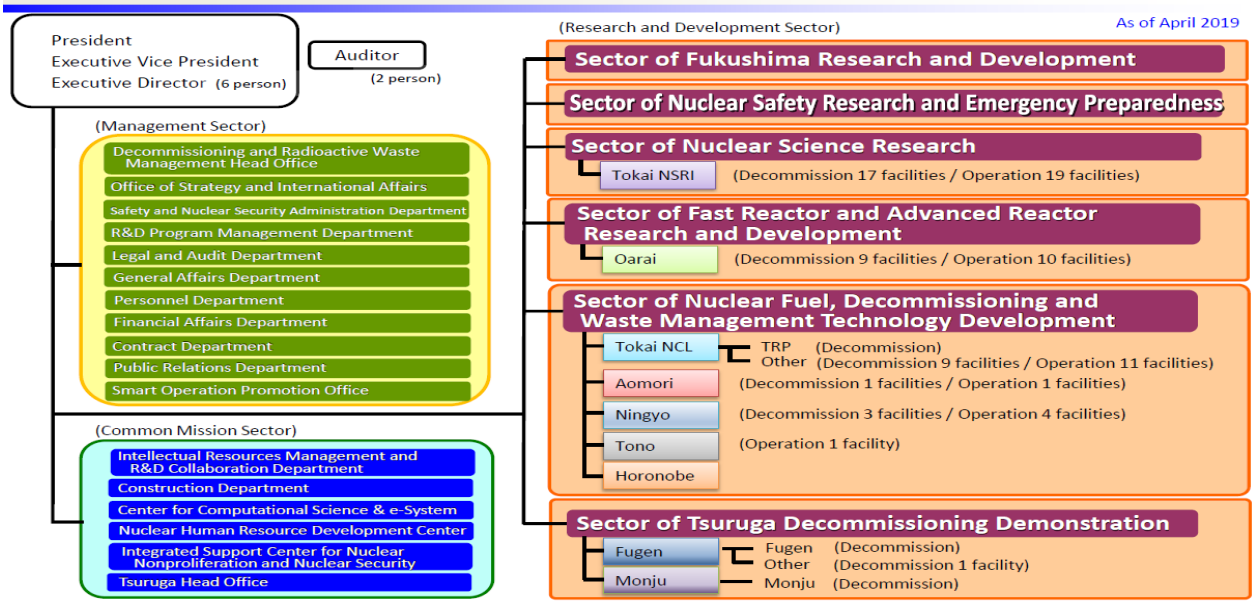
JAEA's strategy to prioritize the structures to be dismantled is based on some key choices, such as the effective mitigation of radiological risk, with the best possible cost optimization.

Across these, JAEA is focused on prioritizing those facilities with high operating costs, where it is possible to obtain the greatest benefits in terms of overall cost reduction and global cost optimization. Among the latter, the Fugen and Monju plants (Fukui Prefecture), and the Tokai reprocessing plant (Ibaraki Prefecture), in terms of size, complexity and cost are those that pose the most relevant challenges of the entire JAEA decommissioning plan.

During the discussion with the JAEA counterparts, the current organizational arrangements for its facilities and associated its budgets and programmes were expanded. JAEA noted the challenges of motivating staff to make the transition from an R&D focus to a decommissioning focus - acknowledging that this is more challenging on sites where both activities are taking place but less challenging on sites that have completely transitioned to decommissioning, for example, Fugen.

During the presentation and discussion JAEA described the organizational arrangements that currently exist for managing their different sites and the facilities within the sites. These included arrangements for ensuring that requirements of their site licenses are met. JAEA noted the importance of knowledge management as part of this programme.

3. JAEA Organogram



ARTEMIS Observation

The Review Team observed that JAEA is in a period of transition from an organization with a long history of nuclear related R&D that has served the needs of the Japanese Government and the country's nuclear industry, to one that must carry out both its original R&D mission and the new mission of safe, effective, reliable and cost-effective decommissioning of some of its facilities. With time, the balance of effort may evolve with an increasing focus on decommissioning activities. The approach needed for these different roles have some common elements but there are also some very distinct requirements.

The Review Team observed that JAEA has a number of governance committees and departments linked with its routine operations and its transition to decommissioning. It also appears that some facilities report progress for R&D activity separately from decommissioning. It may be possible for JAEA to more strongly focus and align its organizational structure more closely with its dual mission objectives. This will require engagement and discussion with a range of organizations including MEXT.

Opportunities to optimize the overall programme could be strengthened with enhanced organizational focus. There are examples in other countries where this has been done. For example, in the UK, the Nuclear Decommissioning Authority (NDA) is responsible for 17 decommissioning sites. Operations are still carried out on some of these sites, for example reprocessing of Magnox fuel at Sellafield and, in these cases, there is a clear separation between the operations organization and the decommissioning organization. Further examples include the European Commission's Joint Research Centre (JRC), a research organization with a large number of sites and facilities, including nuclear facilities. In 2020, JRC reorganized its organizational structure and working arrangements to more clearly separate its ongoing R&D work from its decommissioning and radioactive waste management programme. The French Alternative Energies and Atomic Energy Commission (CEA) is structured with a clear separation of its decommissioning and waste management mission from its research and operational responsibilities and activities. In 2008, Orano formed a Decommissioning Business

Unit to separate decommissioning from other parts of its business, for example, reprocessing activities. In the USA, the Department of Energy's Office for Environmental Management (DOE-EM) was formed in 1989 to address nuclear legacy facilities and wastes, separating it from R&D. Where both activities occur at a geographic site, they are managed by different organizations and implemented through separate contracts. The Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA), began to decommission four permanently closed nuclear facilities in the late 1990s. It soon became clear that carrying out research and decommissioning in parallel presented challenges for effective delivery of the decommissioning projects. In 2003 all of ENEA's decommissioning activities were transferred to SOGIN, the Italian national decommissioning and radioactive waste organization, to enable a single focus on decommissioning for these facilities.

1	RECOMMENDATIONS, SUGGESTIONS AND GOOD PRACTICES
Observation: *JAEA plans to carry out the safe operation of a range of R&D and operational facilities at the same time as progressing with decommissioning activities. The current organizational division of responsibilities appears to be combined rather than clearly delineated.*	
(1)	**BASIS**: GSR Part 2 – Leadership and Management for Safety Requirement 2: Demonstration of leadership for safety by managers *"Managers shall demonstrate leadership for safety and commitment to safety."*
(2)	**BASIS**: GSR Part 6 – Decommissioning of Facilities Requirement 9: Financing of decommissioning *"Responsibilities in respect of financial provisions for decommissioning shall be set out in national legislation. These provisions shall include establishing a mechanism to provide adequate financial resources and to ensure that they are available, when necessary, for ensuring safe decommissioning."*
(3)	**BASIS**: GSR Part 2 – Leadership and Management for Safety Requirement 4: Goals, strategies, plans and objectives. *"Senior management shall establish goals, strategies, plans and objectives for the organization that are consistent with the organization's safety policy."*
R1	**Recommendation:** JAEA should review a range of options to more clearly separate their organisational and resourcing (people and budget) responsibilities for R&D and decommissioning to strengthen the focus on each mission.

1.2 PROGRAMME OPTIMIZATION PROCESS

MEXT/JAEA Position

JAEA provided a high-level overview of the planning processes that are currently in place. These include the 10-year 'Medium/Long-term Management Plan of JAEA's Facilities' and the 'Plan to Achieve Medium to Long-Term Objectives of JAEA' (7-year Medium to Long-term Plan). They recognized that the data underpinning the 10-year mid-to-long term plan continues to be developed and that this is not fully reflected in the 7-year plan. In addition, JAEA referred to the current levels of integration and noted that there were opportunities to do more in this area which could maximize the potential efficiencies by not foreclosing options.

The operational reviews carried out since the Great East Japan earthquake in 2011 pointed to the need to decommission many more facilities. This adds significant additional complexity to decommissioning planning for JAEA.

The Advanced Reference Material included a summary bar chart showing the outline timing for decommissioning of all facilities. During the review, information was further provided on the more detailed planning tools being used at Fugen and Monju. Different software planning tools are used for each of these sites because the Fugen decommissioning project began several years before the Monju project.

Risk and opportunity analysis is at an early stage of evolution and there is a desire to be able to utilize these tools more effectively to be able to better understand ways of optimizing the overall programme.

JAEA provided an explanation of the interaction with Nuclear Regulatory Authority (NRA) with regard to approval of the overall decommissioning plan followed by further more detailed applications.

ARTEMIS Observation

The Review Team recognizes that JAEA is at an early stage of developing its decommissioning planning, and that a relatively small number of its facilities have been fully decommissioned.

To enhance the capability for optimization of the overall programme it is important to be able to compare projects at facilities and sites in a consistent way. A common basis for detailed planning, including risk and opportunity analysis, would enable effective scenario planning to be carried out and would facilitate modelling of a range of factors important to successful programme outcomes. This could include, for example, budget increases and decreases, resourcing availability and waste storage availability. Recognizing that it will take time to implement a uniform systematic way to do this, it should be possible, in the interim, to develop a common reference system (e.g., work breakdown structure, resource coding, procurement planning) to enable programme level oversight. This enables development of a detailed plan for each facility and site.

There are many positive case studies from other international programmes which could be regarded as industry best practice. For example, in the UK, when the Nuclear Decommissioning Authority (NDA) was formed in 2004, it needed to establish a common baseline across its areas of responsibility. It defined a systematic approach in a series of Programme Controls Procedures, developed in line with its Baseline Management System Programme Controls

Procedure Manual. In the USA, DOE-EM utilizes detailed, site-specific baselines to support its approach to award contracts for decommissioning (in some cases, up to 10-year duration), and is also able to synthesize all 17 sites into an overall programme estimate. The European Commission's JRC established a Decommissioning & Waste Management (D&WM) Programme in 1999, which covers all its nuclear facilities at four different sites. The planning and budget of the D&WM Programme are periodically reviewed in order to align progress of projects with priorities, and with needs of the programme as a whole. This process also provides the data for the preparation of the future budget requests.

These detailed plans will provide the basis for the Facilities Management Promotion Committee and Back End Head Office to review execution, drive budget requests and identify opportunities for optimization. (See also Observations 16 and 17)

The decommissioning plans should be periodically reviewed, the timing depends on many factors and so the periodicity for plan review should therefore have some flexibility. Experience internationally suggests that conditions within decommissioning programmes can change, sometimes quite suddenly, and it is important that stakeholders understand this. Scenario planning can be very helpful in being ready to respond to such changes.

2	RECOMMENDATIONS, SUGGESTIONS AND GOOD PRACTICES
Observation: *The Back-End Roadmap provides an initial lifecycle strategy and vision for completing decommissioning. The detailed planning is at an early stage of development. The opportunity exists to significantly strengthen the strategy through incorporation of industry best practice in project planning.*	
(1)	**BASIS**: GSR Part 2 – Leadership and Management for Safety Requirement 4: Goals, strategies, plans and objectives. *"Senior management shall establish goals, strategies, plans and objectives for the organization that are consistent with the organization's safety policy."*
(2)	**BASIS**: GSR Part 6 - Decommissioning of Facilities: Requirement 2: Graded approach in decommissioning *"A graded approach shall be applied in all aspects of decommissioning in determining the scope and level of detail for any particular facility, consistent with the magnitude of the possible radiation risks arising from the decommissioning."*
R2	**Recommendation:** JAEA should develop an integrated unified resource loaded programme schedule which would enable programme level risk and opportunity analysis and resource allocation planning to be conducted.
S1	**Suggestion:** JAEA should consider how to identify and evaluate alternative scenarios and integration opportunities. This could lead to greater efficiencies

	and effectiveness in its programme in order to maximize progress within funding constraints.
S2	**Suggestion:** Given the large number of structures to be decommissioned and the limited availability of human and financial resources, JAEA should consider, once the plant-by-plant priorities have been established, to proceed with the definition of an action programme for each plant, and then evaluate any interdependencies between these plans.
S3	**Suggestion:** JAEA should consider carrying out periodic reviews of the decommissioning plans. This should be done on an ongoing basis throughout the programme, since the circumstances and conditions can change continuously and quite suddenly during decommissioning.

1.3 PROGRAMME PLANNING

MEXT/JAEA Position

The JAEA Back End Roadmap covers decommissioning, processing, storage and disposal of waste and management of nuclear fuel material.

The 1st period of about 10 years (until FY2028) is devoted to implementing back-end measures while giving priority to ensuring safety of facilities, such as measures to ensure conformity with new regulatory standards, measures to strengthen the countermeasures against the earthquake, measures against the ageing of nuclear facilities and risk reduction measures.

The 2nd period of about 20 years (from FY2029 to FY2049) is a transitional period toward full-scale decommissioning through the implementation of the disposal of radioactive waste and the establishment of waste processing facilities. During this period JAEA intends to introduce an appropriate process management mechanism to adjust the plan to the variably changing condition of the facilities along with the progress achieved, by setting hold points in the decommissioning process for each facility.

The 3rd period of about 40 years (from FY2050 to end) is dedicated to implementing full-scale back-end measures toward completion.

ARTEMIS Observation

The Review Team observed that JAEA has a structured approach to the 70-year time period for decommissioning, with three distinct periods to support the planning activities. The detail within these periods understandably changes in line with the amount of information available. It is typical for more detail to be available in the near term with less detail available in the longer term.

The relationship between the JAEA plans, e.g., the 7-year and 10-year plans referred to in 1.2 above, is important. Effective delivery of the decommissioning programme requires that the key interactions are understood and the key dependencies are highlighted. These includes factors such as rate of waste arisings, viability of storage facilities (on-site and off-site),

resource availability and technology deployment. Bringing these aspects together into a single executable near-term work plan, should make it possible for JAEA to enhance the effective and efficient delivery of the broad mission of decommissioning facilities and sites. The development of an entirely new plan should not be necessary, but rather development of what exists today, evolved for the purpose of work performance and delivery management.

Whilst this recommendation is focussed on the near term, JAEA should also consider opportunities within the second phase of activities, including undertaking early radiological characterization of the systems and components, where possible, and also commencing the environmental impact assessments required to support decommissioning. It may be possible to accelerate these activities therefore enabling greater efficiency of delivery at a later stage.

Development of a comprehensive near-term work plan relies upon a detailed, commonly coded project plan for each facility and site ('horizontal view'), so that for the delivery period (near term, medium term etc.) it is possible to look consistently through all these ('vertical' or 'integrated' view). Importantly, this does not mean there are multiple plans. The planning process should use the same source information but this may be displayed and analyzed differently for the different purposes. Accountability for the detail remains with the responsible person in each site or facility.

3	RECOMMENDATIONS, SUGGESTIONS AND GOOD PRACTICES
Observation: *The Review Team noted that there are a number of different plans (covering varying timeframes) for JAEA's decommissioning activities. There does not appear to be a clearly defined near-term plan, that is needed to form the basis of delivery. In addition, there are a number of critical decisions in the near term that are required in order for the programme to proceed to successfully deliver the Back-End Roadmap.*	
(1)	**BASIS**: GSR Part 6 - Decommissioning of Facilities Requirement 2: Graded approach in decommissioning *"A graded approach shall be applied in all aspects of decommissioning in determining the scope and level of detail for any particular facility, consistent with the magnitude of the possible radiation risks arising from the decommissioning."*
(2)	**BASIS**: GSR Part 6 - Decommissioning of Facilities Requirement 8: Selecting a decommissioning strategy *"The licensee shall select a decommissioning strategy that will form the basis for the planning for decommissioning. The strategy shall be consistent with the national policy on the management of radioactive waste."*
R3	**Recommendation:** JAEA should further develop a detailed near term work plan to be used alongside the Back-End Roadmap to communicate clearly its goals

	and priorities both in the near and long-term using the planning processes as required by MEXT.

1.4 STAKEHOLDER ENGAGEMENT

MEXT/JAEA Position

JAEA explained the large number of stakeholders that exist and the impacts they can have on their work. In this sense, the definition of stakeholder is used in its broadest sense including, for example, staff, regulators, national government, local government (prefectures, municipalities, towns etc.), businesses, the supply chain and local residents.

JAEA recognized that different stakeholders have different interests in their work and varying needs for information, dialogue and engagement. Many stakeholders have a long relationship with JAEA and are familiar with their R&D work they carry out but may be less familiar with the future decommissioning activities that will be taking place at the sites and facilities over the coming years.

JAEA explained the current position with regard to stakeholders, including the complexity of the interactions associated with its scope of activities. The importance of effective communication and engagement was emphasized.

ARTEMIS Observation

The ARTEMIS Review Team encourages JAEA to further expand its stakeholder engagement activities as it progresses with preparation for increased decommissioning planning and delivery. International experience highlights the value of early and continuous interaction the stakeholders during normal operational activities on a site and this is increased during periods of change. It is also important to understand the differing needs of stakeholders and the most appropriate ways to engage.

Early engagement with regulatory bodies is seen as very positive and has been recognized as good practice during recent meetings of the parties to the Joint Convention on Radioactive Waste Management and Spent Fuel Management.

JAEA could benefit from planning and implementing a holistic approach to stakeholder engagement that leads to a total picture view of the full range of topics needed for the Back End Roadmap to be optimized – with objectives such as:

- Raise awareness that facilities exist and decommissioning must proceed to address the inherent risks, which only increase as facilities age.
- Waste volumes will necessarily be generated through decommissioning and realistic plans are needed for their safe and efficient storage and ultimately their safe and efficient disposal.
- Waste management facilities are expensive, and it is in the public interest that these be optimized. It is in the national interest to reduce the cost and environmental impact of waste disposal, which can be achieved in part by ensuring wastes that do not require disposal to protect human health are diverted to other management routes – encouraging support for clearance.

— A lifecycle approach is needed to balance factors. No action is not an option and is likely to involve greater risk.
— There are significant opportunities for economic benefit to local communities – in future land use and near-term industry development, jobs, training, education, etc.

4	RECOMMENDATIONS, SUGGESTIONS AND GOOD PRACTICES
Observation: *There exists a wide range of recognized stakeholders that have the potential to affect JAEA decision making and activities across their sites and facilities. It is not clear if a comprehensive stakeholder analysis has been carried out showing the individual impacts and approaches that are needed.*	
(1)	**BASIS**: GSR Part 2 – Leadership and Management for Safety Requirement 5: Interaction with interested parties *"Senior management shall ensure that appropriate interaction with interested parties takes place."*
(2)	**BASIS**: NW-G-2.1 Policies and Strategies for the decommissioning of Nuclear and Radiological Facilities 5.10. *"Build a long-term trust among stakeholders engaged in the management of radioactive waste, decommissioning, and contaminated facilities and sites."*
R4	**Recommendation:** JAEA should further develop their stakeholder analysis process. This should identify approaches for engagement, dialogue and decision making based on a priority assessment. Any potential impacts to successful delivery should also be reflected in the relevant project and programme risk management.
S4	**Suggestion:** JAEA should consider seeking to develop and maintain an active dialogue with the regulator already at an early stage in the programme in order to build a mutual understanding concerning the principal elements of JAEA's back-end strategy. In doing so, JAEA should be seeking also to obtain insights into any issues that might give rise to regulatory concern, so that it might take appropriate mitigation steps in advance.

2. WASTE MANAGEMENT

2.1 WASTE INVENTORY

MEXT/JAEA Position

Radioactive waste in Japan is classified into two main classes according to its level of activity, namely high-level radioactive waste (HLW) and low-level radioactive waste (LLW). LLW is further subdivided into:

— L3: Very low-level radioactive waste (VLLW)
— L2: Relatively low-level waste
— L1: Relatively high-level waste
— Uranium waste
— Long-lived, low heat-generating transuranic (TRU) waste[1]

			Origin of waste	*Disposal concept*
Low-level radioactive waste (LLW)	**Long-lived, low heat-generating Transuranic waste (TRU)**		Waste generated from the operating and dismantling of reprocessing facilities and MOX fuel fabrication facilities	Geological Disposal
				Intermediate depth disposal
				Concrete vault disposal
				Trench disposal
	Waste from research facilities, etc.	**Relatively high-level waste**	Waste generated from research, research reactor, medical and industrial facilities using or producing radioisotopes	Intermediate depth disposal
		Relatively low-level waste		Concrete vault disposal
		Very low-level waste		Trench disposal
	Uranium waste		Waste generated from uranium enrichment and uranium fuel fabrication facilities	Not yet

At present, the estimation of waste volume, including expected future arisings, is reviewed every term seven years in the 'Plan to Achieve Medium to Long-term Objectives of Japan Atomic Energy Agency (Medium to Long-Term Plan)'. The inventory of wastes in storage is updated annually and reported to the regulator, as required by the relevant regulations.

ARTEMIS Observation

The ARTEMIS Review Team notes that the IAEA Specific Safety Guide on classification of radioactive waste (GSG-1) states that adequte determination and documentation of the characteristics of the waste form, the waste container and/or the waste package should be ensured to provide data necessary for decisions about the future management of the waste (e.g. for its disposal).

The Review Team considers that a prerequisite for planning of technical means required for managing radioactive waste in the defined planning timeframe (e.g. 70 years) is the establishment, and regular updating an inventory of all radioactive waste to be managed, providing information on the waste source, location, quantity and properties (including both radiological and chemical). The inventory should include all radioactive waste requiring management: existing waste and that which is predicted to arise from future nuclear activities.

[1] Waste destined for geological disposal is sometimes unofficially designated as 'L0'.

It is essential that data used to compile the inventory is credible, collected in a consistent and efficient manner and is presented appropriately to meet stakeholder needs and requirements. Once the current and future waste inventories have been established, their assessment will enable the identification of management needs for dealing with identified waste streams.

The ARTEMIS Review Team acknowledged that JAEA has developed an inventory of all types of radioactive waste. It should continue its ongoing efforts to identify and implement areas for improvements in its waste inventory approach.

In comparison to current practice in countries with similarly large and complex inventories, the level of detail provided in the Back-End Roadmap radioactive waste inventory is limited to numbers and volumes of conditioned waste packages and weights of unconditioned waste. More detailed information about future inventory projections is needed to support future waste managing planning. As a mechanism for improving transparency with respect to inventory reporting, additional information could be provided giving a description of the main types of radioactive waste by location as well as the inventories for each waste type in terms of current and projected weight or volume of unconditioned waste, total activity, the current conditioned and projected waste volumes, and total number of packages.

The Review Team suggests that consideration should also be given to providing data on radioactive material that is not currently declared as radioactive waste, but may be in the future.

Detailed inventory information may be of particular value in relation to designing and assessing the safety of radioactive waste management facilities and activities (essential input for safety assessment).

The Review Team was informed that the inventory information on several problematic waste streams currently is incomplete as their characterisation poses technical challenges.

The Review Team considers that JAEA inventory projection in terms of equivalent 200-litre packages is useful and facilitates communication with the stakeholders.

The Review Team was told that there is a degree of stability around the total volume of lifetime arisings of radioactive waste. Although recognizing this view, the Review Team considers that, given the current early phase of programme implementation, it is likely that the total volume will change as strategies are further refined. It was emphasized that JAEA should maintain the inventory under configuration control so changes upward (in particular) warrant review and consideration of approaches to limit the increase or offset the impacts.

At present, the estimation of waste volume arisings is undertaken by JAEA every 7 years, which is longer than the intervals in other programmes internationally. In the UK and France, the revision period is 3-yearly, but in several other countries this timeframe is even shorter.

The Review Team concluded that JAEA should create a more detailed inventory and introduce a systematic process for its regular and more frequent updating. A more frequent review of the quality of the inventory data enables the identification of waste for which information is not fully available and where it can be improved. This need could then be incorporated into the waste characterization programme of the relevant facility.

The Review Team also sees value in using inventory reporting to monitor changes over time, i.e. comparison with previous inventories, as a mechanism for demonstrating the outcomes of waste minimization initiatives.

5	RECOMMENDATIONS, SUGGESTIONS AND GOOD PRACTICES
Observation: *JAEA has developed an inventory of all types of radioactive waste. However, the current inventory is not sufficiently comprehensive to inform waste management strategy. At present the estimation of waste volume arisings is reviewed by JAEA every 7 years which is longer than the intervals in other programmes internationally.*	
(1)	**BASIS**: GSR Part 3 - Radiation Protection and Safety Sources: International Basic Safety Standards Requirement 31, para. 3.131 (e) *"Registrants and licensees, in cooperation with suppliers, as appropriate: shall maintain an inventory of all radioactive waste that is generated, stored, (1) transferred or disposed of"*
(2)	**BASIS:** SSG-47: Decommissioning of Nuclear Power Plants, Research Reactors and Other Nuclear Fuel Cycle Facilities *8.37. ...The proper determination and documentation of the characteristics of the waste form, the waste container and/or the waste package should be ensured to provide data necessary for future management of the waste (e.g. for its disposal).*
S5	**Suggestion:** JAEA should consider introducing a systematic process for the regular and more frequent updating of the current 7-year inventory.

2.2 INTERDEPENDENCIES OF STORAGE AND DISPOSAL

MEXT/JAEA Position

JAEA's current strategy is to safely and securely store radioactive waste until disposal routes become available. It acknowledges that the implementation of storage and disposal options are impacted by external factors, and recognizes that the non-availability of storage facilities could impact on delivery of its overall programme. Retaining shutdown facilities over long periods may present risks of facility degradation and increased cost.

JAEA reported that only generic waste acceptance criteria (WAC) have so far been defined. Definition of final WAC are not possible, because the disposal site is not decided yet. It is important that such criteria be derived for long-term storage of waste.

ARTEMIS Observation

The Review Team believes that it is very important to take an integrated view of the Back-End Roadmap to ensure that influences from, and impacts on, back-end actions are clearly identified

and understood, enabling effective decision making to guarantee efficient, safe and secure management of the generated waste.

The Review Team encourages JAEA to fully observe interdependences among all steps in the predisposal management of radioactive waste, as well as the impact of the anticipated disposal options.

The Review Team recognizes the significant challenges associated with the very tight schedule of implementation of disposal facilities for various waste categories (L2 and L3).

The available storage capacity is forecast to be saturated by the 2030s and there is a need to licence a disposal site for L2/L3 waste as soon as possible. Given the complexity of the remaining challenges for site selection, safety assessment and licensing, the ARTEMIS Review Team observes that the identified planning milestone of L2/L3 disposal being available in 2028 (as documented in the ARM) is extremely challenging.

To implement the Back-End Roadmap, a carefully planned storage strategy should be devised looking at possibilities such as:

— Lifetime extension of the existing facilities (with due consideration to the aging status);
— Repurposing of existing buildings (from decommissioned facilities) to storage facilities;
— Construction of new interim stores (especially for waste destined for geological disposal[2] or intermediate depth disposal (L1)) considering long enough design life, with appropriate care and maintenance programmes in place.

The Review Team recognizes the significant challenges associated with the deriving the generic storage and disposal WAC. This is important with regard to the question of whether it can be assumed that susequent site-specific WAC will be consistent with the generic WAC and any pre-disposal waste management activities undertaken to enable decommissioning to proceed. This represents a key issue with regard to the interdependencies between different steps of waste management, i.e. between the planning of waste treatment and waste disposal facilities being conducted in parallel. If there are substantial differences between generic and site-specific WAC for the disposal facilities, significant issues could result for the overall programme if waste treatment facilities have been planned and possibly already constructed based on the generic WAC. It is also possible that packaged wastes will require additional handling and packaging to meet the final disposal WAC.

The Review Team encourages JAEA to consider that there are many pre-disposal activities which can and should be undertaken despite L2/L3 disposal facilities not having been established and in the absence of site-specific WAC. For example:

— Make sound and bounding assumptions about waste form and package size and proceed with processing and packaging where it makes sense to do so.
— Ensure the details and results should be fully considered to drive future disposal to ensure it accommodates what has been packaged.

[2] Waste destined for geological disposal is sometimes unofficially designated as ‘L0’.

— Consider the evaluation and use of waste management information from other programmes/sites that have proven to be adequate and which provide a bounding representation of what JAEA will face for L2/L3 disposal.
— Proceed with dismantling, where necessary to address safety issues, and place wastes in a configuration that facilitates their future processing
— Characterize the wastes at the time of initial packaging.

The ARTEMIS Review Team suggests that consideration be given to improving the generic WAC to ensure these are sufficient to preclude large future impacts on programme implementation, time scales and costs. The risks resulting from possible changes of the WAC for the future facilities should be identified and evaluated. The development of bounding, generic WAC facilitates mitigation of the risks identified.

6	RECOMMENDATIONS, SUGGESTIONS AND GOOD PRACTICES
Observation: *The Review Team notes that the current storage capacity for short-lived radioactive waste is likely to be saturated by the 2030s whereas a disposal facility for L2/L3 waste is unlikely to be available on this timeframe. To advance progress in development of needed disposal capacity the Review Team noted a need for JAEA to progress to the next phase with minimal delay, i.e. from a conceptual design for a generic site towards basic design for a site-specific phase and associated safety cases.*	
(1)	**BASIS**: GSR Part 5 - Predisposal Management of Radioactive Waste Requirement 6.: *"Interdependences among all steps in the predisposal management of radioactive waste, as well as the impact of the anticipated disposal option, shall be appropriately taken into account."*
R5	**Recommendation:** JAEA should adopt a clear strategy that aims to align the storage capacities with the availability of the disposal facilities (L2/ L3), taking account of the possibility of delay.
S6	**Suggestion:** JAEA should consider approaches to further improve its safety cases for L2 and L3 disposal facilities, proceeding towards generic site conceptual designs, in order to move the process forward in a timely manner and consistent with its continuous improvement initiatives.

2.3 WASTE HIERARCHY

MEXT/JAEA Position

Material generated from operation and maintenance of nuclear facilities and from facility decommissioning, having very low radioactivity concentrations, is classified as 'material not required to be handled as radioactive waste', following approval and confirmation by the NRA. It is appropriate that such material can be appropriately recycled or disposed of within a

clearance framework. Clearance levels have already been published for solid waste from light water reactors, gas-cooled reactors, heavy water reactors, fast breeder reactors and fuel-cycle facilities, together with details of methods for their certification.

There are four principles for the treatment and disposal of radioactive waste clearly set in the 'Framework for Nuclear Energy Policy':

1) The liability of generators
2) Minimization of radioactive waste
3) Rational treatment and disposal
4) Implementation based on mutual understanding with the public.

Following the waste minimization principle, the operators conduct initiatives to minimize the quantity of such waste and in so doing reduce the resources required for its management.

Under the clearance system that has been established, operators seek the 'Approval of Methods on Radioactivity Concentration Measurement and Evaluation' for concrete, metals, and other materials generated from the nuclear installation in question, pursuant to the provisions of the Reactor Regulation Act. Material with a radioactivity concentration below the reference value does not need to be managed as radioactive waste. JAEA is currently storing or reusing materials suitable for unconditional reuse.

The *Basic Policy for Nuclear Energy* states that some nuclear industry and R&D institutions are running short of waste storage capacity. To ensure the smooth implementation of full-scale decommissioning in the years ahead, it will therefore be necessary to secure suitable waste disposal sites and to expand their capacity by means of clearance process. A pressing challenge here is securing the understanding of the general public and local residents, which is an important prerequisite for implementation of such activities.

ARTEMIS Observation

The Review Team acknowledges JAEA's efforts on minimizing the radioactive waste and encourages it to further promote the fundamental principle of waste minimization.

The Review Team considers that JAEA should pursue effective volume reduction techniques and decontamination methods to significantly reduce the amount of radioactive waste. The operators (waste producers) should conduct further initiatives to minimize the quantity of waste and in so doing reduce the resources required for its management.

JAEA should consider how to further facilitate changes in waste management behaviours and culture to ensure waste producers consider all stages in the waste hierarchy (waste avoidance, waste minimization, and waste segregation).

7	RECOMMENDATIONS, SUGGESTIONS AND GOOD PRACTICES

Observation: *The Review Team noted that JAEA has developed a clearance process that has been approved by the regulator. However, waste minimization activities may be restricted by practical difficulties in releasing cleared material from their nuclear sites.*

(1)	**BASIS**: SF-1 Princ.7. 3.29. *"The generation of radioactive waste must be kept to the minimum practicable level by means of appropriate design measures and procedures, such as the recycling and reuse of material"*.
(2)	**BASIS**: GSR Part 5- Predisposal Management of Radioactive Waste Requirement 8: *"All radioactive waste shall be identified and controlled. Radioactive waste arisings shall be kept to the minimum practicable."*
(3)	**BASIS**: SSG-47 - Decommissioning of Nuclear Power Plants, Research Reactors and Other Nuclear Fuel Cycle Facilities *Specific plans for the reuse, recycling, storage or disposal of the waste should be developed. Such plans should aim to minimize the volume of waste to be disposed of as radioactive waste, facilitate future downstream processing of the waste and reduce overall costs.*
S7	**Suggestion:** JAEA should consider further developing effective volume reduction techniques and decontamination methods, in order to significantly reduce the amount of radioactive waste produced. It should also consider initiatives aimed at encouraging the use of recycled materials.

2.4 MANAGEMENT STRATEGY FOR L1 WASTE

MEXT/JAEA Position

Regulation for intermediate depth disposal of L1 waste was discussed in 2015 by a specialist Nuclear Regulatory Authority (NRA) sub-committee, which also took into consideration radioactive waste generated from commercial nuclear power plants. This Committee's discussions were focused on classification of radioactive waste to be disposed for an intermediate depth repository, requirements for repository design and institutional control, assessment scenarios, and dose criteria for safety assessment.

ARTEMIS Observation

The Review Team understands that the current strategy for L1 waste envisages its disposal in an intermediate depth repository, the schedule for which is yet to be determined.

The Review Team noted that the inventory of this type of waste is yet to be completed, and it is likely that current storage capacity will be insufficient for storage needs pending the availability of the envisaged repository. These factors present a risk to the successful implementation of the roadmap.

The Review Team considers it important to enable necessary waste packaging and storage plans (to enable decommissioning of related facilities). In line with the suggestions made for L2/L3, JAEA should consider those activities they can undertake to prepare L1 for future disposal, including developing safety cases for pre-disposal activities. Doing so enables JAEA to develop rational plans for the wastes that will be generated by decommissioning, despite uncertainty in

the timing of and requirements for L1 disposal. TRP provides a pertinent example: this facility will generate L1 wastes and JAEA has identified it as one of its higher priority projects. Delays in implementation of an L1 disposal facility would have likely impacts on implementation of the TRP decommissioning plan. Developing a generic safety assessment around some general assumptions for L1 waste would help mitigate this risk.

8	RECOMMENDATIONS, SUGGESTIONS AND GOOD PRACTICES
Observation: *The current strategy for L1 waste envisages its disposal in an intermediate depth repository, the schedule for which is yet to be determined. The Review Team noted that the inventory of this type of waste is yet to be completed and it is likely that current storage capacity will be insufficient for storage needs pending the availability of the envisaged repository. These factors present challenges to the successful implementation of the Back-End Roadmap.*	
(1)	**(1)** SSR-5 - Disposal of Radioactive Waste Paragraph 2.24 *"The impact of non-radioactive material present in a disposal facility has to be assessed in accordance with national or other specific regulations and this may be significant in some cases, for example, for some mining wastes and mixtures of radioactive and toxic wastes. If non-radioactive material may affect the release and migration of radioactive contaminants from the radioactive waste, then such interactions have to be considered in the safety assessment."*
(2)	No. GSR Part 6 - Decommissioning of Facilities *Requirement 14: Radioactive waste management in decommissioning* *8.7. Radioactive waste, arising from operational activities, that remains at the facility and radioactive waste that is generated during decommissioning shall be disposed of properly. If disposal capacity is not available, radioactive waste shall be stored safely in accordance with the relevant requirement.* *8.8. Prior to starting decommissioning, the licensee shall ensure the availability of adequate processing and storage capabilities and transport packages for the radioactive waste.*
(3)	SSG-47 - Decommissioning of Nuclear Power Plants, Research Reactors and Other Nuclear Fuel Cycle Facilities *8.34…. The waste management plan should define the manner by which material and radioactive waste will be removed from the facility and the means for segregating radioactive waste from non-radioactive and hazardous waste. The waste management plan for decommissioning should be part of the decommissioning plan.*

	8.35. If existing waste processing systems cannot cope with the waste generated during decommissioning with respect to the volumes or types of waste expected, the construction of new facilities for storage or waste processing or the use of existing facilities for storage should be considered. *8.36. .... The licensee should ensure that the waste management plan for decommissioning is implemented and maintained* *8.38. Decisions on the processing of radioactive waste generated in decommissioning should take into account existing or anticipated options for waste disposal.*
R6	**Recommendation:** JAEA should conduct appropriate L1 waste management, including providing storage capacity, until a disposal facility is available.
S8	**Suggestion:** In light of the interdependencies between the different steps of waste management, JAEA should consider developing safety cases for pre-disposal activities for L1 waste.

3. NUCLEAR FUEL MATERIAL MANAGEMENT

3.1 SAFETY MANAGEMENT OF FACILITIES WITH NUCLEAR FUEL MATERIAL

MEXT/JAEA Position

JAEA considers the nuclear fuel material it possesses should generally be regarded as a resource, e.g., for use in future research. However, some of this material may be difficult to reuse for technical or economic reasons. In managing nuclear fuel material, appropriate material accountancy controls, transparent safeguards measures and strict nuclear security, as well as securing safety, are to be considered as basic requirements.

The general framework of the management of nuclear fuel material is described below.

- Surplus nuclear fuel material is to be used for R&D in accordance with the government's energy policy, including the nuclear energy policy, or to be transferred to entities in Japan and overseas.
- Nuclear fuel material which is not to be transferred should be stored at JAEA. Nuclear fuel material whose reuse is difficult should be stored for the time being, pending a decision on final disposition. Meanwhile, setting disposal as a final goal, necessary measures will be taken to stabilize the material. At the same time JAEA will pursue the development of technology to make it difficult to separate weapon-usable material and divert it to weapons purposes. JAEA will also explore possibilities of the disposal in other countries.
- JAEA will reduce overall risks and costs for the storage by the consolidation of storage and reduction of the number storage facilities subject to physical protection.
- During the 1st period (until FY2028), nuclear fuel material located at the facilities categorized to be decommissioned in the Medium/Long Term Management Plan of JAEA Facilities, is to be consolidated in facilities planned for ongoing use, with the exception of material scheduled to be transferred to other entities. However, depending on the limitations for the transferred facilities, part of the materials will be consolidated at new facilities.
- During the 2nd period and thereafter, the consolidation of storage in new facilities will be implemented in a phased manner together with the effective utilization of existing facilities in order to enable the decommissioning of in line with the Medium/Long-Term Management Plan of JAEA Facilities.
- JAEA will take note of and follow the procedures required for nuclear fuel material by the safeguards agreement with IAEA and bilateral nuclear cooperation agreements, in consolidating the storage and in transferring nuclear fuel material in and out of Japan.

The 1957 Act on the Regulation of Nuclear Source Material, Nuclear Fuel Material, and Reactors (the Reactor Regulation Act) provides regulation for all aspects of nuclear use in Japan. The Act was revised in September 2012.

On the basis of the 2012 revision, severe accident measures have been added to the regulations applicable to commercial nuclear power reactors, fuel fabrication and enrichment facilities and reprocessing facilities. Periodic Assessment of Safety Improvement, which is the comprehensive safety assessment periodically conducted by licensees, has been introduced as

a requirement. Licensees are obliged to submit the result of Periodic Assessment of Safety Improvement to the NRA and make it publicly available.

During the Review the ARTEMIS Review Team was informed by the counterparts that:

- Periodic safety review only applies to commercial nuclear power reactors, fuel fabrication and enrichment facilities and reprocessing facilities.
- JAEA's activities are outside the scope of this legal requirement, and there is no mandate for JAEA to undertake such assessments.
- Safety assessments are included in the decommissioning plans submitted for approval to NRA.

ARTEMIS Observation

The ARTEMIS Review Team recognizes that JAEA, as a nuclear operator and research organization, maintains a high level of safety in its facilities.

The ARTEMIS Review Team wishes to emphasize that the safety assessment should demonstrate consistency among the safety measures during the entire process of decommissioning, and it should be updated when necessary to reflect the ongoing changes in the status of the facility, as decommissioning actions progress.

The safety case and supporting safety assessment, including the management systems used for their implementation, should be periodically reviewed in accordance with regulatory requirements. The review of management systems should include aspects of safety culture. In addition, the safety case and supporting safety assessment should be reviewed and updated:

- When there is any significant change to the facility or to its radionuclide inventory that may affect safety.
- When changes occur in the site characteristics that may impact on the storage facility, e.g., industrial development or changes in the surrounding population.
- When significant changes in knowledge and understanding occur (such as from research data or from feedback of operating experience).
- When there is an emerging safety issue due to a regulatory concern or an incident.
- Periodically, at predefined periods, as specified by the regulatory body. Some States specify that a periodic safety review be carried out not less frequently than once in ten years.

The ARTEMIS Review Team recommends that JAEA should undertake periodic safety reviews of those facilities under permanent shutdown in order to ensure that there is no degradation of the safety conditions over time, and to identify possible actions to further enhance safety.

9	RECOMMENDATIONS, SUGGESTIONS AND GOOD PRACTICES

Observation: *JAEA, as a nuclear operator and research organization, is committed to maintaining a high level of safety in its facilities. Safety assessments are only included in the decommissioning plans submitted to NRA for approval prior to commencing*

decommissioning, and in the event of changes to the plan during implementation of decommissioning, in line with relevant regulations.	
(1)	**BASIS**: GSR Part 4 Safety Assessment for Facilities and Activities Requirement 12: Assessment of safety over the lifetime of a facility or activity The safety assessment shall cover all the stages in the lifetime of a facility or activity in which there are possible radiation risks.
(2)	**BASIS**: GSR Part 6 - Decommissioning of Facilities Requirement 3: Assessment of safety for decommissioning *"Safety shall be assessed for all facilities for which decommissioning is planned and for all facilities undergoing decommissioning."*
(3)	**BASIS:** SRS 77 Safety Assessment for Decommissioning 2.8 SAFETY REVIEW "*It is good practice for the safety assessment to be reviewed by experts other than those who contributed to its development. This independent review is normally carried out by, or on behalf of, the operator. There may also be a review carried out by, or on behalf of, the regulatory body. This is referred to in this report as a regulatory review to distinguish it from the operator's independent review."* CONTROL OF CHANGES TO SAFETY ASSESSMENTS *"A decommissioning activity or operation may be changed or modified as compared with that planned in the original strategy and scope of work set out in the decommissioning plan. If such changes are safety related and affect the validity of the safety arguments, it is important that the original safety assessment is reviewed and, if necessary, modified to properly reflect and justify the changes to the plan".*
R7	**Recommendation**: JAEA should undertake periodic safety reviews of those facilities under permanent shutdown in order to ensure that safety is maintained over time, and to identify possible actions to further enhance safety.

3.2 MANAGEMENT OF FUEL FRAGMENTS & DEBRIS

MEXT/JAEA Position

Surplus nuclear fuel materials are to be used for R&D in accordance with the Government of Japan's energy policy, including the nuclear energy policy, or to be transferred to entities in Japan and overseas. As noted above, this means that nuclear fuel material which is not to be transferred elsewhere should be stored at JAEA. Nuclear fuel material whose reuse is difficult should be stored for the time being, pending a decision on its final disposition. Meanwhile, setting disposal as a final goal, necessary measures will be taken to stabilize the material. At the same time, JAEA will pursue the development of technology to make it difficult to separate

weapon-usable material and divert it to weapons purposes.

In implementing decommissioning of various JAEA facilities, novel decommissioning technologies may need to be developed, including those needed for remote retrieval of waste from areas with a high radiation field.

JAEA possesses nuclear fuel materials which are not reusable as reactor fuels, but may be usable for R&D activities. It has recently begun a basic study on the potential for stabilization of scrap nuclear fuel materials in a ceramic matrix. It is presently performing cold tests of microwave melting of several ceramic materials.

TRP has various recoverable nuclear materials (shearing powder collected through the clean-up work of the shearing machine, purified Pu solution, purified U solution and powder, and other liquid wastes), which were not recovered after previous processing operations in the main plant. Flush-out is necessary to recover the nuclear materials remaining in the system before decontamination and dismantling of facility.

Flush-out will be performed without extraction operations being undertaken. Since the equipment used for the flush-out process is more limited when using this approach, the risk of accidents is reduced and the preparation period for adapting to any new regulatory standards is shortened. Flush-out is performed to manage risk, including criticality, fire, and radiation exposure of the decommissioning workforce.

JAEA has studied 3 methods to flush out the installations. The preferred method involves the shearing powder being discarded as high active liquid waste after dissolution. This method has following advantages:

- It can be implemented by existing equipment
- Numbers of operating equipment can be minimized by limiting the equipment to be used compared with conventional reprocess operations (i.e. the risk is reduced)
- There is no change in material accountancy.
- Flush-out will be carried out based on the safety results (boiling, hydrogen explosion and exposure) and the NRA approval of the method will be required.

ARTEMIS Observation

The ARTEMIS Review Team noted that JAEA has inventoried a number of spent fuel materials in various conditions, from powders, to plutonium and uranium solutions. Over the course of decommissioning, other such items could be found in the facilities.

The ARTEMIS Review Team recognizes the difficulty in recovering and processing fuel element debris. Outside Japan, similar problems have been observed in nuclear facilities involving removal of sediments from tanks. For such spent fuel materials and sludges (debris, sediments) specific solutions will need to be developed depending on their physical or radiological nature.

Together with the need to conduct an extensive characterization programme to identify all such items (see also Observation 20), the strategy may initially consist of interim storage of such materials pending the identification of a solution matching the future repository capacities.

Considering the challenge of managing material which contains nuclear material, it is important

to establish a systematic early identification, and management strategy for all material bearing debris, including its recovery and treatment, in close association with the regulator and the IAEA (where relevant).

10	RECOMMENDATIONS, SUGGESTIONS AND GOOD PRACTICES
Observation: *JAEA has fuel element debris for which no long-term management route has been identified.*	
(1)	**BASIS**: GSR Part 5 - Predisposal Management of Radioactive Waste Requirement 10: Processing of radioactive waste The processing of radioactive waste shall be based on appropriate consideration of the characteristics of the waste and of the demands imposed by the different steps in its management (pretreatment, treatment, conditioning, transport, storage and disposal).
(2)	**BASIS**: SSG-15 Storage of Spent Fuel Material (Rev.1) **Fuel integrity** 6.125: *"The integrity of spent fuel might become degraded and lead to a release of radioactive material to the storage facility environment."* **Retrieval of spent fuel** 6.134: *"If spent fuel or a spent fuel package cannot be retrieved from storage with normal operating procedures, special operating procedures should be developed to ensure safe retrieval of the spent fuel or the spent fuel package."*
R8	**Recommendation:** JAEA should develop a comprehensive strategy for the management of fuel element debris, including its recovery and treatment.

3.3 MANAGEMENT OF SPENT FUEL

MEXT/JAEA Position

Japan's spent fuel management is described in the Strategic Energy Plan[3] (July 2018) as follows:

> *"Regarding the situation of spent fuels, even when we only consider those of OECD/NEA member states, there are approximately 227 000 tons of spent fuels as of 2015, and how to manage spent fuels is a global challenge. As spent fuels are sure to be produced through the use of nuclear energy, it is essential to implement measures to*

[3] https://www.enecho.meti.go.jp/en/category/others/basic plan/5th/pdf/strategic energy plan.pdf)

resolve this challenge as a responsibility of the current generation so that the burden is not passed on to future generations. Therefore, Japan will drastically reinforce and comprehensively promote efforts to resolve the challenge of how to manage and dispose of spent fuels."

"As the current generation that has produced radioactive waste, the government of Japan (GOJ) will reinforce measures toward final disposal of high-level radioactive waste and take the initiative in solving this problem. However, the process will take a long time. In the meantime, spent fuels produced by nuclear power generation must be safely managed. It is therefore necessary to expand the capacity for storing the spent fuels and is urgently important to broaden the range of choices for managing the spent fuels while ensuring safety. It will make flexibility of policies and response, and contribute to medium-term energy security.

Based on this concept, the storage capacity of spent fuels will be expanded. Specifically, while studying a wide range of locations as possible sites, regardless of whether they are inside or outside the premises of a power plant, GOJ will strengthen its effort for facilitating construction and utilization of new intermediate storage facilities and dry storage facilities."

In the ARM, and more specifically in the National Framework presented therein, reference is made to the *Basic Policy for Nuclear Energy of Japan* (Japan Atomic Energy Commission, July 20, 2017) which affirms, *inter alia*: "Steady implementation of radioactive waste disposal is the responsibility of the present generation".

ARTEMIS Observation

Spent fuel material is likely to remain in storage for several decades before a final geological repository is available. Potential problems with the integrity of the spent fuel or of storage casks should be considered in advance of the need for interventions, such as placing the spent fuel into new casks before the existing storage containers begin to lose their integrity. In some cases, rather than placing the fuel into a new cask, it may be necessary to move the storage casks to another storage facility.

It is evident that storage of spent nuclear fuel (SNF) underwater or in dry storage is generally considered by the international expert community to provide adequate safety. However, SNF or the waste packages in which it is contained may lose integrity over an extended period of time (e.g. over several decades). An ageing management plan should therefore be foreseen, including monitoring the condition of the SNF, with mitigation plans being put in place in the event that degradation should occur.

11	RECOMMENDATIONS, SUGGESTIONS AND GOOD PRACTICES
Observation: *Spent fuel material is likely to remain in storage for several decades before the final geological repository is operational. Currently, there is no comprehensive ageing management plan in place for long-term storage of spent fuel.*	

(1)	**BASIS**: Requirement 11 of GSR Part 5: Storage of radioactive waste *"Waste shall be stored in such a manner that it can be inspected, monitored, retrieved and preserved in a condition suitable for its subsequent management. Due account shall be taken of the expected period of storage, and, to the extent possible, passive safety features shall be applied. For long term storage in particular, measures shall be taken to prevent degradation of the waste containment".*
(2)	**BASIS**: SSG-15 Storage of Spent Nuclear Fuel (Rev.1) 6.11: *"For storage beyond the original design lifetime, consideration should be given to mitigation of the consequences of potential changes in the storage facility and the stored spent fuel. Changes in the storage facility might be caused by radiation, heat generation and chemical or galvanic reactions. Changes in the stored spent fuel and storage cask might include the following:* *(a) The generation of gases that might cause hazards, by chemical and radiolytic effects (e.g. the generation of hydrogen gas by radiolysis) and buildup of overpressure;* *(b) The generation of combustible or corrosive substances;* *(c) The corrosion of metals;* *(d) The degradation of the spent fuel confinement system.* *Such considerations are especially important for storage beyond the original design lifetime as small effects might accumulate over long periods of time."* 6.144: *"Prolonged irradiation of cladding material, gaskets or other materials relevant to ensuring the confinement of the spent fuel might result in degradation of safety functions. An ageing management programme should be established to deal with ageing related degradation. The programme should specify the monitoring necessary for early detection of any deficiency.*"
R9	**Recommendation**: JAEA should develop an ageing management plan considering the long-term storage of spent fuel.

4. DECOMMISSIONING COST ASSESSMENT

4.1 COST ASSESSMENT METHODOLOGIES

MEXT/JAEA Position

The cost for facility dismantlement is one of the two areas of cost for back-end measures presented in the Back-End Roadmap (the other being the costs for processing and disposal of waste, see section 5).

The cost for facility dismantlement for most of JAEA's facilities has been calculated based on the *Simplified Decommissioning Cost Estimation Code for Nuclear Facilities* (DECOST) developed by JAEA. The DECOST methodology is described in the Advance Reference Material and in the presentation by JAEA. In summary, JAEA describes DECOST as a simple method used to estimate the dismantling cost, based on historic cost data, in line with the initial decommissioning plan. JAEA indicated that DECOST provides point estimates and that it does not include consideration of contingency. JAEA also indicated that there were a number of exclusions of potential cost categories in the estimates prepared by DECOST.

As JAEA considers that DECOST is not suitable for calculating the cost of dismantling of the Fugen and Monju facilities, the cost assessment for these facilities was performed by another method. The methodology followed for Fugen and Monju is briefly described in the Advance Reference Material and during the Review, and can be summarized as calculating the cost of dismantling based on the quantity of the decommissioning waste.

JAEA and MEXT emphasized that both these approaches are designed to provide preliminary, approximate, "order of magnitude" estimates, in conjunction with preliminary decommissioning plans. In their view, the estimates should be seen as equivalent to Class 5 of AACE International.

There is also a new method for estimating dismantling cost currently under development at JAEA, known as the *High-precision method*. The goal is for this to be ready for use in about two years. JAEA describes this as a detailed estimation method which will be used to calculate the dismantling costs based on the final decommissioning plan. JAEA indicated that it aims to use this method for those facilities for which permanent shutdown has already been decided and for facilities that are undergoing decommissioning, and thus enable more complete decommissioning plans. The methodology under development is described by JAEA in the Advance Reference Material and in the presentation. JAEA indicated that this estimation approach will incorporate both 'bottom-up' accumulation and parametric methods, will address additional cost categories, and will consider contingency. JAEA noted that they expect the High-precision method will produce estimates that correspond to Class 3 of AACE International, with a greater degree of accuracy compared with the current methods used by JAEA.

ARTEMIS Observation

The Review Team notes that JAEA has developed methods for decommissioning cost assessment and intends to develop its methods further.

The Review Team acknowledges that the purpose of the current decommissioning cost assessment methods used by JAEA is to provide preliminary, approximate estimates with

limited accuracy. The Review Team noted that, in DECOST, historic reference data is used and not all cost categories are considered. The Review Team noted also that contingency is not included in the current cost assessment methodologies. The Review Team considers that, in light of these considerations, that the decommissioning cost assessment methods currently used at JAEA do not provide a full understanding of the costs.

From the information presented during the Review, the Review Team recognizes that the aim of developing the High-precision method is to produce more complete estimates and that it will include consideration of contingency. The Review Team notes that the term 'contingency' appears to be narrowly defined in this context. The Review Team considers that, at this stage of its development, it is not possible to evaluate the High-precision method and whether it will achieve the level of accuracy being sought.

As noted above, the cost assessment methods currently in use or being developed by JAEA either exclude contingency or apply a narrow definition of contingency. As a consequence, these methods do not fully address the overall uncertainty in the cost estimates. In addition, there are wider risks (both threats and opportunities) that may impact on the costs of the decommissioning programme. JAEA recognizes such events can occur, and highlighted the example of unexpected contamination found during dismantling. JAEA indicated it plans to investigate such cases and evaluate the rate of occurrence of unexpected events and their impact for decommissioning. JAEA also acknowledged that major changes to decommissioning strategy or end state could have significant impacts on the cost assessment. The Review Team noted that such wider risks do not appear to be systematically addressed in the current cost assessment methods in use, and it is unclear if and to what extent they will be addressed in the High-precision method under development at JAEA.

The Review Team considers it essential that a comprehensive, systematic approach to analyzing and addressing uncertainty and wider aspects of risk is included in the decommissioning cost assessment. To this end, the Review Team recommends that JAEA include a comprehensive approach to risks and uncertainties in further development of the cost assessment methodologies. Developing quality decommissioning cost estimates, including a comprehensive approach to risks and uncertainties, would provide JAEA with a more complete understanding of the costs of dismantling its facilities.

The Review Team recommends that JAEA give consideration to relevant international guidance specifically relating to decommissioning cost estimation, including uncertainty and risk, as it proceeds in developing the JAEA cost assessment methodology. International guidance specifically addressing uncertainty and risk in the context of decommissioning cost assessment can be found in the joint IAEA and OECD Nuclear Energy Agency publication *Addressing Uncertainties in Cost Estimations for Decommissioning Nuclear Facilities*.[1]

In addition, the Review Team encourages JAEA to consider examples internationally of good practice and experience relating to cost assessment in the context of large, complex programmes. There are a number of organizations which have a similarly diverse, large portfolio of nuclear facilities which are being decommissioned, including: CEA and Orano (France), NDA (UK), DOE–EM programme (USA), SOGIN (Italy), and JRC (European

Commission). These organizations have dismantling cost information and cost assessment methods which may complement and supplement those of JAEA.

[1] Addressing Uncertainties in Cost Estimations for Decommissioning Nuclear Facilities (joint report by IAEA & OECD NEA), NEA No. 7344, OECD 2017.

12	RECOMMENDATIONS, SUGGESTIONS AND GOOD PRACTICES
Observation: *JAEA has developed methods for decommissioning cost assessment and intends to develop these further. The decommissioning cost assessment methods currently used at JAEA do not provide a full understanding of the costs, nor do these methods fully address the overall uncertainty in the estimates and wider risks (both threats and opportunities) that may impact on the decommissioning programme.*	
(1)	**BASIS**: GSR Part 1 (Rev. 1) - Governmental, Legal and Regulatory Framework for Safety Requirement 10, para. 2.33 states that *"Appropriate financial provision shall be made for:* *(a) Decommissioning of facilities …*
(2)	**BASIS**: GSR Part 6 – Decommissioning of Facilities Requirement 9, para. 6.2 states that "*The cost estimate for decommissioning shall be updated on the basis of the periodic update of the initial decommissioning plan or on the basis of the final decommissioning plan. The mechanism used to provide financial assurance shall be consistent with the cost estimate for the facility and shall be changed if necessary."*
(3)	**BASIS**: SSG-47 para 6.10 states that *"Cost estimates and financial provisions should be reviewed periodically and should be adjusted as necessary to allow for proper consideration of inflation and other factors, such as technological advances, waste management costs or regulatory changes, especially in the case of a deferred dismantling strategy where decommissioning might be completed only decades after shutdown of the facility."*
R10	**Recommendation:** JAEA should ensure that its decommissioning cost assessment methods are further developed in order to be able to provide a comprehensive understanding of the total costs of dismantling its facilities, and address the associated uncertainties and risks.

4.2 FURTHER DEVELOPMENT OF DECOMMISSIONING COST METHODS

MEXT/JAEA Position

MEXT and JAEA indicated that to-date decommissioning cost assessment has been mainly used to produce preliminary, approximate, 'order of magnitude', estimates of the cost of facility dismantling. MEXT and JAEA indicated that JAEA is required to produce and submit such estimates of decommissioning costs to the Japanese authorities.

MEXT also note that the ongoing decommissioning project at Fugen and the imminent decommissioning projects at Monju and Tokai Reprocessing Plant (TRP), are attracting broad attention from society and stakeholders. MEXT indicated that, in the past, limited consideration has been given to cost issues by stakeholders. MEXT also indicated that an increase in the costs of decommissioning, from those assumed at the early stages of the project, might have significant consequences, especially if this were considered to be due to cost escalation. In this context, MEXT stated that it appreciates the importance of developing higher precision estimating methods, and indicated that further development of cost calculation and budget tools are a priority.

JAEA indicated that the current cost assessment based on the preliminary estimates has not been applied in the context of project management. Moreover, JAEA indicated that it does not consider these estimates have sufficient accuracy to be suitable for use for actual decommissioning project management. JAEA is therefore proceeding with development of the High-precision method (see section 4.1).

ARTEMIS Observation

The Review Team concurs with MEXT and JAEA on the importance of having a good insight into the costs of dismantling its facilities at an early stage, and that cost escalation is a serious issue. The Review Team noted that there is an urgent need for quality decommissioning cost information, as the dismantling of Fugen is already well underway, and the start of dismantling activities at Monju and TRP are imminent.

The Review Team indicated that issues relating to increases in the cost estimates for decommissioning programmes, the implications for budgets, and related stakeholder concerns, have arisen in several other countries. In general, this experience indicates that apparent cost increases may be due to a range of factors, such as: correction of previous errors in cost estimation; the inclusion of scope that had been omitted; modification of scope as the decommissioning plan evolves; actual cost escalation; and additional scope needed in response to uncertainties and risks becoming manifest. These various causes need to be addressed in differing ways - some through improvements in cost calculation methods, others through ensuring that uncertainty and risk are fully incorporated into cost assessments, and others require refinements and maturity in near-term decommissioning planning, management and execution.

The Review Team noted that, in order to address concerns about cost growth, it is essential to develop as complete as possible understanding of the costs, uncertainties and risks, as discussed in section 4.1. The Review Team emphasised that it is essential that information about these

and how they may evolve in the future be communicated effectively to decision makers and stakeholders.

The Review Team noted that the decommissioning cost assessment methods currently used by JAEA give certain insights into the costs of decommissioning. The Review Team emphasised that there is a need to ensure that JAEA has suitable quality decommissioning cost information and tools to enable effective programme and near-term project management. This means being suitable to address a range of needs and uses. These include providing cost-related inputs to: the development of an integrated resource-loaded programme schedule; underpinning budget provisioning requests; programme and project development; risk management processes; project approvals; contract development and procurement decisions; and analyses of project delivery and performance. Some specific examples where JAEA needs quality cost information include:

- In development of an integrated resource loaded programme schedule for JAEA, and exploring alternative decommissioning and schedule scenarios (see also section 1.2)
- In setting goals and targets for project delivery, and in monitoring and developing performance (e.g., Earned Value Management, Key Performance Indicators)
- In its relations with the supply chain, JAEA needs to be able to engage as an 'intelligent client'. As such, JAEA will need to be provided with current, quality cost information that will inform its procurement decisions, its contract negotiations, and its performance evaluations of contractors and suppliers (see also section 6.3)

The Review Team noted that JAEA will need to address whether JAEA's decommissioning cost information and tools can be further developed so that they can be suitable to support such diverse needs and used in decision making and risk management processes. Such an assessment would need to consider a range of issues, including:

- The expectations for the information to be obtained from the estimation methods and how it will be used
- Assurance that the information and tools are logical, accurate, comprehensive and have been developed robustly, and clarification of how this will be demonstrated
- The quality of the data and assessments of whether it is appropriate for use
- The quality of assumptions and to assess the evidence base and rationale for inclusion
- The drivers and sensitivities, and usefulness to quantify uncertainty
- How the information will be integrated into decision making and risk management systems
- How estimates are compared with actual outcomes in order to inform future development
- Decision-making in the context of residual uncertainties, given constraints on data and estimating methods
- How information will be presented to decision makers, for example how findings are presented in a business case and budget applications
- How this will be used to track on-going performance as a monitoring tool, and in setting targets

The Review Team encourages JAEA to consider examples internationally of good practice and experience relating to incorporating cost assessment into programme management and delivery tools in the context of large, complex programmes. In addition, the Review Team notes that there are a number of organizations which have a similarly diverse, large portfolio of nuclear facilities which are being decommissioned (see the examples provided at the end of section 4.1). These organizations have developed programme management tools and processes that may JAEA might find to be of particular relevance in the further development of its programme.

13	RECOMMENDATIONS, SUGGESTIONS AND GOOD PRACTICES
Observation: *The decommissioning cost assessment methods currently used by JAEA give certain insights into the costs of decommissioning, however they do not meet the full range of needs and uses for which JAEA requires quality decommissioning cost information. These needs include providing cost-related inputs to: the development of an integrated resource-loaded programme schedule; underpinning budget provisioning requests; programme and project development; risk management processes; project approvals; contract development and procurement decisions; and analyses of project delivery and performance.*	
(1)	**BASIS**: GSR Part 1 (Rev. 1) - Governmental, Legal and Regulatory Framework for Safety Requirement 10, para. 2.33 states that *"Appropriate financial provision shall be made for:* *(a) Decommissioning of facilities …*
(2)	**BASIS**: GSR Part 6 – Decommissioning of Facilities Requirement 9, para. 6.2 states that "*The cost estimate for decommissioning shall be updated on the basis of the periodic update of the initial decommissioning plan or on the basis of the final decommissioning plan. The mechanism used to provide financial assurance shall be consistent with the cost estimate for the facility and shall be changed if necessary."*
(3)	**BASIS**: SSG-47 para. 6.5 states that *"The cost estimate for decommissioning should cover all actions required to plan and perform the decommissioning. There will be additional costs for other actions, which might be included as part of the decommissioning, depending on the national legal framework. These typically include financing for the management of waste from operation, pre-decommissioning actions during the transition phase, waste storage and disposal, and spent fuel management."*
(4)	**BASIS**: SSG-47 para 6.10 states that *"Cost estimates and financial provisions should be reviewed periodically and should be adjusted as necessary to allow for proper consideration of inflation and other factors, such as technological advances, waste management costs or regulatory changes, especially in the case of a deferred*

	dismantling strategy where decommissioning might be completed only decades after shutdown of the facility."
R11	**Recommendation:** JAEA should ensure that the further development of its decommissioning cost assessment methods align with JAEA's short- and long-term needs by providing comprehensive, robust and traceable decommissioning cost information that is suitable for use in multiple contexts.

5. WASTE COST ASSESSMENT

5.1 SCOPE OF WASTE COST ESTIMATE & UNCERTAINTY ANALYSIS

MEXT/JAEA Position

Waste processing methods, using appropriate techniques, were selected taking account of the characteristics of radioactive waste on each site.

Specific to L0[4] and L1 disposal sites, costings have been identified via third parties (such as NUMO for L0) and 'unit cost' data provided by such third parties forms the basis of the cost analysis when multiplied by the JAEA L0 and L1 waste inventories at each site. The level of precision is different at each site based on known technical challenges and waste planning uncertainties. For example, the site processing costs at NSRI for L0 and L1 has been assumed to be the same. By way of comparison, the analysis at NFCEL sites (including TRP) is more detailed and L0 and L1 have been separately costed.

For known plutonium contaminated waste, the treatment, installation and running costs were available and identifiable in waste cost estimates. For uranium contaminated wastes this was not the case and future investment costs were uncertain and had therefore been excluded from the waste cost calculation. Additional exclusions are considered in section 5.2.

It was also recognized that some special nuclear material types would give rise to more problematic waste types in the future (e.g., uncharacterized plutonium contaminated material or fuel fragments, or specialist products from R&D having specific radiological characteristics). This material is not considered to be high in volume and therefore could be better considered within a risk or uncertainty costing analysis process.

The inventory of L2/L3 wastes is represented in terms of equivalent 200-litre drums. The derived unit cost for disposal of a 200-litre drum of L0 waste was around 4 times that for L1; and L1 was around 4 times that for L2 for an engineered concrete vault disposal. Waste processing steps had been declared for each site. This showed existing and planned future investments. Future investments had been costed both in terms of capital costs (new investments and asset care) and in terms of operational costs. This process led to assessments of lifecycle L2/L3 process costs being assimilated as costs per 200-litre drum equivalent. These costs included steps such as segregation, compaction, melting, waste passivation and immobilization and production of container waste inventory records. There are known technical challenges specific to the design and installation and operation of some waste facilities - specifically HASWS and LWTF downstream processing at TRP. Assumptions have been made as to the likely process and hence costs in this area have been attributed.

Where the radioactive waste processing method was not yet decided at a site – for example at Aomori – unit cost data was used by analogy from other site processes where more definitive information and waste treatment plans were available.

Waste related activities were presented as attributing 72% to the total costs in the Back-End Roadmap across all 79 facilities and within the 70-year plan duration. As two separate lifecycle

[4] 'L0' is an unofficial descriptor for waste designated for geological disposal. 'L1' refers to "relatively high level waste" (see Section 2.1); this waste is designated for intermediate depth disposal.

scope costing methods had been adopted, the boundaries (scope definition) between the Decommissioning Cost Calculation Assessment and the Waste Cost Calculation were discussed during the review. This highlighted an area of risk but also of opportunity – for example it was now realized that container costs had been built into both and this was now a recognized double-account.

Cost for Back-end measures unit: 10 billion yen

	Aomori	Nuclear Science Research Institute	Nuclear Fuel Cycle Engineering Laboratories	Oarai R&D Institute	Tsuruga	Ningyo-toge	Total
Cost for facility dismantlement	1	9	21	9	14*1	1	54*3
Cost for Waste processing and disposal	1	27*2	83*2	19*2	8	-*2	137*3
Total	1*3	35*3	104	28	22	1	191

*1: This figure includes the cost for the preparation of decommissioning stipulated in Decommissioning Plan for "Fugen" and "Monju".
*2: These figures do not include the cost for uranium waste. Cost for uranium waste will be calculated after the system concerning the uranium waste burial is established.
*3: Totals may not equal the sum of individual figures because figures are rounded off.

ARTEMIS Observation

On the basis that prices are available from approved sources it is understood that JAEA is obligated to use this data in its L0 and L1 cost assessment process.

For HASWS and LWTF downstream processing at TRP it is known that these costs are subject to change and carry higher levels of uncertainty.

As an example of an exclusion: at the Ningyo-toge facilities the uranium waste processing cost will be estimated after establishment of the system for uranium waste disposal. Therefore, it is evident why the uranium waste processing costs are currently excluded from the Back-End Roadmap.

The boundaries (scope definition) between the Decommissioning Cost Assessment and the Waste Cost Calculation represent an area of further uncertainty. Some cost reduction is likely as container costs had been built into both. Equally, an integrated costing process may well uncover scope gaps as well as double accounting.

An uncertainty analysis is best conducted when all scope has been defined and costed against a known plan and timeline. Given the long duration of the overall programme, the Back-End Roadmap is subject to large uncertainties – many of which are stated explicitly therein – e.g., L0/L1/L2/L3 interim storage versus disposal timescales. The significance of the size of the waste management cost (72%), and the level of uncertainty in finding suitable waste disposal sites in Japan should not be under-estimated. To help manage such uncertainties, JAEA should align its thinking to an integrated waste management approach, i.e., one that considers its 79-facility national programme and the demography and needs of its sites. This will not only support a better and more integrated Back-End Roadmap but it will also inform near-term decisions on waste facility investments and priorities. Such an integrated approach should

consider both the waste hierarchy (reduce, reuse, recycle) and the waste lifecycle (waste inventory from each of the 79 facilities and how this material evolves into waste packages that are assigned to disposal locations). By doing so, JAEA will necessarily debate alternative scenarios that could better shape the boundaries of the full waste cost envelope. This will inform JAEA of the least risk and best cost opportunities across its full 70-year programme of work.

As noted also in the Decommissioning Cost Assessment section, the Review Team considers it essential that a comprehensive, systematic approach to analysing and addressing uncertainty and wider aspects of risk is included in the waste cost assessment. To this end, the Review Team recommends that JAEA include a comprehensive approach to risks and uncertainties in further development of its overall cost assessment methodology. As previously described, international guidance specifically addressing uncertainty and risk in the context of decommissioning and waste cost assessment can be found in the joint IAEA and OECD Nuclear Energy Agency publication *Addressing Uncertainties in Cost Estimations for Decommissioning Nuclear Facilities*[5].

In developing an integrated waste management approach, the Review Team notes that JAEA has already considered several aspects in its Back-End Roadmap. All the key stages identified below can be taken together and could to be more fully considered and reviewed as part of the next Back-End Roadmap revision. This can be achieved by benchmarking ideas and JAEA processes with selected waste management programmes internationally.

- Stage 1: agree key assumptions about number and proximity of each future or current disposal site for waste categories L1-L3.
    - Agreeing initial Waste Acceptance Criteria for all disposal sites against L1-L3 concepts
    - Designing site waste facilities and packages that can be matched to the WAC for L1-L3
- Stage 2: produce some initial scenarios that show how optimisation is possible across the full system of waste consignor sites, waste disposal sites and waste processing facilities.
- Stage 3: use this information to enable investment cases to be made against a preferred option/scenario.
- Stage 4: set out these early investment commitments against an updated Back-End Roadmap (include these extra investment costs) but also map the benefits as waste processing cost savings across the 70-year plan lifecycle.
- Stage 5: build a near-term plan (covering first 10 years of the Back-End Roadmap) that delivers these longer-term waste management and disposal benefits.
- Stage 6: revisit and continually optimise processes, WAC and disposal container options

[5] The Appendices of this joint NEA/IAEA report provide examples of risk analysis specific to decommissioning. By analogy to waste management, the same principles and approach described in this report would apply, insofar as a delay to an agreed Back-End Roadmap assumption for L2/L3 waste disposal in Japan can be translated into a risk. In this case the risk initiating event would be failure to deliver the disposal facility and the impact would be a consequence in cost (new stores) or a consequence in decommissioning programme delivery schedule. Mitigation against this risk could be delivered either through committing to new L2/L3 storage capacity now, or by prioritizing decision-making against timely delivery of L2/L3 waste disposal facilities.

to realize further opportunities as part of an enduring JAEA waste management planning process as it enacts the Back-End Roadmap.

14	RECOMMENDATIONS, SUGGESTIONS AND GOOD PRACTICES
Observation: *The current waste cost assessment process as defined in the Back-End Roadmap does not consider the full range of options and uncertainties associated with waste processes and waste routes.*	
(1)	**BASIS:** GSR Part 5, Requirement 20 states that… *"The operator shall develop, in the design stage, an initial plan for the shutdown and decommissioning of the predisposal radioactive waste management facility"*
(2)	**BASIS:** GSR Part 5, Section 3.23 states that… *"In considering possible options for the processing of waste, care has to be taken to avoid conflicting demands that might compromise safety. It is not consistent with an integrated approach to optimize one step in the predisposal management of radioactive waste in such a way that it imposes significant constraints on the subsequent steps or forecloses viable options."* **BASIS:** GSR Part 5, Section 5.1 states that… *"The development of authorizations and of limits, conditions and controls for the predisposal management of radioactive waste benefits from close communication and cooperation between the operators, regulatory bodies and other interested parties"* The need for an integrated approach is important to safety but just as significant is the opportunity to optimize costs in parallel.
(3)	**BASIS:** GSR Part 5, Requirement 6 states that… *"Interdependences among all steps in the predisposal management of radioactive waste, as well as the impact of the anticipated disposal option, shall be appropriately taken into account."*
(4)	**BASIS:** Addressing Uncertainties in Cost Estimations for Decommissioning Nuclear Facilities, IAEA & OECD NEA, 2017 [NEA No. 7344] *https://www.oecd-nea.org/jcms/pl_15036/addressing-uncertainties-in-cost-estimates-for-decommissioning-nuclear-facilities*
R12	**Recommendation:** JAEA should list, assess and manage uncertainties associated with site waste processing, interim storage and final disposal options. *[Refer also to the Section 'Decommissioning Cost Assessment']*

S9	**Suggestion:** To help manage uncertainties, JAEA should consider aligning its near-term planning decisions to an integrated waste management approach covering its full programme. Such an integrated approach should consider both the waste hierarchy (reduce, reuse, recycle) and the waste lifecycle (waste inventory from each of the 79 facilities and how this evolves into packages assigned to disposal locations).
S10	**Suggestion:** JAEA should consider cost benchmarking with selected waste management programmes internationally. This will establish a better basis for some of the waste related cost estimates and support optimization of the waste management processes.
S11	**Suggestion:** JAEA should consider good practice in uncertainty and risk analysis to derive a contingency provision as part of the JAEA waste cost estimating process.

5.2 ADDRESSING SCOPE EXCLUSIONS IN THE WASTE COST ESTIMATE

MEXT/JAEA Position

For uranium contaminated wastes future investment costs were uncertain and had therefore been excluded from the waste cost calculation. Other exclusions were clearly identifiable in the Back-End Roadmap and clarified through discussion, such as:

- Decommissioning of the new (on-site) waste processing facilities
- Additional on-site waste storage facilities
- Site clean-up/environmental restoration to final end-state
- Pre-disposal and non-radioactive wastes, e.g., including asbestos

ARTEMIS Observation

The Review Team considers that the application of many scope exclusions by JAEA in the Back-End Roadmap could lead to a sub-optimal waste management plan.

The project controls framework used by many in the international decommissioning community and general project management community uses a process of *Assumptions* and *Exclusions*. These terms are often contextualized by the contractual framework under which decommissioning and waste management work is being executed. The *Assumptions* help define and bound the scope; and the *Exclusions* are used to inform the plan owners/funders that delivery of certain aspects are presently outside of their remit or control or contractual responsibility. National decommissioning authorities generally seek to remove exclusions in their lifecycle cost analysis, as to include these would create a plan that is not representative of the full decommissioning programme. In this regard, a more complete lifecycle approach is beneficial when planning near-term work execution and when estimating lifecycle costs. Where there are certain exclusions which cannot be removed, these will require discussion and agreement. In this case the ARTEMIS Review Team suggests inclusion of a clear statement to this effect. Such an approach would enable JAEA to better explain why some scope is excluded;

and by doing so inform its ideas about possible inclusion and consider the option of a provisional sum of money as a placeholder estimate.

In order to illustrate the above approach on an issue where there is inevitably a high level of uncertainty, the Review Team wishes to highlight site clean-up and final environmental restoration. Planning now for an end state that is decades away is subject to very high uncertainty. Given that JAEA's current policy is that all sites will be available for further use following completion of decommissioning, JAEA may wish to consider defining interim end states as a way of bounding the end point of the roadmap for each site. This could help explain this aspect of the current cost assessments and may in fact help better optimize decommissioning planning in general. Interim end states are neither definitive nor illustrative but are effective in helping bound material quantities and hence waste cost estimates.

15	RECOMMENDATIONS, SUGGESTIONS AND GOOD PRACTICES
Observation: *The exclusions presented in the Back-End Roadmap and supplementary information are clear and well stated. These exclusions however lead to an incomplete picture of the waste management landscape and associated costs.*	
(1)	**BASIS**: GSR Part 6 Requirement 9, para. 6.2 states that… *"Prior to starting decommissioning, the licensee shall ensure the availability of adequate processing and storage capabilities and transport packages for the radioactive waste."*
R13	**Recommendation:** JAEA should take action to include costs for all areas of currently excluded scope. This will support development of a more complete cost for the decommissioning and waste management programme.
S12	**Suggestion:** For each identified area where waste related scope has been excluded JAEA should propose assumptions for its inclusion and calculate a derived placeholder estimate. Areas to review include: • Uranium and plutonium contaminated waste • Decommissioning of the new (on-site) waste processing facilities • Additional on-site waste storage facilities • Site clean-up and site environmental restoration to end-state

6. PROJECT AND CONTRACT MANAGEMENT

6.1 COMPETENCY DEVELOPMENT FOR DECOMMISSIONING

MEXT/JAEA Position

Organizational Responsibilities

JAEA provided detailed information on the organizational structure and defined roles and responsibilities of its various organizational elements. They also described the purpose and structure of two coordination committees which serve important roles in the planning and management of decommissioning planning and implementation throughout the JAEA programme. The Back-End Roadmap Committee and the Facility Management Promotion Committee are notable and very positive elements of the JAEA programme, which will support the stated goal of optimizing the Back-End Roadmap.

The Back-End Roadmap Committee serves two core functions: to develop the roadmap as the long-term policy of JAEA; and to consider various methods of decommissioning work management. Simply stated, this high-level committee sets the vision for the Back-End Roadmap. Another notable element is the inclusion of four external advisors on the committee, two from academia and two from the business/management industry. The Committee is currently focused on the further developing the road map and discussing decommissioning strategy. In contract, the Facility Management Promotion Committee focuses on implementation details, including providing needed assistance and integration functions for the JAEA sites.

To support those high priority, near term decommissioning activities in the Tsuruga Area – specifically, the work underway at Fugen and Monju research reactors – JAEA established the Head Office of Tsuruga Decommissioning Demonstration in April 2018. This Head Office organization enables the coordinated undertaking of the three parallel projects/sites in this geographical area.

To strengthen planning and coordination of the overall decommissioning programme, JAEA formed the Decommissioning and Radioactive Management Head Office (also called the Back-End Head Office) in April 2019. The Back-End Head Office provides overall coordination, solves similar problems between organization, and controls the overall back-end measures to promote efficiency, though conduct of informational exchanges with the Tsuruga Decommissioning Demonstration Sector and other JAEA sites.

JAEA recognized that the current number of staff and capacity in Back-End Head Office may not be sufficient for the future management of the Back-End Roadmap activities. Currently, there are between 50-60 individual contracted to the Head Office, but all are not full-time employees.

At the facility and site level, JAEA noted a “recognized need to reform the structure quickly and drastically in order to properly implement project management in large scale facilities.”. They also noted that the Back End Head Office will continue to provide coordination and support to all JAEA sites, and facilitate management across the six sectors within JAEA, three of which have direct ties to the Back-End Roadmap. These three sectors each have a Planning and Coordination Office, which perform project management functions. The Management

Sector of JAEA includes numerous support functions that are also critical to the implementation of the Back-End Roadmap, including Contract Department, Public Relations Department, and Personnel Department.

The primary responsibility for tracking actual progress of decommissioning progress rests with the head of each sector and the head of each site. They determine the allocation of human resources, develop licensing applications and communicate execution information. The Back-End Head Offices perform important oversight functions through periodic review. When sites face obstacles, whether technical or budgetary, the Back-End Head Office facilitates needed adjustments.

JAEA explained that, while there was no explicit intent to establish a formal pilot programme when the Tsuruga Decommissioning Demonstration Sector was designated in 2018, there are practical lessons being realized in the ongoing decommissioning activities that may be applicable to future activities within the JAEA decommissioning programme. These include new technologies, utilization of 3rd party contractors for work in the same region, coordination of multiple site activities within a geographical centre. As such, JAEA is well positioned to capture important lessons learned that will inform future decommissioning projects.

Adequacy of Staffing

Using a co-efficient approach, JAEA has estimated the number of JAEA staff required to provide management of decommissioning of 79 facilities included in the Back-End Roadmap. The estimate reflects a 1:2 ratio between JAEA staff and outsourced workers performing decommissioning activities. It was explained that this is not a resource projection for actual programme implementation.

JAEA acknowledged their current staff is not fully aligned to meet demands of the increasing decommissioning programme and that gaps exist in needed skills. They reported that additional expertise is needed in following areas:

- Project management experience
- Facility management
- Working experience at site, in oversight of operations

JAEA estimated that of its current JAEA-wide head count of approximately 3 100, there are approximately 250 staff support decommissioning in some way. This equates to approximately 8% of the total JAEA organization supporting decommissioning. The near-term work requires more precise staffing plans requiring a bottom-up approach, in conjunction with financial planning. JAEA recognized the need for more reliable staffing estimates and confirmed the intent to improve their future plans.

Needed Skills and Capacity

JAEA is in the early stages of human resource development for decommissioning. There is no systematic training for JAEA staff, but they described planning towards the development and launch of a decommissioning and project management school, which will include course work on key technical topics, such as waste management. They envision the education programme will have a phased approach, initially providing classroom education and later field-based

training. Very appropriately, JAEA has stated the objective of the first phase is to provide their staff with an overview of decommissioning and the fundamentals of project management.

ARTEMIS Observation

The Review Team observed that JAEA is in the early phase of defining a complete and detailed understanding of the needed personnel capacity and skills required to effect implementation of the decommissioning programme. JAEA has implemented valuable first steps in this area, including a projection of potential staffing needs derived from and integrated with the DECOST estimate and the Back-End Roadmap.

The Review Team notes that the Facility Management Promotion Committee serves an important function in these areas and has a stated responsibility to develop the human capital strategy.

Although JAEA has begun its development, there is currently no specific capacity building strategy or system. The Review Team recommends that JAEA proceed immediately with the development of a formal capacity building and workforce development plan to prepare JAEA to effectively manage the planned decommissioning activities, to include technical matters (e.g., facilities management, waste management, decommissioning techniques) and foundational and advanced project management training, as appropriate. A detailed hiring and human resource development plan is needed, to align to the priorities of the Back-End Roadmap.

The Review Team recommends that this plan include field assignments, training at mock up test facility, and potential staff exchanges with other decommissioning programmes. External training may be an effective resource on some topics. Further, JAEA is encouraged to review and consider the significant capacity building resources provided by IAEA (eLearning, networks, knowledge management), the European Commision, as well as other programmes internationally, established to address decommissioning programme capacity challenges similar to JAEA's.

JAEA should also consider development of knowledge management and retention programme. While it is not the case in all countries, some national decommissioning programmes have faced challenges in staff hiring and retention because the field of decommissioning is not viewed positively, due to its inherent terminal nature. As the decommissioning programmes progress, JAEA's staff development and utilization plans should consider methods to make optimal use of experienced, successful managers through reassignment to and/or mentoring at other facilities in order to facilitate transfer of knowledge and promote optimization. The use of worker incentives should also be considered to retain the most skilled and experience JAEA staff to meet optimization goals.

Given the importance of strong project planning and management skills to optimization of the Back-End Roadmap, JAEA should consider evaluation and use of available commercial training and certificates in project management and contract management.

16	RECOMMENDATIONS, SUGGESTIONS AND GOOD PRACTICES
Observation: *JAEA has identified the need for additional personnel, capabilities and skills in order to implement the Back-End Roadmap. JAEA has identified a preliminary estimate of the number of personnel required, the needed knowledge and skills. The Review Team noted a need for further elaboration of this estimate.*	
(1)	**BASIS**: GSR-Part 2, Requirement 9: "*Senior management shall determine the competences and resources necessary to carry out the activities of the organization safely and shall provide them.*" [Including 4.21-4.24]
(2)	**BASIS**: GSR-Part 6, Requirement 7: *"4.4. Individuals performing decommissioning actions shall have the necessary skills, expertise and training to perform decommissioning safely. Provisions shall be made to ensure that institutional knowledge about the facility is obtained and made accessible and, as far as possible, that key staff from the facility are retained."*
(3)	**BASIS**: GS-G-3.1: ***"**2.23. ...For satisfactory implementation, planning and the deployment of adequate resources are necessary. All individuals should be trained to achieve proficiency."* *"2.25. The implementation plan should include provisions for recruiting, selecting, training, assigning and retraining adequate numbers of individuals, in a manner consistent with schedules for implementation and workloads. Consideration should be given to needs for special skills and training. Such provisions should take into account demographic and economic conditions."*
R14	**Recommendation:** JAEA should establish a framework to address the staffing skills, capabilities and number of personnel required to implement the programme. In the near term, JAEA should implement a plan to hire, train and retain the needed staff. The plan should also include defined activities to retrain current R&D staff to manage decommissioning activities, and be aligned to the detailed work plan (i.e., the Medium to Long-Term Plan)
S13	**Suggestion:** JAEA should consider evaluation and use of available commercial training and certificates in project management and contract management.
S14	**Suggestion**: JAEA should consider development of education and training programmes in decommissioning and waste management for its personnel. JAEA should also consider development of knowledge management and retention programme.

6.2 MANAGING THE SUPPLY CHAIN

MEXT/JAEA Position

JAEA identified limitations in the supply chain adjacent to the JAEA sites and acknowledged the need to identify strategies to facilitate various vendors entering into the decommissioning market. JAEA's awareness of this need is notable, as well as the Back-End Roadmap Committee's ongoing consideration of strategies that would make decommissioning work more attractive to vendors, such as modified payments arrangements.

It was reported that JAEA has a number of supply chain initiatives in process and there was clear awareness that this is a critical issue. In the current financial year, survey programmes are underway to solicit interest of local businesses in the Ibaraki region. There is also an effort to target businesses with no experience in nuclear industry, recognizing the need to assist them with a successful transition into the a more regulated environment. Another initiative involves engagement of professional associations with interests in decommissioning.

JAEA also reported a transition, in some cases, to the use of multi-year contracts. They reported that establishment of this system makes it easier for vendors with limited funds to enter into the market.

JAEA specifically requested that the Review Team provide advice related to proven strategies grow the market (e.g., expansion method of newcomers, evaluation methods of contractors, incentive contracts).

JAEA explained that they invited vendors with no previous decommissioning experience to utilize the mock up test facility, Fukui Smart Decommissioning Technology Demonstration Base ('Sumadeco'). The Review Team noted this as a Good Practice worthy of documentation and sharing with other programmes internationally.

ARTEMIS Observation

A robust supply chain capable of effectively performing the full range of decommissioning activities within the Back-End Roadmap is required for the next 70 years at least, and more likely for a century or more. This includes the need for several generations of workers skilled in various technical areas. As JAEA describes, the current commercial decommissioning market is too small and does not offer specialized services.

The Back-End Roadmap scope provides significant opportunity for industry growth and economic development, including in local communities near the JAEA facilities. JAEA is already undertaking strategies to promote expansion of the supply chain to achieve competition and skill needed to optimize the decommissioning programme. Local communities and stakeholders stand to benefit directly from JAEA's activities.

To consolidate and concentrate its various initiatives, JAEA should consider development and implementation of a detailed plan to expand the supply chain for decommissioning. The plan should define objectives that will facilitate optimization, including increased competition, greater use of defined performance criteria, progressive incorporation of contractor incentives. The plan should also establish and rely on a defined communication and engagement programme, where detailed information on the projected activities and needs are shared with industry, both nationally and locally (i.e., townhalls and industry forums).

JAEA is especially encouraged to consider mechanisms to facilitate entry of small local businesses into the market, as well as transition of commercial non-nuclear businesses into the market. These mechanisms should involve partnering and training on the additional safety and quality requirements inherent to work within a nuclear environment. Several countries have successful models that can be leveraged by JAEA as they develop this plan, including formal collaborative programmes between industry and research institutions.

The basic tenet of supply and demand will have a direct impact on programme costs. Based on experience of other international programmes, the optimization of decommissioning costs relies in part of a strong competitive market, which contributes to lower costs and increased quality in vendor performance. Clear and tailored contracting strategies are among the most effective tools for growing the supply chain. Based on the Review Team's experience, factors that encourage an active and growing supply chain include:

— Earning potential
— Visibility of long-range opportunities, for which vendors can plan, invest and hire
— A clear and reliable procurement schedule
— High-quality contract documents, with clearly defined requirements
— A fair and competitive process
— Availability of mentoring support

Based on experience in other countries, mentoring support can be provided either by JAEA through actions taken to facilitate vendors' entry into the market (e.g., training assistance), or by formal arrangements through which large, experienced businesses assist smaller, less experienced businesses to enter and perform in the market (e.g., mentor/*protégé* agreement programmes).

In Observation 18, the Review Team provides further detail and advice on contract strategy. As such JAEA is encouraged to consider actions in response to Observation 17 and 18 synergistically.

17	RECOMMENDATIONS, SUGGESTIONS AND GOOD PRACTICES
Observation: *JAEA indicated that it seeks to expand the number of suppliers offering services in the decommissioning market in order to better meet its needs.*	
(1)	**BASIS**: GSR-Part 2 Requirement 11 *"The organization shall put in place arrangements with vendors, contractors and suppliers for specifying, monitoring and managing the supply to it of items, products and services that may influence safety.*"
R15	**Recommendation:** JAEA should develop a strategy to promote expansion of the supply chain in order to facilitate entry of suppliers into the decommissioning market and further develop the necessary skills among suppliers. Such a strategy could also be tailored to directly benefit the local communities and stakeholders.

S15	**Suggestion**: JAEA should consider implementing a partnering approach with suppliers that aligns with near term work planning activities.
GP1	**Good Practice:** As part of the Fukui Smart Decommissioning Technology Demonstration Base ('Sumadeco'), JAEA invited vendors from the region who had no previous experience in decommissioning activities to train on the mock up facility at Tsuruga.

6.3 CONTRACT MANAGEMENT STRATEGY

MEXT/JAEA Position

Throughout the ARM, JAEA provided details on their planned contracting strategy to implement the decommissioning programme. Specifically, they stated the "will steadily pursue initiatives set out in the document on *Promotion of Incorporated Administrative Agencies' Efforts to Streamline their Procurement,"* and a plan to "optimize the value of its contracts by securing optimal contract types."

The ARM also described arrangements for the JAEA contracting approaches to be inspected by the agreement monitoring committee and a requirement for contracting results to be provided on its website.

The Back-End Roadmap Committee has recently addressed numerous contract-related topics including the use of multi-year contracting to increase efficiency and reduce costs, options for use of private financing to reduce reliance on government funding and alternative payment options to attract more vendors.

JAEA's current contracting process generally relies on competitive awards based on lowest bid price, in which lump sum payment is provided at the end of the contract term. However, as noted above, there is ongoing consideration of alternative, periodic payment arrangements, especially in the case of multi-year contracts.

JAEA has conducted a study of contracting systems, based on the experience of countries that are leaders in conducting decommissioning programmes. They are aware of programmes that utilize incentive-based contracting approaches. At present, JAEA has concluded that use of incentive-based contracting presents challenges. Contract standards must be established within the JAEA contracting system to enable use of incentives. Due to reliance on government funds and annual audit requirements, JAEA is concerned that payment of vendor incentive fees after project completion may be judged as excessive.

ARTEMIS Observation

The Review Team observes that within long term programmes such as JAEA's Back-End Roadmap, it is natural for the contracting approaches to evolve as implementation experience is gained. To facilitate this, it is important that JAEA captures contract-related experiences and results in the early decommissioning phase to inform future actions and decisions.

JAEA's planning and near-term execution (within the next 10 years) would benefit significantly from a documented contracting plan, to include projected services and a timeline for the competitions. Visibility of this plan will facilitate industry's readiness to respond (supporting the Supply Chain actions described in Observation 17). The plan should be sufficiently detailed to ensure it can be linked to the Medium/Long Term Plan activities and facilitate adequate work scope definition (including technology readiness, as appropriate) and the appropriate safety and quality requirements that must be met by all vendors. The plan should also be updated regularly to incorporate programme changes required due to changes in funding, priority, facility conditions and other factors.

Based on the information provided during this review, it is the Review Team's view that JAEA's current contracting methods are not well-suited to enable successful decommissioning and would likely deter optimization. To support the detailed planning and implementation of the Medium/Long-Term Management Plan activities, as well as to underpin continual efforts to optimize the Back-End Roadmap, a detailed contracting strategy is required. This strategy should emphasize and achieve three specific objectives, each of which are expected to support optimization through the selection of highly-skilled vendors for implementation.

1) Performance documentation. JAEA is encouraged to document and evaluate the performance of vendors recently and currently employed, and to continue this practice going forward to build a performance record of their supply chain. This could be achieved through written assessments by the site management at the end of each year (in the case of multi-year contracts) or at the conclusion of the contract term.
2) Expanded evaluation criteria: JAEA is encouraged to consider factors other than cost in the selection criteria, including prior related experience (even if in adjacent market), qualifications of personnel, company safety record. A simple evaluation method could be adopted to objectively compare and weight these factors in the decision/selection process. Useful information on company performance may be publicly available for those companies that are active in the commercial market. However, more reliable information, including prior project reference checks, could be obtained by requiring its submission within the proposal to JAEA contract opportunities. This is standard practice in several other countries.
3) List of qualified (and in this sense, preferred) vendors: JAEA is encouraged to establish a system for well-experienced, high performing businesses which can be utilized to streamline select competitions, in particular high-risk work activities. This list need not be used to preclude broader competitions that promote entry of new businesses to the industry. It is equally important to document those businesses whose performance results in unsatisfactory results, especially in cases of weak safety performance.

As the pace and complexity of decommissioning activities increases, there is potential for the contracting process to become an obstacle to successful implementation. That is, delays in contract competition and award present a risk to programme implementation and could likely lead to schedule extension and increased costs. Therefore, it is vital that sufficient number and skill of contract planning and oversight resources be available in JAEA.

The continued use of lump sum, low-bid contracting decisions also presents a risk to successful implementation within the available budget. There are a multitude of performance-based

contracting approaches that do not require lump sum fee payments at project end. With careful planning, JAEA could incrementally increase its use of clear performance criteria and fee based on objective criteria ('performance-based incentives') and mechanisms to encourage contractors to optimize cost and schedule using standard earned value methodologies ('cost performance index' and 'schedule performance index'). As a result of such approaches, JAEA could effectively achieve a balance of risk and accountability with the supply chain in a manner that drives optimization, while simultaneously stimulating growth in the supply chain, which will bring ancillary benefits to JAEA and the local communities adjacent to JAEA's facilities and sites. The economic benefits in local industry markets are likely to also have a nation-wide positive impact.

Such contracting methods rely on several factors, including:

- Adequate competency in the organization's contract and project management staff
- Well-defined work scope within a detailed, resource-loaded schedule (see Observation 2)
- High confidence cost estimates
- Predictable funding
- System of rigorous performance measurement
- Effective risk and opportunity management

It is the opinion of the Review Team that there is considerable potential for JAEA to incrementally incorporate selected contracting principles and practices from other countries' decommissioning programmes and adapt them effectively within the Japanese culture to optimise the Back-End Roadmap and also benefit the Japanese economy and industry.

The Review Team encourages JAEA to evaluate various technical documents developed by the IAEA related to contracting for decommissioning, as well as the wealth of case studies available at the IAEA.

18	RECOMMENDATIONS, SUGGESTIONS AND GOOD PRACTICES
Observation: *There would be advantages if JAEA's current contracting methods and standards were further developed to facilitate successful decommissioning. As the intensity and complexity of decommissioning activities increases, there is a risk that the contracting process may become an obstacle to its successful implementation.*	
(1)	**BASIS**: GSR-Part 2 Requirement 11: *"4.33. The organization shall retain responsibility for safety when contracting out any processes and when receiving any item, product or service in the supply chain.* *4.34. The organization shall have a clear understanding and knowledge of the product or service being supplied. The organization shall itself retain the competence to specify the scope and standard of a required product or service,*

	and subsequently to assess whether the product or service supplied meets the applicable safety requirements. *4.35. The management system shall include arrangements for qualification, selection, evaluation, procurement, and oversight of the supply chain.* *4.36. The organization shall make arrangements for ensuring that suppliers of items, products and services important to safety adhere to safety requirements and meet the organization's expectations of safe conduct in their delivery."*
R16	**Recommendation**. JAEA should develop and communicate with industry a detailed contracting plan for near term execution (over the next 10 years), which defines needed services and a realistic schedule for the procurement processes.
S16	**Suggestion:** JAEA should consider opportunities to evolve the current contracting approach for ongoing and near-term contract actions in three manners: expanded evaluation criteria for selection; documented evaluation of performance; and established list of preferred qualified suppliers.
S17	**Suggestion**: JAEA should consider options and contracting approaches that ensure balanced sharing of risk and accountability for delivery between JAEA and suppliers.

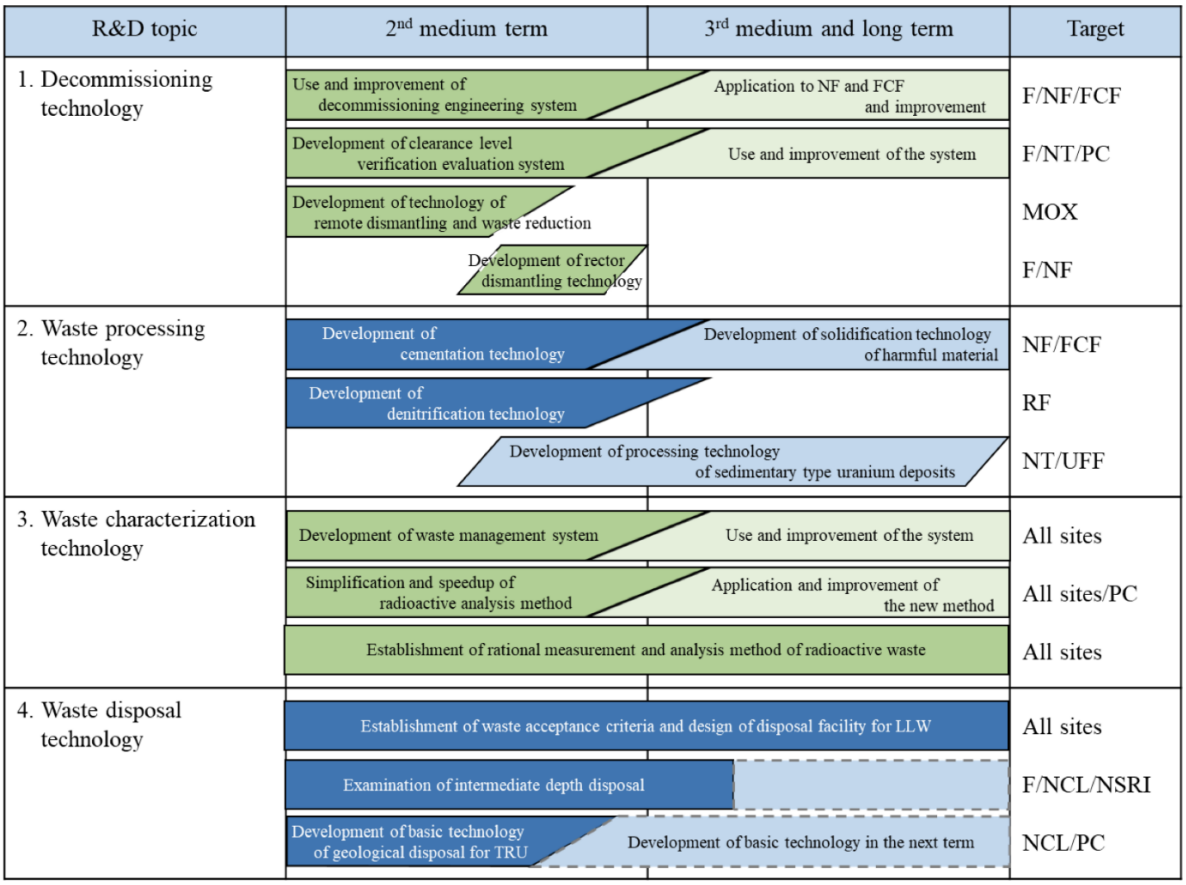
7. TECHNOLOGY FOR DECOMMISSIONING

7.1 MANAGING TECHNOLOGY DEVELOPMENT

MEXT/JAEA Position

JAEA has engaged in the elaboration of decommissioning related technology development as early as 2005, in the first medium term plan. This development plan, which began with basic research and feasibility studies, evolved through the years to practical research and actual demonstration of certain developments and applications.

The plan covers a number of technical areas, illustrated in the figure below, corresponding to the highest priority waste bottlenecks or needed technical developments. Some technical developments are specific to the needs of a given JAEA site while others are of potential interest to several or all sites.



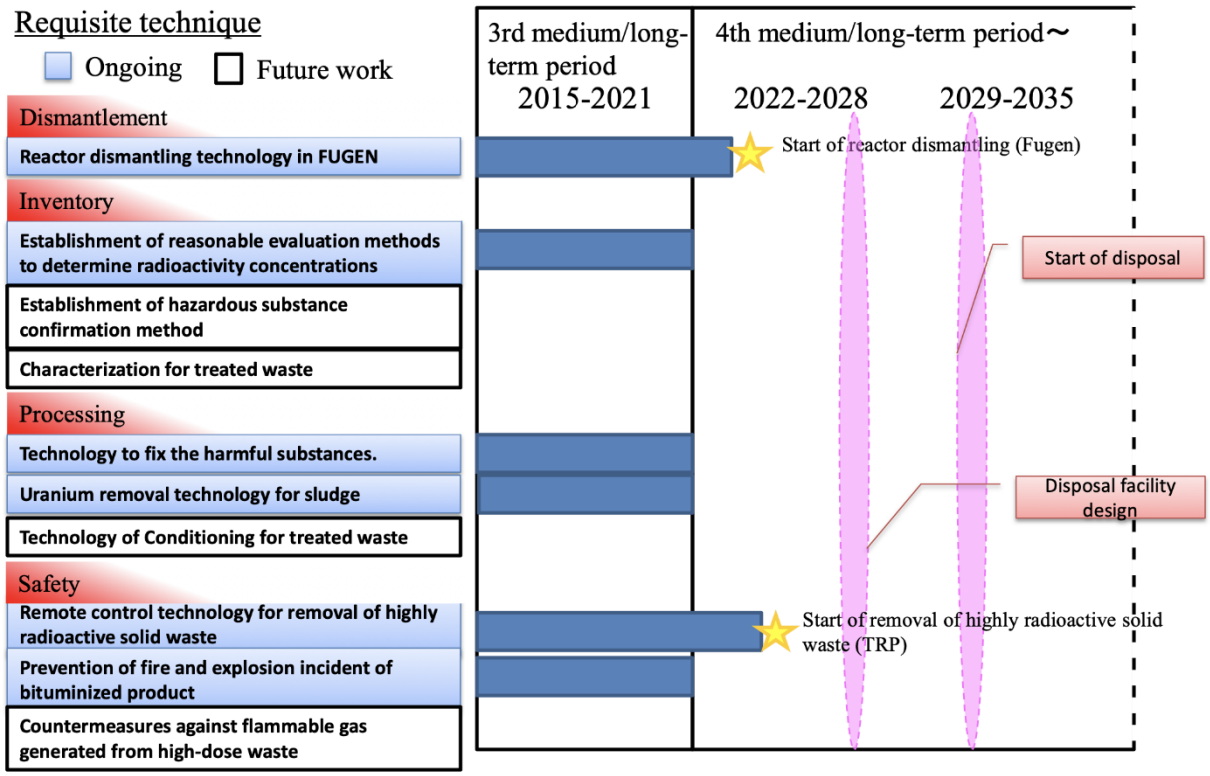
In 2019 JAEA reviewed its organization and created a Decommissioning and Radioactive Waste Management Head Office (Back-end Head Office) whose main mission is the coordination and consolidation of all decommissioning, waste management and technology development activities. The Decommissioning and Waste Management Head Office updates the technology development every 7 years and is currently preparing the 4th mid to long term development plan. In order to do so, it consolidates the technology development needs expressed by the different sites, and organizes if needed the prioritization based on budget, resource, or schedule constraints.

Current management of technology development initiatives can either be done at site level, if the development is specific to a given site, or at the Back-End Head Office level if the development is of potential interest across several sites.

Budget allocation for technology development is generally received from the overall decommissioning budget, which is independent from the general R&D and plant operation budget. However, in some boundary situations, a portion of the R&D budget can be allocated to decommissioning technology development initiatives.

The majority of the technology development projects are associated with waste characterization, decontamination, and conditioning. Some technology development initiatives are focused on the improvement of decommissioning project management processes. Yet another portion of the projects is dedicated to developing solutions for the currently most significant decommissioning projects which are the dismantling of the FUGEN reactor and the retrieval of HASWS waste on the Tokai reprocessing plant.

Important development delivery milestones have been identified, linked to the actual Back-End Roadmap decommissioning schedule (see figure below).



ARTEMIS Observation

The ARTEMIS Review Team observes that JAEA has been deploying and updating a decommissioning technology roadmap since 2005, focusing on the priority challenges of the Back-End Roadmap, which up to now, revolve around waste management and two major projects (Fugen and HASWS)

The ARTEMIS Review Team further observes that the recent changes in organization (2019) have facilitated putting in place a centralized management structure which allows

consolidation, prioritorization and coordination of technology development initiatives in a satisfactory manner.

The ARTEMIS Review Team was told the JAEA prioritizes development topics on the basis of an analysis of technology bottlenecks, as well as an evaluation of benefits versus effort for the topics related to reduce the overall cost and schedule.

The Review Team noted that JAEA has not yet established a formal risk and opportunity management process at the Back-End Roadmap level, and that although there is a degree of analysis of benefits versus effort, there is no systematic process in place to evaluate all technology development needs under such an approach.

Establishing a risk and opportunity management system at the level of the Back-End Roadmap, would significantly facilitate identification of critical technology development needs in the programme, and the potential impact of delayed development. Furthermore, it would provide a formal and quantitative approach to evaluate the potential benefits of developing technologies for risk reduction or opportunity delivery. This quantified analysis of the potential impact of risks and opportunities could serve as a basis to address risks, opportunities and uncertainties in the future cost estimation tools that JAEA will develop (see observation No. 12)

Additionally, the ARTEMIS team noted from earlier discussions related to the optimization of the overall decommissioning programme that, currently, there are several project planning tools in place within the organization.

The progressive ramp-up of decommissioning delivery activities within the present decade will generate an increase in the need for technology development, both in quantity and diversity. Furthermore, the technology development needs may be more closely associated to decommissioning milestones since they will be part of each programme's work breakdown structure. The management of interactions and inter dependencies between decommissioning project and technology development will consequently become more critical over time.

Integrating the project management and planning tools of Back-End Roadmap decommissioning programme with the technology development portfolio would likely facilitate significantly the coordination of both types of activities, and provide an integrated management system to the entire JAEA organization.

19	RECOMMENDATIONS, SUGGESTIONS AND GOOD PRACTICES
Observation: *JAEA has established an organization and governance arrangements to manage technology development for decommissioning. There is a process to consolidate and prioritize technology developments, and to manage projects at central or local level. Planning and project management tools are used to perform these tasks.*	
(1)	**BASIS**: GSR Part 6 -Decommissioning of Facilities Requirement 7 (Integrated Management System):

	4.1. "An *integrated management system shall provide a single framework for the arrangements and processes necessary to address all the goals of the operating organization* "
(2)	**BASIS**: IAEA, Technical report series No. 399, Section 4.3-Risk management, p.21
S18	**Suggestion:** JAEA should consider establishing a Back-End Roadmap risk and opportunity management process which would allow clear identification and quantification of technology developments that could provide risk mitigation or contribute to reduce the programme cost and schedule.
S19	**Suggestion:** JAEA should consider integrating the 'technology development' planning and project management tools with the overall Back-End Roadmap planning and project management tools [*refer to observation n°2 of section 'Optimization of the overall decommissioning programme'*].

7.2 TECHNOLOGY NEEDS FOR PROBLEMATIC WASTE

MEXT/JAEA Position

JAEA has developed and continues to develop technology solutions for the characterization and treatment of some problematic waste such as solid high-activity waste and uranium contaminated sludges.

JAEA identifies that some treatment technology developments will be needed for high activity waste. In particular, hydrogen generation prevention in stabilization matrices is currently being studied with disposal implementers.

Regarding hazardous waste, JAEA notes that, in the absence of clearly defined disposal criteria, it is not possible to define waste treatment solutions.

JAEA has identified the presence of a number of problematic waste items in its facilities, such as shearing powder in the shear cell of Tokai reprocessing plant and is currently working on establishing a complete inventory of such waste types.

Considering the unanticipated decision to shut-down Tokai reprocessing plant, JAEA has not yet been able to develop a complete knowledge of the types and quantities of potentially problematic waste items within TRP.

ARTEMIS Observation

The ARTEMIS team noted that JAEA is in the process of establishing a complete inventory of all potential problematic waste on its sites and that there is currently an incomplete knowledge of the types and quantities of potentially problematic waste items within Tokai reprocessing plant, but possibly also on other sites and facilities.

The ARTEMIS team explained that the term 'problematic' covered a variety of waste items, ranging (upper end) from intermediate level waste deposits inside the cells or equipment of the

plants, to specific solid waste items or liquids resulting from laboratory activities, or decommissioning waste that could prove problematic in the near future such as asbestos or contaminated oils.

The ARTEMIS team observes that such problematic waste will need to be recovered from the facilities prior to delivering dismantling activities. The presence of such waste in the facilities can generate a concern for a long care and maintenance (safe enclosure) period, and will inevitably generate specific safety measures for monitoring.

International experience has shown that the recovery of such waste from fuel cycle facilities, especially when performed years or decades after the end of plant operation, requires the development of a number of technologies covering the full range of the recovery process, and not only treatment:

- Characterization,
- Retrieval,
- Interim conditioning,
- Stabilization,
- Interim storage,
- Final conditioning and disposal.

The ARTEMIS Review Team considers that conducting an extensive characterization survey in the main process cells and equipment of the plants at an early stage, would facilitate establishment of a comprehensive inventory of all potentially problematic waste at an early stage, and provide sufficient time to define and qualify solutions, including technology developments, needed to manage such waste items. Subsequently, a staged approach for recovery of the waste could be deployed in order to limit the cost and schedule impact of retrieving this waste.

A staged approach could begin with an extensive plant cleanout using the available plant processes and equipment, and continue with the development of technology solutions, as needed, for the recovery of those waste items which could not be managed with the existing plant equipment and processes. Such an approach could be considered as a complement to the 'process cleaning and decontamination' listed in the outline schedule for the decommissioning of TRP presented in the Back-End Roadmap. It could also contribute to:

- Mitigating the overall cost burden of managing problematic waste,
- Reducing the treatment and disposal cost of metallic decommissioning waste by reducing the radioactive inventory of decommissioning waste
- Significantly reducing the future cost of decommissioning by allowing the maximization of simple dismantling operations versus complex robotic dismantling projects.

20	RECOMMENDATIONS, SUGGESTIONS AND GOOD PRACTICES
Observation: *JAEA has identified a number of problematic intermediate level waste items in Tokai reprocessing plant, and there may be additional problematic waste present in the facility and in other JAEA facilities. The presence of such waste may provide additional challenges for decommissioning programme delivery. Based on experience elsewhere, technology developments will likely be needed for retrieval and management of a significant portion of these problematic waste items.*	
(1)	**BASIS:** GSR Part 6 – Requirement 10, section 7.2 page 30 *"At the siting stage, a background survey of the site, including the obtaining of information on radiological conditions, shall be performed prior to the construction of a new facility, and the baseline data shall be updated prior to its commissioning. This information shall be used to determine background radiological conditions"*
(2)	**BASIS:** IAEA Specific Safety Guide SSG-47, section 5.26 page 34 *"The diversity of types of nuclear facility makes characterization of the facility a critical step in the process of selecting a decommissioning strategy because the results of characterization are used in defining the scope of the proposed project"*
R17	**Recommendation:** JAEA should conduct an extensive characterization campaign in all the main process equipment and cells of the plants, including sampling, in order to build a complete picture of the nature and quantity of potentially problematic waste.
S20	**Suggestion:** JAEA should consider conducting extensive post operation activities to retrieve and evacuate the maximum amount of problematic waste through existing process routes.
S21	**Suggestion:** JAEA should consider developing plans for early recovery and interim storage of problematic waste that cannot be evacuated through flush-out. This could also include identification of technology developments needed.

8. ABBREVIATIONS

ARM	Advanced Reference Material
CEA	French Alternative Energies and Atomic Energy Commission
CL	Cleared Waste
DECOST	Simplified Decommissioning Cost Estimation Code for Nuclear Facilities
DOE EM	US Department of Energy – Office of Environmental Management
DP	Decommissioning Plan
ENEA	Italian National Agency for New Technologies, Energy and Sustainable Economic Development
GDF	Geological Disposal Facility
HASWS	Highly Radioactive Solid Waste Storage Facility
IRQ	Initial Review Questions
ISDC	International Structure for Decommissioning Costing of Nuclear Facilities
JRC	European Commission Joint Research Centre
NDA	UK Nuclear Decommissioning Authority
NR	Non-Radioactive Waste
NUMO	Nuclear Waste Management Organization of Japan
R&D	Research & Development
SNF	Spent Nuclear Fuel
SOGIN	Nuclear Plant Management Company of Italy - Società Gestione Impianti Nucleari
WAC	Waste Acceptance Criteria

APPENDIX A – TERMS OF REFERENCE

Introduction

On 25th April 2019, Mr. Chihara Yoshiyuki, Deputy Director-General of the Research and Development Bureau, Ministry of Education, Culture, Sports, Science and Technology ("MEXT") requested the IAEA to undertake an ARTEMIS review of the long-term policy of the Japan Atomic Energy Agency ("JAEA") on decommissioning of its installations and processing and disposal of associated radioactive waste, as indicated in the 'Back-End Roadmap' published in December 2018.

Background

MEXT's responsibilities encompass nuclear research and development policies aimed at improving the standard of science and technology in Japan, including oversight of the annual budget of JAEA, an independent National Institution covering a wide spectrum of related activities in the domain of nuclear research and development. To promote the safe and efficient management of the decommissioning of JAEA's nuclear facilities, JAEA published the 'Back-End Roadmap' in December 2018.

The 'Back-End Roadmap' is a 70-year decommissioning plan for JAEA's 79 facilities. The total cost for decommissioning these facilities and associated radioactive waste processing and disposal is estimated as being approximately 1.9 trillion yen, equivalent to about 15 billion Euros (2019 prices). As JAEA has limited experience of dismantling such a diverse range of nuclear and research facilities, the cost estimation incorporates significant uncertainties. JAEA intends to update the cost estimates in due course, taking benefit from external reviews, and MEXT will also have to consider the comprehensiveness of the 'Back-End Roadmap' in order to promote public understanding for the substantial future budget required by the JAEA.

Objective of the Review

The Review will provide an independent international evaluation of JAEA's 'Back-End Roadmap', with a particular focus on the estimation of future liabilities. The Review findings should assist MEXT and JAEA in aligning the planning and implementation of decommissioning, and the robustness of the decommissioning cost estimates, with good international practice.

Scope of the Review

The ARTEMIS review will evaluate the overall substance of the 'Back-End Roadmap', and the specific topics to be addressed are the following:

1. Adequacy of the overall decommissioning programme, including timeframes and general approach to facility dismantlement, processing and disposal of associated radioactive waste and handling of nuclear fuel material;
2. Methodology, quality and content of decommissioning cost estimates for facility dismantlement and for processing and disposal of associated radioactive waste;
3. Facilitating effective implementation of the decommissioning programme in line with current good international practice, including management of the relationship between JAEA and its contractors and making optimal use of available human, technical and financial resources.

The 'Back-End Roadmap' covers 79 facilities, including nuclear reactors, nuclear fuel uses facilities, reprocessing facilities, fuel fabrication facilities and waste management facilities.

Basis for the Review

The Review Team will base its conclusions on the IAEA's safety standards and technical publications and on proven international practice and experience in this field, following the guidelines for the ARTEMIS review service[6].

Review Team

The IAEA will convene a team of international experts to perform the ARTEMIS review mission according to the agreed Terms of Reference. The team will comprise:

— Eight qualified and recognized international experts with wide range of professional experience. The expertise of the experts will include the following specific areas, addressing programmatic, technological, as well as safety considerations, as appropriate:
  - o Optimization of the Overall Decommissioning Programme
  - o Waste Management
  - o Nuclear Fuel Material Management
  - o Decommissioning Cost Assessment
  - o Waste Management Cost Estimation
  - o Project and Contract Management
  - o Technology for Decommissioning

— The Coordinator of the mission is Mr. Patrick O'Sullivan, Division of Nuclear Fuel Cycle and Waste Technology. The Deputy Coordinator of the mission is Mr. Gerard Bruno, Division of Radiation, Transport and Waste Safety, Mr. Kamitani Koji, Division of Nuclear Fuel Cycle and Waste Technology, will provide administrative support to assist the Coordinator and Deputy Coordinator.

The peer review team will be led by a Team Leader from the review team. The Team Leader will be assisted by a Deputy Team Leader, also from the review team. The IAEA will inform the National Counterpart of the composition of the proposed review team prior to conducting the mission.

Organizational Arrangements

The working language of the Review Mission will be English. Interpretation facilities (English / Japanese) will be provided.

The National Counterpart for the mission is MEXT, and the Liaison Officers for communications with the IAEA are Ms. Kawakami Akiko of MEXT and Mr. Nakayama Takuya of JAEA.

[6] The guidelines can be downloaded from the IAEA's Global Nuclear Safety and Security Network (GNSSN) website:
https://gnssn.iaea.org/main/ARTEMIS/Documents/Core%20Documents/ARTEMIS%20Guideline%20Draft.pdf

As a pre-condition for their participation, the experts selected by the IAEA will be asked to sign a confidentiality and non-disclosure agreement to protect any classified or restricted material provided by MEXT or JAEA.

Background and Supporting Materials

The basis for the ARTEMIS review will encompass all documentation submitted by Japan according to the scope of the review. The Advance Reference Material (ARM), a complete list of documents to be provided in advance of the mission is shown in Annex 1. All documents for the purpose of the ARTEMIS review will be submitted in English. Additional documents will be identified after the ARM is delivered if needed.

Reporting and Deliverables

The findings of the ARTEMIS review will be documented in a final report that will summarise the proceedings of the review and contain any recommendations, suggestions and good practices. The report will reflect the collective views of the team members and not necessarily those of their respective organizations or Member States nor the IAEA.

Prior to its finalization, the ARTEMIS Review Report will be delivered to the National Counterpart for fact-checking.

According to preliminary discussions, Japan indicated its intention to publish an executive summary of the report, listing the review recommendations. Japan will decide if the full version of the final report may be made available to the public, bearing in mind that IAEA encourages that ARTEMIS review service reports be published.

Schedule for the Peer Review

The proposed schedule for the ARTEMIS review is the following:

- Preparatory meeting: 3rd and 4th September 2019
- Delivery of ARM to the IAEA: 31st January 2020
- Questions and comments for clarification from the expert team to Japan: middle of March 2020
- Peer review mission: 18 to 28 May 2020 – over a period of up to 11 days
    - Arrival for Day 0: team meeting of the experts
    - Day 1 morning: entrance meeting
    - Day 1 afternoon to Day 3: presentations, interviews, discussions with/by Japan on the basis of preliminary analysis
    - Day 3 afternoon to Day 5: site visits for Monju, Fugen, Tokai Reprocessing Plant (TRP) and others
    - Day 6: presentations, interviews, discussions with/by Japan
    - Day 7 and Day 8: drafting of the report
    - Day 9 and Day 10: discussions and fact checking with/by Japan - finalization of draft report
    - Day 11: draft report delivery – exit meeting
- Final Review report sent to Japan for factual check: middle of June 2020
- Final Review report forwarded by the IAEA to Japan: End of July 2020

Funding of the Mission

The ARTEMIS review will be funded by Japan. The costs for the services will be limited to the travel costs and per diem costs of external experts and IAEA staff and external expert fees in line with IAEA Financial Regulations and Rules. The costs of interpretation facilities will also be covered.

The IAEA will inform the National Counterpart of the estimated costs for the services prior to conducting the mission. Japan is aware that the estimated cost of the mission includes 7% programme support costs.

ANNEX: List of Advance Reference Material (ARM)

0. National Framework

0.1 Government agencies for nuclear energy

0.2 Budgetary framework

Budgeting authorization processes

0.3 Legal and regulatory framework

New regulatory requirements after Fukushima Daiichi NPP accident
The Act on the Regulation of Nuclear Source Material, Nuclear Fuel Material, and Reactors (the Reactor Regulation Act), amended in 2017
Licensing procedure for decommissioning

0.4 Institutional framework

The Act on the Japan Atomic Energy Agency, Independent Administrative Agency

Relationship between MEXT and JAEA

0.5 Spent fuel and waste management framework

1. Overview of JAEA

1.1 JAEA profile

Operational history

Strategy

Medium to Long-term Plan (2015-2021)

Budget trend for decommissioning (past and next 10 years)

1.2 R&D institutes and centers

Geographical location

Overview of sites

R&D for decommissioning

1.3 Detailed organization for decommissioning

Roles and responsibilities

Back-End Roadmap Committee

2. Back-End Roadmap

2.1 Overall decommissioning strategy for JAEA

2.2 Medium/Long-Term Management Plan of JAEA's Facilities

2.3 Details of the Back-End Roadmap

2.3.1 Facility A

2.3.2 Facility B

….

2.3.79 Facility ZZZ

2.4 Conclusion (schedule, cost, rationale for Table 2 in the Back-End Roadmap)

3. Methodology of Cost Estimates for Facility Dismantlement, Processing, and Disposal of Associated Radioactive Waste

3.1 Estimation items compared with ISDC level 1 (items included or not in the cost estimates)

3.2 Facility dismantlement

3.3 Waste processing

3.4 Waste disposal

4. Streamlining and Optimization of Back-end Measures

4.1 Transition from operation to decommissioning including safety management

4.2 Processing and disposal of radioactive waste

4.3 Contract management and relationship to supply chain

4.4 Optimization of technologies

4.5 Human resources skills and allocation

APPENDIX B – MISSION PROGRAMME

	11-Apr	12-Apr	13-Apr	14-Apr	15-Apr	16-Apr	17-Apr	18-Apr	19-Apr	20-Apr	21-Apr	22-Apr
		Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu
	Day 0	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10	Day 11
Morning 8 :30am - 11am (CET) (3:30pm-6pm (JST))	Arrival	Online Meeting With Counterparts (MWC) ※Opening remarks 1)Optimisation of the Overall Decommissioning Programme	MWC 2)Waste Management	MWC 3)Nuclear Fuel Material Management	MWC 5)Waste Management Cost Estimation※	MWC 7)Technology for Decommissioning	TM ※to draft Recommendations, etc. - to be conveyed to Counterparts	TM to draft Mission Report	MWC ※ address any comments on the draft Recommendations/Suggestions /Good Practices.	FT ※MEXT and JAEA review the draft Mission Report until noon (CET) on Monday.	MWC to address comments	TM to finalize Mission Report
Afternoon 1pm - 3:30pm (CET) (8:00pm-10:30pm (JST))	Team meeting (TM)	MWC 1)Optimisation of the Overall Decommissioning Programme	MWC 2)Waste Management	MWC 4)Decommissioning Cost Assessment	MWC 6)Project and Contract Management	MWC extra time for discussion Or TM	TM to draft Mission Report	TM to draft Mission Report	TM ※To be conveyed to counterparts	TM to draft eventual Press Release etc, if needed (Around noon, MEXT conveys comments, if any.)	MWC to address comments	MWC to present Mission Report virtual handover of Report to Counterparts
5:30pm -7:30pm (CET)	Free Time (FT)	TM	TM	TM	TM	TM	TM	TM	TM	TM	TM	

APPENDIX C – RECOMMENDATIONS AND SUGGESTIONS

TOPIC		R: Recommendation S: Suggestion GP: Good Practice	RECOMMENDATIONS, SUGGESTIONS AND GOOD PRACTICES
1.	**OPTIMIZATION OF THE OVERALL DECOMMISSIONING PROGRAMME**	R1	JAEA should review a range of options to more clearly separate their organisational and resourcing (people and budget) responsibilities for R&D and decommissioning to strengthen the focus on each mission.
		R2	JAEA should develop an integrated unified resource loaded programme schedule which would enable programme level risk and opportunity analysis and resource allocation planning to be conducted.
		S1	JAEA should consider how to identify and evaluate alternative scenarios and integration opportunities. This could lead to greater efficiencies and effectiveness in its programme in order to maximize progress within funding constraints.
		S2	Given the large number of structures to be decommissioned and the limited availability of human and financial resources, JAEA should consider, once the plant-by-plant priorities have been established, to proceed with the definition of an action programme for each plant, and then evaluate any interdependencies between these plans

		S3	JAEA should consider carrying out periodic reviews of the decommissioning plans. This should be done on an ongoing basis throughout the programme, since the circumstances and conditions can change continuously and quite suddenly during decommissioning.
		R3	JAEA should further develop a detailed near term work plan to be used alongside the Back-End Roadmap to communicate clearly its goals and priorities both in the near and long-term using the planning processes as required by MEXT.
		R4	JAEA should further develop their stakeholder analysis process. This should identify approaches for engagement, dialogue and decision making based on a priority assessment. Any potential impacts to successful delivery should also be reflected in the relevant project and programme risk management.
		S4	JAEA should consider seeking to develop and maintain an active dialogue with the regulator already at an early stage in the programme in order to build a mutual understanding concerning the principal elements of JAEA's back-end strategy. In doing so, JAEA should be seeking also to obtain insights into any issues that might give rise to regulatory concern, so that it might take appropriate mitigation steps in advance.
2.	**WASTE MANAGEMENT**	S5	JAEA should consider introducing a systematic process for the regular and more frequent updating of the current 7-year inventory.
		R5	JAEA should adopt a clear strategy that aims to align the storage capacities with the availability of the disposal facilities (L2/ L3), taking account of the possibility of delay.

		S6	JAEA should consider approaches to further improve its safety cases for L2 and L3 disposal facilities, proceeding towards generic site conceptual designs, in order to move the process forward in a timely manner and consistent with its continuous improvement initiatives.
		S7	JAEA should consider further developing effective volume reduction techniques and decontamination methods, in order to significantly reduce the amount of radioactive waste produced. It should also consider initiatives aimed at encouraging the use of recycled materials.
		R6	JAEA should conduct appropriate L1 waste management, including providing storage capacity, until a disposal facility is available
		S8	In light of the interdependencies between the different steps of waste management, JAEA should consider developing safety cases for pre-disposal activities for L1 waste.
3.	**NUCLEAR FUEL MATERIAL MANAGEMENT**	R7	JAEA should undertake periodic safety reviews of those facilities under permanent shutdown in order to ensure that safety is maintained over time, and to identify possible actions to further enhance safety.
		R8	JAEA should develop a comprehensive strategy for the management of fuel element debris, including its recovery and treatment.
		R9	JAEA should develop an ageing management plan considering the long-term storage of spent fuel.
4.		R10	JAEA should ensure that its decommissioning cost assessment methods are further developed in order to be able to provide a comprehensive

			understanding of the total costs of dismantling its facilities, and address the associated uncertainties and risks.
	DECOMMISSIONING COST ASSESSMENT	R11	JAEA should ensure that the further development of its decommissioning cost assessment methods align with JAEA's short- and long-term needs by providing comprehensive, robust and traceable decommissioning cost information that is suitable for use in multiple contexts.
5.	**WASTE COST ASSESSMENT**	R12	JAEA should list, assess and manage uncertainties associated with site waste processing, interim storage and final disposal options. *[Refer also to the Section 'Decommissioning Cost Assessment']*
		S9	To help manage uncertainties, JAEA should consider aligning its near-term planning decisions to an integrated waste management approach covering its full programme. Such an integrated approach should consider both the waste hierarchy (reduce, reuse, recycle) and the waste lifecycle (waste inventory from each of the 79 facilities and how this evolves into packages assigned to disposal locations).
		S10	JAEA should consider cost benchmarking with selected waste management programmes internationally. This will establish a better basis for some of the waste related cost estimates and support optimization of the waste management processes.
		S11	JAEA should consider good practice in uncertainty and risk analysis to derive a contingency provision as part of the JAEA waste cost estimating process.

		R13	JAEA should take action to include costs for all areas of currently excluded scope. This will support development of a more complete cost for the decommissioning and waste management programme.
		S12	For each identified area where waste related scope has been excluded JAEA should propose assumptions for its inclusion and calculate a derived placeholder estimate. Areas to review include: • Uranium and plutonium contaminated waste • Decommissioning of the new (on-site) waste processing facilities • Additional on-site Waste Storage facilities Site clean-up and site environmental restoration to end-state
6.	**PROJECT AND CONTRACT MANAGEMENT**	R14	JAEA should establish a framework to address the staffing skills, capabilities and number of personnel required to implement the programme. In the near term, JAEA should implement a plan to hire, train and retain the needed staff. The plan should also include defined activities to retrain current R&D staff to manage decommissioning activities, and be aligned to the detailed work plan (i.e., the Medium to Long-Term Plan)
		S13	JAEA should consider evaluation and use of available commercial training and certificates in project management and contract management.
		S14	JAEA should consider development of education and training programmes in decommissioning and waste management for its personnel. JAEA should also consider development of knowledge management and retention programme.
		R15	JAEA should develop a strategy to promote expansion of the supply chain in order to facilitate entry of suppliers into the decommissioning market and

			further develop the necessary skills among suppliers. Such a strategy could also be tailored to directly benefit the local communities and stakeholders.
		S15	JAEA should consider implementing a partnering approach with suppliers that aligns with near term work planning activities.
		GP1	As part of the Fukui Smart Decommissioning Technology Demonstration Base ('Sumadeco'), JAEA invited vendors from the region who had no previous experience in decommissioning activities to train on the mock up facility at Tsuruga.
		R16	JAEA should develop and communicate with industry a detailed contracting plan for near term execution (over the next 10 years), which defines needed services and a realistic schedule for the procurement processes.
		S16	JAEA should consider opportunities to evolve the current contracting approach for ongoing and near-term contract actions in three manners: expanded evaluation criteria for selection; documented evaluation of performance; and established list of preferred qualified suppliers.
		S17	JAEA should consider options and contracting approaches that ensure balanced sharing of risk and accountability for delivery between JAEA and suppliers.
7.	**TECHNOLOGY FOR DECOMMISSIONING**	S18	JAEA should consider establishing a Back-End Roadmap risk and opportunity management process which would allow clear identification and quantification of technology developments that could provide risk mitigation or contribute to reduce the programme cost and schedule.

		S19	JAEA should consider integrating the 'technology development' planning and project management tools with the overall Back-End Roadmap planning and project management tools *[Refer to Observation 2]*
		R17	JAEA should conduct an extensive characterization campaign in all the main process equipment and cells of the plants, including sampling, in order to build a complete picture of the nature and quantity of potentially problematic waste.
		S20	JAEA should consider conducting extensive post operation activities to retrieve and evacuate the maximum amount of problematic waste through existing process routes.
		S21	JAEA should consider developing plans for early recovery and interim storage of problematic waste that cannot be evacuated through flush-out. This could also include identification of technology developments needed.