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Mission Report

IAEA INTERNATIONAL PEER REVIEW MISSION ON MID-AND-LONG-TERM ROADMAP TOWARDS THE DECOMMISSIONING OF TEPCO'S FUKUSHIMA DAIICHI NUCLEAR POWER STATION

(Fourth Mission)

Tokyo and Fukushima Daiichi NPS, Japan

5-13 November 2018

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MISSION REPORT TO THE GOVERNMENT OF JAPAN

Tokyo and Fukushima Daiichi NPS, Japan

5-13 November 2018

MISSION REPORT

Mission date: 5-13 November 2018

Location: Tokyo and Fukushima Daiichi NPS, Japan

Organized by: International Atomic Energy Agency

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CONTENTS

EXECUTIVE SUMMARY

Background

Following the accident at TEPCO's Fukushima Daiichi Nuclear Power Station (NPS) on 11 March 2011, the "Mid-and-Long-Term Roadmap towards the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Station Units 1-4" (hereinafter referred to the "Roadmap") was adopted by the Government of Japan and the TEPCO (Tokyo Electric Power Company) Council on Mid-to-Long-Term Response for Decommissioning in December 2011. The Roadmap was revised in July 2012, June 2013, June 2015 and September 2017. The Roadmap includes a description of the main steps and activities to be implemented for the decommissioning of the Fukushima Daiichi NPS through the combined effort of the Government of Japan and TEPCO.

At the request of the Government of Japan, the IAEA organized three missions of the International Peer Review of the Roadmap, which were implemented within the framework of the IAEA Nuclear Safety Action Plan, in April 2013, in November/December 2013 and in February 2015, respectively. Those missions aimed at enhancing international cooperation and sharing with the international community information and knowledge concerning the accident to be acquired in the future decommissioning process.

The Government of Japan conveyed, in an official correspondence dated 24 August 2018 through the Permanent Mission of Japan in Vienna, its request to the IAEA to dispatch another mission, and the IAEA accepted the request in an official correspondence dated 10 September 2018. During the 62nd IAEA General Conference (Vienna, 17-21 September 2018), the intention to receive another IAEA mission was confirmed (Terms of Reference were signed) by a representative of the Government of Japan, with the aim to continue to work together with the IAEA and the international community.

Following this request, the fourth Mission of the International Peer Review of Mid-and-Long-Term Roadmap towards the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Station, involving 13 international experts, took place from 5 to 13 November 2018 (hereinafter referred to as the "Mission").

The objective of the Mission was to provide an independent review of the planning and implementation of Fukushima Daiichi NPS decommissioning, related radioactive waste management and spent fuel and fuel debris management. The Mission was conducted based on the IAEA Safety Standards, technical guidance and other relevant good practice, aimed at assisting the Government of Japan in the implementation of the Roadmap.

The Government of Japan and TEPCO provided comprehensive information on the current status and future plans of the implementation on the Roadmap. The IAEA Review Team assessed the information, and had extensive discussions with the relevant institutions in Japan, as well as visiting TEPCO's Fukushima Daiichi NPS, to better understand the situation.

The Preliminary Summary report was submitted to METI (Ministry of Economy, Trade and Industry) on 13 November 2018 in Tokyo and published on the METI website and the IAEA website (https://www.iaea.org/sites/default/files/18/11/missionreport-131118.pdf). This final Mission report elaborates on the findings and conclusions of the Preliminary Summary report.

Main Findings and Conclusions

Since March 2011, addressing the situation of the damaged plants of Fukushima Daiichi and moving towards decommissioning while ensuring safety for the workers and the population has remained a very challenging task, requiring resources, commitment, and innovation to tackle a unique situation. The IAEA Review Team considers that significant progress has already been accomplished to move Fukushima Daiichi from an emergency situation to a stabilized situation. This should allow the focus of more resources for detailed planning and implementation of the decommissioning project of the whole site with considerations extended up to the completion of the decommissioning.

The organization put in place by the Japanese government, with clarified roles and responsibilities of the main actors – METI, NDF (Nuclear Damage Compensation and Decommissioning Facilitation Corporation), TEPCO's internal unit FDEC (Fukushima Daiichi Decontamination and Decommissioning Engineering Company), IRID (International Research Institute for Nuclear Decommissioning), JAEA (Japan Atomic Energy Agency) – allows for more effective planning and implementation of the radioactive waste management and decommissioning. Strong collaborative relationships among these organizations should be maintained.

The IAEA Review Team considers the daily activities at the site are well managed, for the areas reviewed. In this respect, many improvements have been recorded since the previous mission in 2015, in particular pertaining to water management (implementation of the multi-layered approach including sub-drain and recently the completion of the "frozen soil wall"), and solid waste management (construction of storage and volume reduction facilities). The IAEA Review Team also noted with appreciation the improvement of working conditions at the site.

The risk reduction strategy is being implemented at a pace commensurate with the challenges of the site-specific situation. In this respect the IAEA Review Team noted the progress being made towards the removal of spent fuel from Unit 3 and then Unit 1 and Unit 2. Looking towards fuel debris retrieval, the Review Team noted with interest the investigations made in the reactors and the Research and Development effort which support this objective.

Despite the improvements in addressing the root causes contributing to the generation of contaminated water, the IAEA Review Team continues to identify water management as critical to the sustainability of decommissioning activities, in particular the resolution of the disposition path for the ALPS (Advanced Liquid Processing System) treated water containing tritium and other radionuclides in tanks. With the volume of ALPS treated water expected to reach the planned tank capacity of 1.37 million m^3 within the coming three to four years, and considering current site facility plan for space allocations, and that further treatment and control of the stored water before disposition would be needed for implementation of any of the five solutions considered by the Japanese Government (as TEPCO expressed at the Sub-committee on handling of ALPS treated water, October 1, 2018), a decision on the disposition path should be taken urgently engaging all stakeholders.

The IAEA Review Team notes with appreciation that the Government of Japan, NDF and TEPCO have given due consideration to the advice provided in previous IAEA missions to enhance planning and safe implementation of decommissioning and radioactive waste management activities.

Considering the challenges ahead towards the safe decommissioning of the site, the IAEA

Review Team encourages Japan to further strengthen programme and project management and related organizational structure for comprehensive and integrated planning for the completion of the site decommissioning.

While fuel debris retrieval is one of the most important and challenging issues, such planning shall also address sustainability and long-term aspects such as radioactive waste management including the waste streams which will come from the decommissioning of the facilities on site.

The implementation of the safe decommissioning of Fukushima Daiichi NPS is a unique complex case and expected to span several decades: the IAEA Review Team considers that it will therefore require sustained engagement with stakeholders, proper knowledge management, and benefit from broad international cooperation.

Acknowledgements and Advisory Points

This report provides highlights of important progress (Acknowledgments) in 17 areas covering the current situation of TEPCO's Fukushima Daiichi NPS and Roadmap implementation, follow-up of the previous IAEA Review missions, public communication, strategy and planning for the decommissioning, institutional and organisational issues and specific topics such as water management including management of ALPS treated water stored in tanks, spent fuel removal and fuel debris retrieval and solid radioactive waste management.

The report also offers 21 Advisory Points where the IAEA Review Team feels that current practices could be improved, taking into account both international standards and the experience from planning and implementation of decommissioning programmes in other countries.

Following is a summary of Acknowledgments and Advisory Points:

Current Situation of Fukushima Daiichi NPS and Roadmap Implementation

Acknowledgement 1

The IAEA Review Team acknowledges the efforts by Japan in the development, implementation and communication of the Roadmap activities including incorporation of regular revisions. The establishment of advisory committees and consultations with Japanese and international experts bring useful contribution to the definition of the programme.

Follow-up of the Previous IAEA Review Mission Conducted in 2015

Acknowledgement 2

The IAEA Review Team appreciates the consideration given to the Advisory Points from the previous Review missions and acknowledges the efforts of NDF, TEPCO and other Japanese organizations and institutions to effectively implement them into the arrangements and practices related to the decommissioning of the Fukushima Daiichi NPS.

Management of ALPS Treated Water Stored in Tanks

As stated in the previous Review missions, the IAEA Review Team is of the opinion that the present plan to store the ALPS treated water containing tritium and other radionuclides in above ground tanks, with the current capacity of 970,000 m^3, can only be a temporary measure while a more sustainable solution is needed. Currently, the Government of Japan is considering five solutions including the possible resumption of controlled discharges to the sea, which are routinely used by operating nuclear power plants and fuel cycle facilities in Japan and worldwide, and for which a large amount of information is readily available.

Acknowledgement 3

The IAEA Review Team acknowledges the work done by METI to identify possible technologies to remove tritium and assess possible disposition paths. The IAEA Review Team also acknowledges ongoing dialogue with all stakeholders, and especially with the local communities. The IAEA Review Team also takes note of the statements issued by the Nuclear Regulation Authority (NRA) on the management of ALPS treated water.

Advisory Point 1

The IAEA Review Team holds that a decision on the disposition path for the stored ALPS treated water containing tritium and other radionuclides, after further treatment as needed, must be taken urgently, engaging all stakeholders, to ensure the sustainability of the decommissioning activities and of the safe and effective implementation of other risk reduction measures.

After the decision on the disposition path is made, TEPCO should prepare and submit to the NRA for authorization a comprehensive proposal for its implementation in conformity with laws and regulations, supported by such items as a safety assessment and analysis of the environmental impacts, including control of the water before disposition, to address radiation safety of the public, workers and environment.

To support the implementation of the chosen disposition path, a robust comprehensive monitoring programme developed by TEPCO and approved by the NRA, supported by a communication plan ensuring a proactive and timely dissemination of information to stakeholders and general public are necessary.

Public Communication

Acknowledgement 4

The IAEA Review Team recognizes that TEPCO has strengthened its process for sharing information with the public, including by publishing radiation data on its website. In addition, the Government of Japan has set up the Sub-committee on handling of ALPS treated water which holds hearings for the public to ask questions and voice concerns, providing important feedback for members of the Sub-committee and officials.

Advisory Point 2

The IAEA Review Team advises to the Government of Japan and TEPCO to take a proactive and timely approach to communicating with the public on matters directly relevant to public concerns. This includes not only disclosing relevant information and data on a regular basis, but providing the general public the information in an easy-to-understand manner, including an explanation of its potential impact on the health and safety of the workforce and public as well as the protection of the environment.

Strategy and Planning for the Decommissioning of Fukushima Daiichi Site

STRATEGY AND PLANNING

Acknowledgement 5

The IAEA Review Team acknowledges the improvement that the Government of Japan, NDF, TEPCO and other organisations have made on revising and developing the strategy for the decommissioning of TEPCO's Fukushima Daiichi NPS. There is evidence of a risk prioritisation based on the radioactive content of the waste materials, as well as on their physical properties and the conditions and environment in which they currently exist. This resulted in refocusing efforts on the removal of spent fuel and fuel debris retrieval, and aids the long-term planning and risk assessment of implementation activities.

Advisory Point 3

The IAEA Review Team advises the Government of Japan and NDF to prepare themselves now in order to develop during Phase 3 an integrated plan for the completion of decommissioning of the entire Fukushima Daiichi site; including all six units, the ancillary radioactive waste treatment and storage facilities, and the management of all forms of radioactive waste arisings during the decommissioning activities. Careful consideration should be given to the assumptions used and how to express the inherent uncertainties involved. In order to successfully produce such a plan, significant effort is expected to be required to determine the options and scenarios that lead to a credible plan for the long term.

PROGRAMME AND PROJECT MANAGEMENT

Acknowledgement 6

The IAEA Review Team is of the opinion that the establishment of the Project Management Organization (PMO) is a good decision and the use of more sophisticated project management tools will improve TEPCO's project delivery and analysis capabilities.

Advisory Point 4

The IAEA Review Team recommends that TEPCO uses project management tools to their full potential, for example by developing a resource loaded schedule for each individual project or activity identified in the Work Breakdown Structure (WBS) and integrating those schedules into a master Fukushima Daiichi project schedule. Integrating individual project activities into a master schedule will help identify constraints on resources, potential conflicts and insertion

points for new technology from R&D activities.

Advisory Point 5

The IAEA Review Team advises that programme and project decision making focus on management of the uncertainties, and hence risks to delivery of the schedule and overall programme.

R&D TO SUPPORT DECOMMISSIONING PROJECT

Acknowledgement 7

The IAEA Review Team appreciates the substantial efforts being undertaken to plan and carryout research and development (R&D) activities to support the Fukushima Daiichi decommissioning. Substantive R&D project outcomes have been produced thus far and capable state-of-the-art facilities with strategic domestic and international cooperation have been established. In particular, the Decommissioning R&D Partnership Council structure appears to be an adequate approach to identify and prioritize R&D needs with input from all relevant parties.

Advisory Point 6

TEPCO has demonstrated a robust approach to technology selection, development and deployment, and is aware of the challenges and risks associated with first-of-a-kind technology deployment that inevitably give rise to schedule uncertainties. The IAEA Review Team advises TEPCO to consider implementation of international good practice approaches to technology maturation and deployment as well as development of contingency plans to accommodate any schedule delays.

SUPPLY CHAIN AND MANAGEMENT SYSTEM

Advisory Point 7

The IAEA Review Team recommends that TEPCO review and strengthen their interface management processes especially for complex situations involving multiple parties and international suppliers. Emphasis should be placed on ensuring the parties understand the technical specifications and programmatic requirements. Periodic joint progress reviews including reviews and inspections at the locations where work is performed are essential to ensuring that interface issues are identified and managed at the earliest possible time to avoid impacts later in the project.

Institutional and Organisational Issues

ROLE AND INTERACTION BETWEEN NDF AND TEPCO

Acknowledgment 8

The IAEA Review Team acknowledges the establishment and full operational status of the NDF and of the TEPCO’s Fukushima Daiichi Decontamination and Decommissioning

Engineering Company. The IAEA Review Team acknowledges the clarification of the roles and responsibilities of the main actors: METI, NDF, TEPCO (FDEC), IRID, JAEA, and the attention given to the coordination of their respective roles and responsibilities.

Advisory Point 8

The IAEA Review Team takes note of the additional roles given to NDF, and the corresponding interactions between NDF and TEPCO. In the current scheme, NDF has an operational role of strategic planning and the role of oversight of TEPCO, while TEPCO has the responsibility for the implementation as a licensee. The IAEA Review Team advises Japan to ensure clear accountability of respective roles and responsibilities between and among NDF and TEPCO, and to create the condition for TEPCO to have the necessary ownership of the solutions that it will implement.

LICENSING PROCESS

Acknowledgement 9

The IAEA Review Team acknowledges that TEPCO has a now well established monthly and weekly communication with NRA, organized within a transparent framework.

Advisory Point 9

In complex situations such as the post-accident situation of the Fukushima Daiichi site, some specific regulatory and licensing criteria may need to be defined when the criteria used in normal situations cannot readily be applied. The IAEA Review Team advises METI, NDF and TEPCO to maintain engagement with NRA to develop a common understanding of the safety requirements for the performance of the decommissioning of the site and to optimize the risk reduction strategy.

KNOWLEDGE MANAGEMENT

Advisory Point 10

The IAEA Review Team encourages TEPCO to develop knowledge management systems that encompass all facets of the relevant workforce (TEPCO and subcontractors) considering the specific requirements of the conditions and life-cycle stage of the site’s facilities for the next several decades.

TRAINING AND HUMAN RESOURCES DEVELOPMENT

Acknowledgment 10

The IAEA Review Team endorses the creation of the Nuclear Education and Training Centre to facilitate the human resource development function, and which is now consolidated into an organization directly under the control of Director of the Nuclear Power & Plant Siting Division of TEPCO, thereby utilizing resources more efficiently. The IAEA Review Team also acknowledges that the education and training programme is designed following the Systematic Approach to Training.

Advisory Point 11

The IAEA Review Team recommends that TEPCO and the PMO utilize the integrated project management tool to maintain an estimate of the number and categories of workers required during different phases of the Fukushima Daiichi decommissioning project. This would include tracking worker demographics to identify recruitment and training requirements.

SAFETY AND RADIATION PROTECTION

Acknowledgement 11 (Safety leadership and safety culture)

The IAEA Review Team recognises the safety leadership that TEPCO, who has primary responsibility as Operator and Licensee, has shown in the period since the last IAEA Review Mission in developing a safety culture at the Fukushima Daiichi site. They have made significant progress in addressing their understanding of the expectations and requirements of the nuclear safety culture in a decommissioning environment. In addition, the IAEA Review Team applauds the adoption of the WANO Traits of a Nuclear Safety Culture and the implementation of systems to measure their organizational performance, with review of the results of the safety culture programme.

Acknowledgment 12 (Occupational Radiation Protection Programme)

Measures for occupational safety and health management have been enhanced at the TEPCO Fukushima Daiichi NPS as required by the Ministry of Health, Labour and Welfare guidelines from August 2015. Radiation Protection Programme, Guidelines for dose exposure reduction management and Guidelines for organization and operation of ALARA committee has been reviewed and revised. Those guidelines are in full practical implementation under the TEPCO's Committees responsible for risk management.

The site working conditions are improved because of the paving action at the site, better work planning by the ALARA Committee, improvement on the protective gear and real-time radiation monitoring. The workers dosimetry and health surveillance programme takes into consideration the demanding and difficult working conditions.

Advisory Point 12 (Safety leadership and safety culture)

The IAEA Review Team encourages TEPCO to promote the safety culture of all workers on site including its contractors, and to continue to consider the specific requirements of the conditions and life-cycle stage of the site's facilities that differ from a normal operating environment, and continue to develop a safety culture management system appropriate to radioactive waste management and decommissioning.

Advisory Point 13 (Occupational Radiation Protection Programme)

TEPCO is encouraged to provide for further optimization of radiation protection exposure by analysing the workers' exposure data for all facilities and types of operation, so as to identify optimization options and dose reduction factors. This is valuable information for current and future actions at the site.

International Cooperation

Acknowledgement 13

The IAEA Review Team acknowledges the development of bilateral cooperation on a number of important topics such as Research and Development, risk assessment and prioritization or communication, and the adoption of internationally recognized practices. The IAEA Review Team also acknowledges the proactive stance of Japan to share with international community the status of decommissioning activities.

Advisory Point 14

The IAEA Review Team advises Japan to further develop a broad array of international cooperation in all domains. Such international cooperation has the potential to bring significant benefits to the safe decommissioning of the Fukushima Daiichi site and to increase knowledge sharing with the international community. The IAEA Review Team encourages Japan to draw upon the global diversity of international good practices, and to integrate and adapt them to fit the unique Fukushima Daiichi site situation.

Specific Topics

MANAGEMENT OF CONTAMINATED WATER AND COUNTERMEASURES AGAINST GROUNDWATER INGRESS

Acknowledgement 14

The IAEA Review Team commends TEPCO for implementing the full set of the countermeasures against the groundwater ingress into the damaged facilities and against leakage of contaminated water from the buildings and from the site, thus contributing to reduction in the generation of contaminated water and to the protection of the workers, public and the environment, and the management of the site boundary dose.

Advisory Point 15

The injected water cooling of the fuel debris mixes with ingressed water and contributes to the generation of contaminated water. The IAEA Review Team encourages TEPCO to perform analyses of the needs for continuous cooling and, depending on the results, to consider further reducing the amount of injected water, ending injected water cooling at some point, or establishing a closed cooling loop.

SPENT FUEL REMOVAL AND FUEL DEBRIS RETRIEVAL

Acknowledgment 15 (Spent fuel)

The IAEA Review Team acknowledges the careful and deliberate approach to the spent fuel removals across the site. The team recognizes the many good practices such as the adaptation of safety controls to the conditions in each Unit, providing hands-on training of the workers, using dummy fuel and casks on the remote operation of the new FHM (Fuel Handling Machine) and crane in Unit 3 before starting the real operations, and measures taken to reduce dust arising

during rubble and spent fuel removal operations for the radiological protection of the workers and the environment.

Acknowledgment 16 (Fuel debris)

The IAEA Review Team also acknowledges significant progress is being achieved in clarification of the fuel debris distribution inside the reactor building of Units 1-3 since the 3rd Review Mission, and the step-by-step approach (from internal PCV investigation, fuel debris sampling and characterization, small scale retrieval to bulk retrieval) currently considered for the fuel debris retrieval.

Advisory Point 16 (Spent fuel)

The IAEA Review Team advises TEPCO to take measures to ensure enough storage capacity will exist among the common spent fuel pool and dry cask storage areas to accommodate all spent fuel on site from Units 1-6.

Advisory Point 17 (Spent fuel)

The IAEA Review Team advises that all the different categories and characteristics of all fuel assemblies on the site be fully considered with regard to conditions affecting its safe management (retrieval, transport and storage). Substantial international experience is available in the management of both intact and damaged BWR spent fuel (e.g. USA, Germany, etc.) that may be drawn upon. While there are as yet no indications of fuel assemblies damaged by the accident, the plan should incorporate the ability to design and store, in the pool and casks, all anticipated fuel assembly conditions.

Advisory Point 18 (Fuel debris)

The IAEA Review Team advises that before the commencement of the fuel debris retrieval activities, there should be a clear implementation plan defined to safely manage the retrieved material. TEPCO should ensure that appropriate containers and storage capacity are available before starting the fuel debris retrieval. Sufficient characterization (e.g. estimation of criticality, hydrogen emission, neutron activity, thermal condition, parameters of neutron-multiplying medium, etc.) of the fuel debris environment will support successful safe debris retrieval and design of related facilities and equipment including containers and any treatment and storage facilities.

Advisory Point 19 (Fuel debris)

Whilst significant progress has been achieved in estimation of the fuel debris distribution inside the reactor building of Units 1-3, there is recognition that more must be done. The IAEA Review Team supports continuing efforts to more precisely understand the fuel debris distribution inside each unit, the associated level and distribution of radiation encountered.

MANAGEMENT OF RADIOACTIVE WASTE

Acknowledgement 17

The IAEA Review Team is of the opinion that good progress has been made with this very

complex series of decommissioning and waste management projects in the face of many significant challenges and constraints. Good progress has been made in establishing strategies to reduce the volume of radioactive wastes, create storage capacity and enhance the stability of wastes by using methods such as incineration and dewatering.

Advisory Point 20

The IAEA Review Team recommends that, in considering the overall duration of the Fukushima Daiichi decommissioning activities, the Roadmap and other planning documents address operational radioactive waste present on site at the time of the 2011 accident and the present arising of radioactive waste from the initial site decontamination and fuel retrieval preparations. In addition, the IAEA Review Team encourages to envisage the generation of waste arising from the decommissioning of 6 units and supporting facilities through the completion of decommissioning, recognizing that at this point in time, significant uncertainty exists in the decommissioning approach and thus the volumes involved. This will help ensure there is an adequate allocation of resources to manage, characterize, treat and dispose of these radioactive wastes and that the work activities for these wastes can be properly sequenced with other activities.

Advisory Point 21

The IAEA Review Team encourages the NDF and TEPCO to continue to actively explore the application of waste hierarchy principles to minimize the volume of material consigned for disposal. Routine use of pre-treatment techniques of sorting, segregation and decontamination of solid material after collection will create opportunities for the recycling of material as well as providing the possibility to remove material from regulatory control. The IAEA Review Team encourages the Government of Japan to support TEPCO in such approach.

1. BACKGROUND, OBJECTIVES AND SCOPE OF THE MISSION

1.1. BACKGROUND

Following the accident at TEPCO's Fukushima Daiichi Nuclear Power Station (NPS) on 11 March 2011, the "Mid-and-Long-Term Roadmap towards the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Station Units 1-4" (hereinafter referred to the "Roadmap") was adopted by the Government of Japan and the TEPCO Council on Mid-to-Long-Term Response for Decommissioning in December 2011. The Roadmap was revised in July 2012 and June 2013. The Roadmap includes a description of the main steps and activities to be implemented for the decommissioning of the Fukushima Daiichi NPS through the combined effort of the Government of Japan and TEPCO.

Upon the request of the Government of Japan, the IAEA organized three missions of the International Peer Review of the Roadmap, which were implemented within the framework of the IAEA Nuclear Safety Action Plan, in April 2013, in November/December 2013 and in February 2015, respectively. Those missions aimed at enhancing international cooperation and sharing with the international community information and knowledge concerning the accident to be acquired in the future decommissioning process.

The first mission was conducted from 15 to 22 April 2013 with the main purpose of undertaking an initial review of the Roadmap, including assessments of the decommissioning strategy, planning and timing of decommissioning phases and a review of several specific short-term issues and recent challenges, such as the management of radioactive waste, spent fuel and fuel debris, management of associated doses and radiation exposure of the employees, and assessment of the structural integrity of reactor buildings and other constructions. The Final Report of the first mission is available on the IAEA webpage http://www.iaea.org/sites/default/files/missionreport220513.pdf.

After the first mission, the Government of Japan and TEPCO revising the Roadmap took into consideration the advice in the first mission report. The revised Roadmap entitled "Mid-and-Long-Term Roadmap towards the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Station Units 1-4, revised 27 June 2013" is available on the website of the Ministry of Economy, Trade and Industry (METI) http://www.meti.go.jp/english/earthquake/nuclear/decommissioning/pdf/20180530_01a.pdf.

The second mission was conducted from 25 November to 4 December 2013. The objective of the second mission was to provide a more detailed and holistic review of the revised Roadmap and mid-term challenges, including the review of specific topics agreed and defined in the first mission, such as removal of spent fuel from storage pools, retrieval of fuel debris from the reactors, management of contaminated water, monitoring of marine water, management of radioactive waste, measures to reduce ingress of groundwater, maintenance and enhancement of stability and reliability of structures, systems and components (SSCs), and research and development (R&D) relevant to pre-decommissioning and decommissioning activities. The Final Report of the second mission is available on the IAEA webpage http://www.iaea.org/sites/default/files/IAEAfinal_report120214.pdf.

The third mission was implemented from 9 to 17 February 2015. The objective of the third mission was to provide an independent review of the activities associated with revisions to the planning and implementation of Fukushima Daiichi NPS decommissioning, including the review of the current situation of TEPCO's Fukushima Daiichi NPS, follow-up of the previous IAEA Review missions conducted in 2013, review of the draft of the second revision of the

Roadmap, review of the draft of the Strategic Plans for decommissioning developed by Nuclear Damage Compensation and Decommissioning Facilitation Corporation (NDF), review of the progress and future plans, including R&D activities, in specific areas such as management of contaminated water, countermeasures against groundwater ingress issue, removal of spent fuel assemblies and damaged fuel debris from Units 1-4, management of radioactive waste (including present storage challenges and the future plans concerning the end point of radioactive waste and the end state of the NPS site) and institutional and organizational issues (i.e., allocation of responsibilities among the relevant bodies, staffing and training of workers, safety culture, communication with the public and dissemination of lessons learned). The Final Report of the third mission is available on https://www.iaea.org/sites/default/files/missionreport130515.pdf.

NDF developed the "Technical Strategic Plan 2015 for Decommissioning of the Fukushima Daiichi Nuclear Power Station of Tokyo Electric Power Company" (hereinafter the "Strategic Plan 2015") on April 30, 2015. The Strategic Plan 2015 is available on http://www.dd.ndf.go.jp/en/strategic-plan/book/20150624_Technology_strategy_plan_e.pdf.

After the third mission, the Government of Japan and TEPCO took into consideration the advice given through the third mission report in the course of revising the Roadmap. The revised Roadmap entitled "Mid-and-Long-Term Roadmap towards the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Station" (12 June 2015) is available on METI website (http://www.meti.go.jp/english/earthquake/nuclear/decommissioning/pdf/20150725_01b.pdf).

The Strategic Plan 2016 and the Strategic Plan 2017 were formulated on 13 July 2016 and 31 August 2017 respectively based the status of the progress made in the site conditions and technical development since the Strategic Plan 2015 was developed.

The Strategic Plan 2016 and The Strategic Plan 2017 are available on http://www.dd.ndf.go.jp/en/strategic-plan/book/20170322_SP2016eFT.pdf and http://www.dd.ndf.go.jp/en/strategic-plan/ book/20171005_SP2017eFT.pdf, respectively.

Since the revision of Roadmap in June 2015, decommissioning and contaminated water management had progressed, and the site conditions has changed. The Roadmap was revised on 26 September 2017 and is available on METI website (http://www.meti.go.jp/english/earthquake/nuclear/decommissioning/pdf/20170926_01a.pdf).

The Government of Japan conveyed, in an official correspondence dated 24 August 2018 through the Permanent Mission of Japan in Vienna, its request to the IAEA to dispatch another mission, and the IAEA accepted the request in an official correspondence dated 10 September 2018. During the 62nd IAEA General Conference (Vienna, 17-21 September 2018), the intention to receive another IAEA mission was confirmed (ToR was signed) by the representative of the Government of Japan, with the aim to continue to work together with the IAEA and the international community.

Following this request, the fourth Mission of the International Peer Review of Mid-and-Long-Term Roadmap towards the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Station, involving 13 international experts, took place from 5 to 13 November 2018 (hereinafter referred to as the "Mission").

The Government of Japan and TEPCO provided comprehensive information on the current status and future plans of the implementation on the Roadmap. The IAEA team assessed the information, and had extensive discussions with the relevant institutions in Japan, as well as visiting TEPCO's Fukushima Daiichi NPS, to better understand the situation.

1.2. OBJECTIVE

The objective of the International Peer Review was to provide an independent review of the activities associated with revisions to the planning and implementation of Fukushima Daiichi NPS decommissioning. The Mission was based on the IAEA Safety Standards and other relevant safety and technical guidance, aimed at assisting the Government of Japan in the implementation of the Revised "Mid-and-Long-Term Roadmap towards the Decommissioning of the TEPCO's Fukushima Daiichi Nuclear Power Station". In particular, the Mission was intended to:

- Provide advice and commentary on both the safety and technological aspects of decommissioning, waste management and other related activities;
- Provide advice to improve the planning and implementation of decommissioning related activities at Fukushima Daiichi NPS; and
- Facilitate sharing of good practices and lessons learned for decommissioning operations after the accident with international community.

1.3. SCOPE OF THE MISSION

The scope of the Review Mission covered following items:

Item 1: Review of the current situation of TEPCO's Fukushima Daiichi NPS;

Item 2: Follow-up of the previous IAEA Review Mission conducted in 2015 (i.e., measures taken or to be taken, progress made and current status, issues/challenges, perspectives and future plans, etc.);

Item 3: Review of the current status of the implementation of the Roadmap;

Item 4: Review of the Strategic Plans for decommissioning developed by the Nuclear Damage Compensation and Decommissioning Facilitation Corporation;

Item 5: Review of the progress and future plans, including R&D activities, in specific areas such as:

- management of contaminated water,
- countermeasures against groundwater ingress,
- removal of spent fuel assemblies and damaged fuel debris from Units 1-3,
- management of radioactive waste (highlighting present storage challenges, features of current waste and activities identifying and managing waste stream), and
- institutional and organisational issues (i.e., allocation of responsibilities among the relevant bodies, staffing and training of workers, safety culture, communication with the public and dissemination of lessons learned).

2. CONDUCT OF THE MISSION

The Mission, involving 13 international experts, was conducted from 5 to 13 November 2018. The Mission consisted of meetings and discussions with METI, TEPCO, NDF, MEXT, IRID, JAEA and NRA in METI Headquarters in Tokyo, a technical site visit of Fukushima Daiichi Nuclear Power Station, and further meetings at the Fukushima Daiichi NPS. In addition, it has been organized short visit of the JAEA Naraha Center for Remote Control Technology Development (see Mission Programme in Appendix I).

Reference documents were made available by Japanese counterparts in advance of the Mission to Japan. These included relevant reports and presentations covering all items of the review scope. The reference documents were used by the experts for self-preparation and effective work during the Mission. In addition, set of technical questions was raised by the experts prior the Mission to Japan to facilitate further discussions there.

The site visit of TEPCO's Fukushima Daiichi NPS provided an opportunity to observe how the Roadmap activities were progressing and to hold discussions with TEPCO's experts in charge of specific tasks, e.g. on radioactive waste management, contaminated water management, countermeasures against groundwater ingress, fuel debris issue, spent fuel management, institutional and organizational issues, on-site safety etc.

Sufficient time was allocated, during the Mission, for internal discussions, drafting of the report and for further interactions and discussions with METI and TEPCO.

The Preliminary Summary report was submitted to METI on 13 November 2018 in Tokyo and published on the METI website and the IAEA website (https://www.iaea.org/sites/default/files/18/11/missionreport-131118.pdf). On the same day, the IAEA Press conference was held in Tokyo.

3. MAIN FINDINGS, ACKNOWLEDGEMENTS AND ADVISORY POINTS

3.1. CURRENT SITUATION OF TEPCO'S FUKUSHIMA DAIICHI NPS AND ROADMAP IMPLEMENTATION

The IAEA team's review of the current situation of Fukushima Daiichi NPS was based on advance information provided by Japanese counterparts in support of the Review Mission, detailed discussions on extensive presentations from Japanese counterparts, and visits to the Fukushima Daiichi site and Naraha Center for Remote Control Technology Development of JAEA.

While the situation remains complex and challenging, the IAEA Review Team notes that since the last mission in February 2015 the on-site conditions have markedly improved in many aspects, both technically and institutionally, with a noticeable evolution in safety and risk management. Such improvements include:

- The operation of countermeasures such as the subdrain repair and frozen soil wall to substantially reduce the arising of contaminated water from approximately 490 m^3/day average in FY2015 to approximately 200 m^3/day average in first half of FY2018. As of October 2018, about 1,100,000 m^3 of treated water is stored on-site, vs. 600,000 m^3 noted in the February 2015 review;
- Preparations for removal of spent fuel from the Unit 3 pool are well advanced, with the removal of large rubble from the pool, and the installation of the dome roof, Fuel Handling Machine (FHM) and crane. Preparations for removal of spent fuel from the Unit 1 pool are progressing, with removal of the roof cover and wall panels allowing the clearing of the refuelling floor to proceed. Preparations for removal of spent fuel from Unit 2 are progressing with the installation of the antechamber allowing investigation and clearing of the refuelling floor;
- Identification of the fuel debris deposits in Units 1-3 has progressed, with internal PCV (Primary Containment Vessel) investigations ongoing supporting eventual fuel debris sampling and the development of retrieval methods;
- The management and storage of solid radioactive waste has benefitted from waste minimization strategies and waste segregation according to dose rate and waste type. Construction and operation of facilities for consolidation of storage and volume reduction treatment/incineration facilities are under way to address the accumulation of solid waste;
- Site clean-up and paving to enhance the working radiological environment for employees of TEPCO and its contractors (currently around 4,500 workers) has greatly increased the areas where ordinary clothing with disposable dust mask may be used. Improvements in the working environment supporting worker comfort and safety have been implemented;
- Deployment of mobile equipment for a response to earthquake / tsunami to higher elevation parts of the site has been implemented. That should ensure availability of means to provide cooling of the spent fuel and fuel debris and station power recovery after an earthquake / tsunami event. Establishment of a tide embankment, closing of building openings and treatment of stagnant water in the buildings are some of the

measures that have been completed or are currently being implemented to mitigate the consequences of a potential tsunami event.

Overall, the leadership and management team demonstrated a strong sense of ownership and technical command of their respective project standings, and the strategies for achieving project objectives. In addition to the many technical changes positively affecting the current situation, the IAEA Review Team noted great improvement against 2015 Mission in the implementation of a safety culture by all levels of the workforce, supported by earnest safety review processes and feedback systems.

The Mid- and Long-Term Roadmap towards the decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Station is in its fourth revision. Revisions of the Roadmap were issued twice between 3rd and 4th Review missions to Japan. The scope of the current Roadmap relates to the management of clean-up activities for the Fukushima Daiichi site and the decommissioning of Units 1-6. The publicly available Roadmap provides visibility of the decommissioning activities at Fukushima Daiichi site and acts as a tool to engagement with the public and local communities.

In response to public concerns regarding the long time-scales for management of contaminated water and decommissioning, METI made the decision to set clear short-term roadmap milestones in the fourth revision to the road map. In addition, recommendations from NDF led to an update of the fuel debris policy (partial submersion with side access to the PCV) and incorporation of the basic principles of containment and isolation as the approach to waste management.

Implementation of the Roadmap is elaborated through the NDF's annual Technical Strategic Plan (last published in October 2018) that is providing reliable technological grounds for the Roadmap and contributing to its smooth and steady execution. Underpinning the Roadmap is an extensive research and development programme under the direction of NDF which involves several Japanese and international technical organizations.

Acknowledgement 1

The IAEA Review Team acknowledges the efforts by Japan in the development, implementation and communication of the Roadmap activities including incorporation of regular revisions. The establishment of advisory committees and consultations with Japanese and international experts bring useful contribution to the definition of the programme.

3.2. FOLLOW-UP OF THE PREVIOUS IAEA REVIEW MISSION CONDUCTED IN 2015

The Japanese counterpart prepared a detailed summary of responses to Advisory Points from the IAEA previous missions in 2013 and 2015. All the Advisory Points were accepted and comprehensive works on advancing their implementation have been carried out.

Regarding the advice from 2015 Mission, Japan assessed that among the 22 Advisory Points (15 Advisory Points from the Mission in February 2015 and 7 Advisory Points from the follow-up expert visit in April 2015) 11 Advisory Points continue to be implemented while 11 Advisory Points appear complete.

The IAEA Review Team recognizes an intensive effort by Japan to carefully address all Advisory Points and to work on their effective implementation. Significant examples of work on previous Advisory Points are as follows:

- Clarification of the roles and responsibilities of different institutions and organizations involved in planning, decision making and implementation of decommissioning works and related R&D activities (related to the Advisory Point 2 from February 2015);
- Comprehensive set of activities related to strengthening of safety culture, training of workers and communication with stakeholders (related to the Advisory Point 3 from February 2015);
- A methodology introduced, adapted and work done on assessments of existing risks and their prioritization (related to the Advisory Point 15 from February 2015 and the Advisory Point 5 from April 2015);
- Planning related to construction of facilities for storage and treatment of solid radioactive waste (related to the Advisory Point 11 from February 2015);
- Waste minimization, recycling and reuse of materials (related to the Advisory Point 8 from February 2015);
- Progress in R&D activities related to physical and radiological characterization of the fuel debris and to development of techniques for the fuel debris retrieval (related to the Advisory Point 4 from December 2013);
- Set of activities related to the management of groundwater and contaminated water and prevention of water leakages (related to the Advisory Point 10 from December 2013).

The IAEA Review Team agrees with the counterparts' summary of responses to Advisory Points from the previous missions, and with the proposed classification of actions as "completed" or "continue to be implemented". All the items marked as "completed" can be considered closed.

Acknowledgement 2

The IAEA Review Team appreciates the consideration given to the Advisory Points from the previous Review missions and acknowledges the efforts of NDF, TEPCO and other Japanese organizations and institutions to effectively implement them into the arrangements and practices related to the decommissioning of the Fukushima Daiichi NPS.

3.3. MANAGEMENT OF ALPS TREATED WATER STORED IN TANKS

As stated in the previous Review missions, the IAEA Review Team holds the opinion that the present plan to store the ALPS treated water containing tritium and other radionuclides in above ground tanks, with the current capacity of 970,000 m^3, can only be a temporary measure and a more sustainable solution is needed. As a high level of transparency with stakeholders is important, the IAEA Review Team also sought clarifications from METI and TEPCO during the Mission on the information which recently came to public attention regarding the presence of radionuclides at higher concentrations than current regulatory limits for discharge into the sea. The content of radionuclides in the tanks and the technical feasibility to further treat this

water were discussed.

Currently, the Government of Japan is considering five solutions including the possible resumption of controlled discharges to the sea, which are routinely used by operating nuclear power plants and fuel cycle facilities in Japan and worldwide, and for which a large amount of information is readily available.

Under the current site facility planning for tank construction providing a capacity of 1.37 million m^3, the storage of ALPS treated water is expected to reach full capacity within the coming three to four years. The physical constraints of the site (the southern half of the site is largely occupied by the tanks, the northern half of the site is needed for waste storage and processing facilities) leave little room for additional tanks beyond 1.37 million m^3. Further treatment of the stored ALPS treated water may be conducted to reduce the radionuclides content to an authorized level as needed[1] before implementing any of the five solutions being considered by the Japanese Government (ground injection, controlled discharge into the sea, discharge as steam, discharge as hydrogen and solidification followed by underground burial). For all options, the disposition path of the water will require management, monitoring and control to ensure that the water to be dispositioned meets regulatory requirements.

Acknowledgement 3

The IAEA Review Team acknowledges the work done by METI to identify possible technologies to remove tritium and assess possible disposition paths. The IAEA Review Team also acknowledges ongoing dialogue with all stakeholders, and especially with the local communities. The IAEA Review Team also takes note of the statements issued by the Nuclear Regulation Authority (NRA) on the management of ALPS treated water.

Advisory Point 1

The IAEA Review Team holds that a decision on the disposition path for the stored ALPS treated water containing tritium and other radionuclides, after further treatment as needed, must be taken urgently, engaging all stakeholders, to ensure the sustainability of the decommissioning activities and of the safe and effective implementation of other risk reduction measures.

After the decision on the disposition path is made, TEPCO should prepare and submit to the NRA for authorization a comprehensive proposal for its implementation in conformity with laws and regulations, supported by such items as a safety assessment and analysis of the environmental impacts, including control of the water before disposition, to address radiation safety of the public, workers and environment.

To support the implementation of the chosen disposition path, a robust comprehensive monitoring programme developed by TEPCO and approved by the NRA, supported by a communication plan ensuring a proactive and timely dissemination of information to stakeholders and general public are necessary.

[1] As TEPCO expressed at the Sub-committee on handling of ALPS treated water (October 1, 2018)

3.4. PUBLIC COMMUNICATION

TEPCO's communications policies have evolved in recent years, partly in response to delays or omissions in reporting on radiation data or events at the Fukushima Daiichi site. TEPCO's communications strategy is based on the principle that relevant information must be shared with the public in a timely, accurate and easy-to-understand manner in order to meet the needs and maintain the trust of all stakeholders, as well as to dispel any harmful rumours. This strategy, which has included the regular publication of radiation data, including on ALPS treated water, on the TEPCO website, is also reflected in the latest revised Roadmap.

In addition, TEPCO has taken a series of measures aimed at strengthening understanding of progress on the clean-up effort as well as boosting the morale of on-site workers and employees, local communities and Japanese citizens at large. These include, for example, an internal communications campaign termed "1 FOR ALL Japan", which has used Internet-based communications as well as pamphlets including such features as interviews with workers to disseminate information about the progress of work at Fukushima Daiichi and to foster a sense of unity among all those involved. According to internal polls, nine out of 10 workers and employees are aware of the "1 FOR ALL Japan" initiative and expressed appreciation for it. Example of further efforts to enhance the overall working environment include the introduction of a self-driving electric bus, with the aim of improving movement on the premises, in turn instilling pride among employees and workers.

Outreach – at the local, national and international level – has also contributed to improved public communications. TEPCO regularly meets with representatives of local communities to discuss decommissioning progress and related issues. The Government, for its part, has set up a sub-committee on handling of ALPS treated water with regular public hearings. And TEPCO has forged strong ties with Sellafield in the United Kingdom through an agreement to share their experiences of technology and stakeholder involvement, including joint studies and meetings with Sellafield representatives with communities around Fukushima Daiichi such as business leaders, teachers, fishermen, doctors and lawyers. The goal is to improve stakeholder involvement and relationships with local communities.

Overall, Japan's efforts have contributed to partly addressing Advisory Point 5 of the previous Review Mission.

In early October 2018 some stakeholders called into question the effectiveness and transparency of TEPCO's communications. TEPCO reported to the Sub-committee on handling of ALPS treated water that ALPS treated water stored on site contains other radionuclides besides tritium at levels above the current regulatory limits for discharge into the sea. While TEPCO has been posting these data on its website since 2015, the company had not provided an easy-to-understand explanation for it to the public.

Acknowledgement 4

The IAEA Review Team recognizes that TEPCO has strengthened its process for sharing information with the public, including by publishing radiation data on its website. In addition, the Government of Japan has set up the Sub-committee on handling of ALPS treated water which holds hearings for the public to ask questions and voice concerns, providing important feedback for members of the Sub-committee and officials.

Advisory Point 2

The IAEA Review Team advises to the Government of Japan and TEPCO to take a proactive and timely approach to communicating with the public on matters directly relevant to public concerns. This includes not only disclosing relevant information and data on a regular basis, but providing the general public the information in an easy-to-understand manner, including an explanation of its potential impact on the health and safety of the workforce and public as well as the protection of the environment.

3.5. STRATEGY AND PLANNING FOR THE DECOMMISSIONING OF TEPCO'S FUKUSHIMA DAIICHI SITE

STRATEGY AND PLANNING

The scope of the latest revision of the Roadmap developed by the Government of Japan (http://www.meti.go.jp/english/earthquake/nuclear/decommissioning/index.html), relates to the management of clean-up of the Fukushima Daiichi site and the decommissioning of Units 1-6.

The guiding principle underpinning the Roadmap is ensuring safety of the workforce, public and the environment through the prioritization of risk reduction measures. However, with the move from an emergency situation to regularized waste management and decommissioning activities, there is a gradual shift from 'urgent resolution of the issues at hand' to a 'project-wise' approach to the Roadmap tasks. This change resulted in revision of majority of milestones in the 2017 Roadmap compared to the 2015 version and an increase in the number of projects from 30 to 50. Given the complexity of Fukushima Daiichi site decommissioning, efforts are being made to increase coordination of activities to optimise the long schedule and drive efficiencies.

Underpinning the Roadmap is an extensive research and development program coordinated by NDF. The R&D program includes sharing of good practices, technologies and lessons learned from decommissioning projects world-wide as well drawing upon research being conducted in universities, research institutes including IRID and JAEA. Support for technology development and maturation is provided through the establishment of testing facilities and centres of expertise and collaboration.

The Figure 1 below shows the relationship and interdependencies between the key documents, funding mechanisms and organizations responsible for decommissioning of the Fukushima Daiichi site.

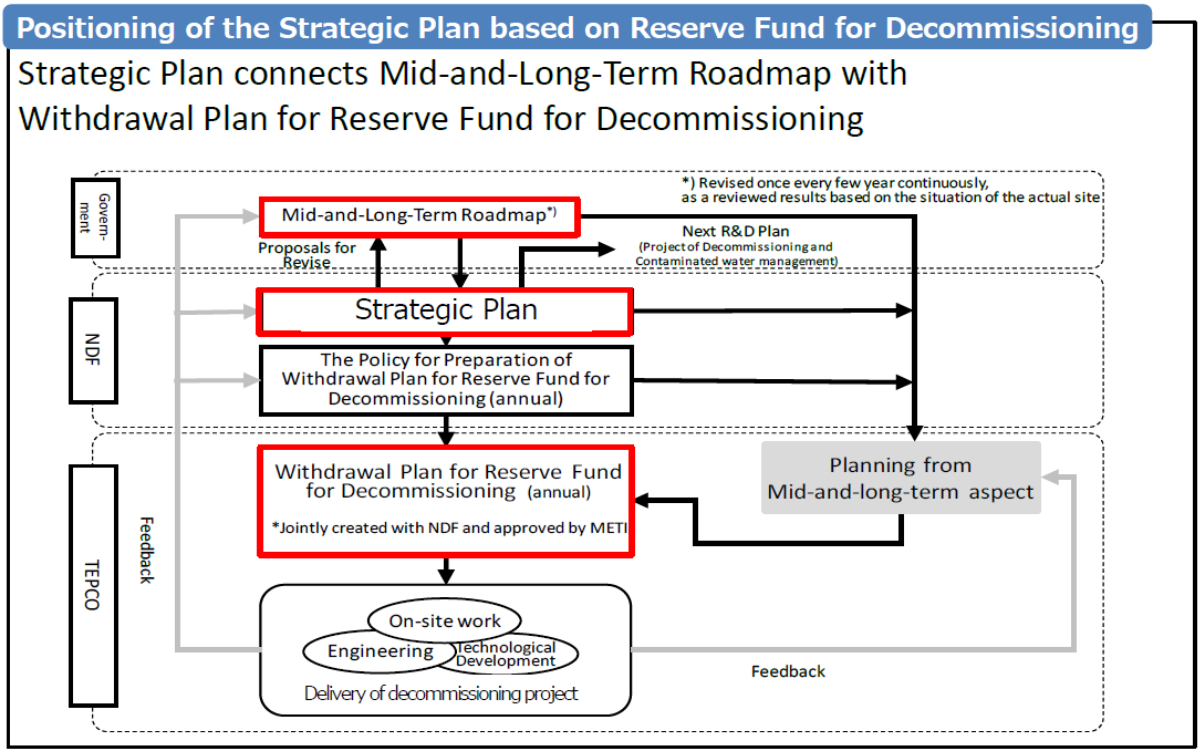

Figure 1. The relationship and interdependencies between the key documents, funding mechanisms and organizations responsible for decommissioning of the Fukushima Daiichi (courtesy of NDF).

The project approach incorporated into the 2017 revision of the Roadmap focuses on programmes for contaminated water management, fuel removal, waste management, fuel debris retrieval and addresses also communication. Each programme has specific mission objectives although the decommissioning end-state is difficult to define at this stage. Within TEPCO the programs are supported by functions related to safety and risk management, communication, HR management, supply chain management and knowledge management. To support this change of strategy TEPCO is working towards an organization structure that will provide greater alignment between the Roadmap and the projects. Implementation of the Roadmap is detailed in the Technical Strategic plan which is updated annually.

Established in 2014, the NDF is the organization responsible for technical studies to support decommissioning. NDF's responsibilities include provision of advice to both the Japanese government and TEPCO, management of the decommissioning fund, development of the R&D strategy and planning, public outreach. It is also responsible for the coordination and funding of organizations involved in activities associated with the decommissioning related R&D.

NDF described the relationship between themselves and the other key organizations – see in Figure 2.

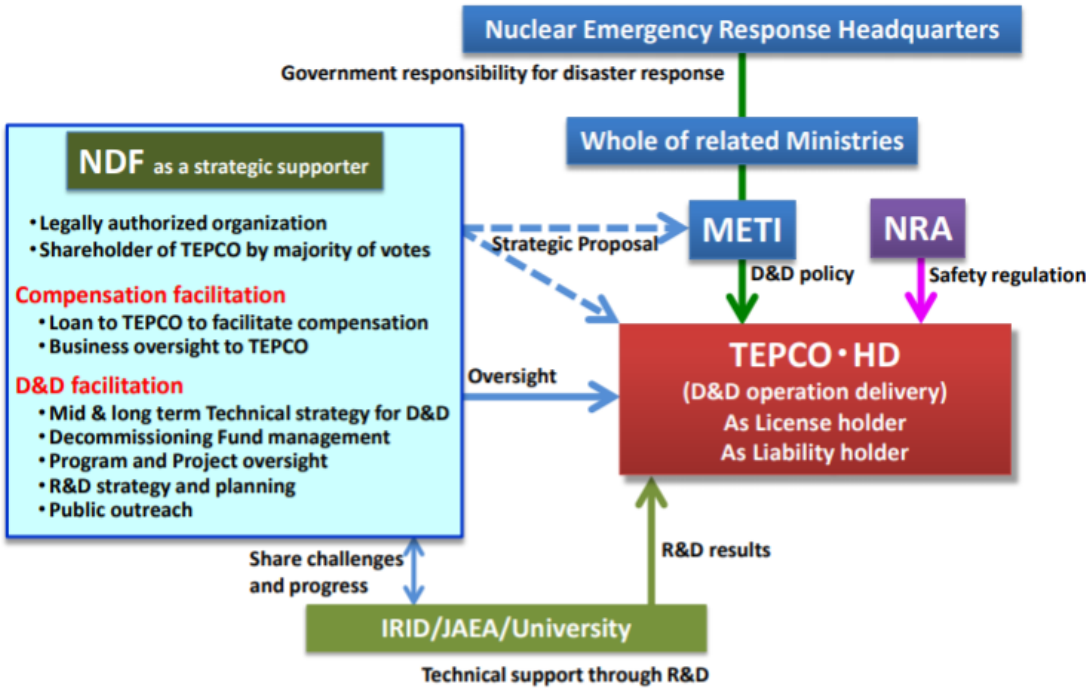

Figure 2. The relationship between NDF and the other key organizations (courtesy of NDF).

NDF shared with the IAEA Review Team how clarity of the roles for all key players responsible for Fukushima Daiichi NPS decommissioning has been improved and how collaboration between all parties has been enhanced. The IAEA Review Team saw this enhanced collaboration reflected in the development of the publicly available 'Technical Strategic Plan 2018 for Decommissioning of the Fukushima Daiichi Nuclear Power Station of Tokyo Electric Power Company Holdings, Inc'.

The IAEA were encouraged to hear how the NDF is using an internationally recognized risk quantification methodology[2] to understand the risk posed by current on-site situation. By applying this methodology NDF refocused its efforts on fuel debris retrieval and spent fuel removal. Based on the output from this risk analysis, NDF have developed a series of specific technical strategies to mitigate the highest risks areas: spent fuel removal, debris retrieval, contaminated water management and radioactive waste management.

Clean-up of the Fukushima Daiichi site will involve multiple organizations, stakeholders and technologies. The inherent uncertainties associated with decommissioning, associated radioactive waste management and spent fuel and fuel debris management as well as the long timescales (~30-40 years) involved will add to the complexity of the task. To optimize resources and the overall clean-up schedule, it is important that these activities and associated responsibilities are understood, planned and integrated.

Acknowledgement 5

The IAEA Review Team acknowledges the improvement that the Government of Japan, NDF, TEPCO and other organisations have made on revising and developing the strategy for the

[2] SED (Safety and Environmental Detriment) Prioritization Methodology used by the Nuclear Decommissioning Authority in the United Kingdom.

decommissioning of TEPCO's Fukushima Daiichi NPS. There is evidence of a risk prioritisation based on the radioactive content of the waste materials, as well as on their physical properties and the conditions and environment in which they currently exist. This resulted in refocusing efforts on the removal of spent fuel and fuel debris retrieval, and aids the long-term planning and risk assessment of implementation activities.

Advisory Point 3

The IAEA Review Team advises the Government of Japan and NDF to prepare themselves now in order to develop, during Phase 3, an integrated plan for the completion of decommissioning of the entire Fukushima Daiichi site; including all six units, the ancillary waste treatment and storage facilities, and the management of all forms of radioactive waste arisings during the decommissioning activities. Careful consideration should be given to the assumptions used and how to express the inherent uncertainties involved. In order to successfully produce such a plan, significant effort is expected to be required to determine the options and scenarios that lead to a credible plan for the long term.

PROGRAMME AND PROJECT MANAGEMENT

Progress has been made within both NDF and TEPCO on implementation of their programme and project management approaches. It is essential that NDF and TEPCO are coordinated in the focus and priorities to be addressed through the alignment of the NDF Strategic Plan and the TEPCO implementation plans. Because of the complexity and inter-dependency of the programmes, and particularly with the growth of the waste inventory, it is not always immediately apparent what the overarching goals and focus are. The programme management approach, alongside other tools, can be used to confirm the relative priorities, constraints, inter-dependencies and map the decisions that need to be taken, and importantly, by when.

Given the long timescales involved in accessing and assessing the fuel debris to be retrieved, many solutions are being designed and evaluated before the full nature and properties, or indeed location, of the debris is known. The projects and programmes associated with retrieval and the subsequent treatment and storage are therefore subject to significant uncertainty. This brings the potential for late design changes; which will consequently impact on safety assessment, training and construction, as well as operating requirements.

TEPCO indicated it recognizes that the evolution of the Fukushima Daiichi undertaking, starting from emergency response and stabilization to long-term decommissioning and radioactive waste management, will require different planning and project management capabilities. Improvements to enhance the project management capabilities are being implemented including the development of a Work Breakdown Structure (WBS) and the use of more sophisticated project management tools. A Project Management Organization (PMO) in TEPCO has been established and is working with the Program Supervision & Support Office (PSO) in NDF, to implement full programme and project management by the spring 2020.

Acknowledgement 6

The IAEA Review Team is of the opinion that the establishment of the PMO is a good decision and the use of more sophisticated project management tools will improve TEPCO's project delivery and analysis capabilities.

Advisory Point 4

The IAEA Review Team recommends that TEPCO uses project management tools to their full potential, for example by developing a resource loaded schedule for each individual project or activity identified in the WBS and integrating those schedules into a master Fukushima Daiichi project schedule. Integrating individual project activities into a master schedule will help identify constraints on resources, potential conflicts and insertion points for new technology from R&D activities.

Advisory Point 5

The IAEA Review Team advises that programme and project decision making focus on management of the uncertainties, and hence risks to delivery of the schedule and overall programme.

R&D TO SUPPORT DECOMMISSIONING PROJECT

Given the anticipated length of decommissioning activities at Fukushima Daiichi and the recognition that there are many challenges for which the technology and techniques have yet to be developed, Japan has put in place facilities and resources to address these for the short and the long term. Some of these R&D efforts are located in the surrounding area of the plant, thus also playing a part in regeneration of the region and the local development of skills and supply chain. In addition, R&D effort can benefit from cooperation established with the international organizations and on bilateral basis between Japan and other countries.

Acknowledgement 7

The IAEA Review Team appreciates the substantial efforts being undertaken to plan and carryout research and development (R&D) activities to support the Fukushima Daiichi decommissioning. Substantive R&D project outcomes have been produced thus far and capable state-of-the-art facilities with strategic domestic and international cooperation have been established. In particular, the Decommissioning R&D Partnership Council structure appears to be an adequate approach to identify and prioritize R&D needs with input from all relevant parties.

Advisory Point 6

TEPCO has demonstrated a robust approach to technology selection, development and deployment, and is aware of the challenges and risks associated with first-of-a-kind technology deployment that inevitably give rise to schedule uncertainties. The IAEA Review Team advises TEPCO to consider implementation of international good practice approaches to technology maturation and deployment as well as development of contingency plans to accommodate any schedule delays.

SUPPLY CHAIN AND MANAGEMENT SYSTEM

Supply chain management and interface management have to be controlled by the operator.

When planning and implementing decommissioning or radioactive waste management activities, project managers responsible for carrying out the work must effectively monitor the subcontractor delivery and/or implementation activities. This becomes more important when managing complex interfaces such as with international partners and suppliers. Effectively managing these interfaces will decrease the likelihood of inaccurate execution of design solutions and the occurrence of unexpected situations during procurement and installation of equipment.

Provisions for unexpected situations during decommissioning activities should also be considered. Provisions might include technical measures as well as organizational alternative actions to be implemented in case that unexpected events occur. The latter is an advisable approach for any nuclear facility under decommissioning but is a more complex challenge for the Fukushima Daiichi facility facing post-accident challenges.

Advisory Point 7

The IAEA Review Team recommends that TEPCO review and strengthen their interface management processes especially for complex situations involving multiple parties and international suppliers. Emphasis should be placed on ensuring the parties understand the technical specifications and programmatic requirements. Periodic joint progress reviews including reviews and inspections at the locations where work is performed are essential to ensuring that interface issues are identified and managed at the earliest possible time to avoid impacts later in the project.

3.6. INSTITUTIONAL AND ORGANISATIONAL ISSUES

The report of the previous mission recognised the profound nature of the change from nuclear power plant operations, to site stabilization activities during transition, and into radioactive waste management and decommissioning activities. It is also recognised the unusual nature of this transition for Fukushima Daiichi, where the speed and urgency required in responding to the nature of the situation was beyond the norm of a standard decommissioning site. Japan has responded to the significant changes at the site with changes to the institutions surrounding these activities. During the 2015 Mission, NDF was a new body and there has been significant development of its role in the subsequent three years. With the complexity of the developing situation and the number of actors, it is essential to continually clarify and reinforce the roles and responsibilities of the various institutions and organisations, throughout the layers of all those institutions and organisations.

ROLE AND INTERACTION BETWEEN NDF AND TEPCO

The role of NDF is to be responsible for technical studies to ensure that decommissioning is conducted properly and steadily from a mid- and long-term perspective. NDF has also a function to manage the reserve fund to promote decommissioning.

Regarding decommissioning of Fukushima Daiichi NPS, together with providing a technical foundation to the Government's 'Mid and-Long Term Roadmap', the NDF contributes to the Roadmap's steady implementation by developing an annual Strategic Plan, provides technical assistance to deal with main decommissioning challenges, coordinate R&D projects, and

disseminates information regarding the decommissioning efforts. TEPCO is responsible for implementing and delivering the decommissioning plan and is the licensee under the regulatory oversight of the NRA.

The organization of the programme, from planning to delivery, has been enhanced in 2017 by the addition of the annual "Withdrawal Plan for Reserve Fund for Decommissioning" jointly developed by NDF and TEPCO and approved by METI, see in Figure 3.

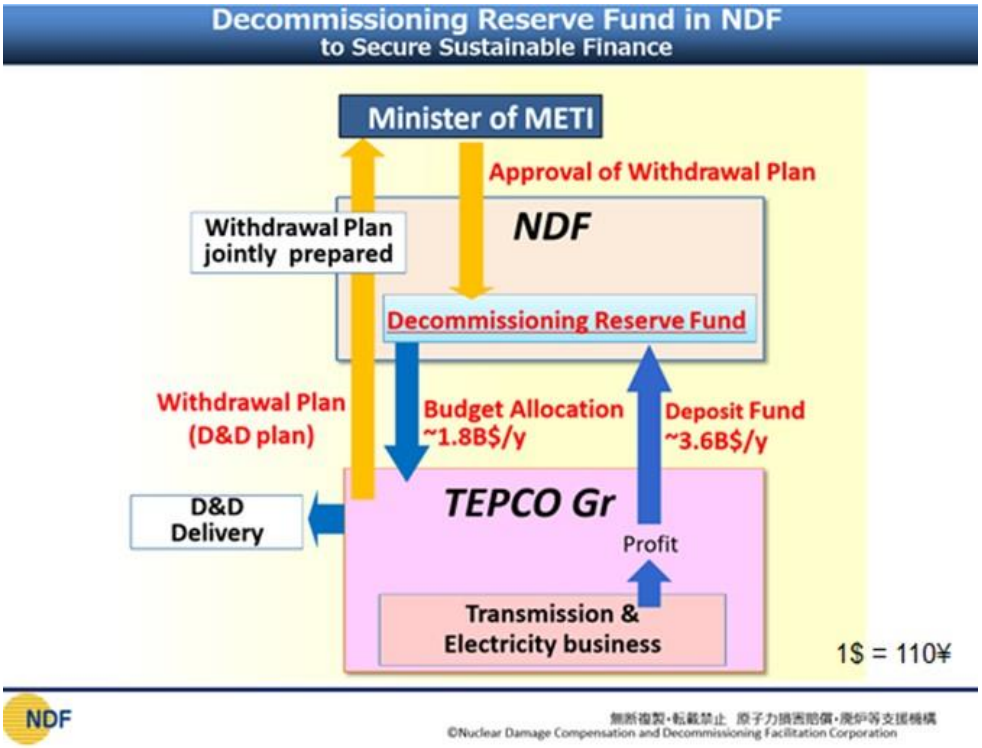

Figure 3. Decommissioning Reserve Fund in NDF (courtesy of NDF).

Acknowledgment 8

The IAEA Review Team acknowledges the establishment and full operational status of the NDF and of the TEPCO's Fukushima Daiichi Decontamination and Decommissioning Engineering Company. The IAEA Review Team acknowledges the clarification of the roles and responsibilities of the main actors: METI, NDF, TEPCO (FDEC), IRID, JAEA, and the attention given to the coordination of their respective roles and responsibilities.

Advisory Point 8

The IAEA Review Team takes note of the additional roles given to NDF, and the corresponding interactions between NDF and TEPCO. In the current scheme, NDF has an operational role of strategic planning and the role of oversight of TEPCO, while TEPCO has the responsibility for the implementation as a licensee. The IAEA Review Team advises Japan to ensure clear accountability of respective roles and responsibilities between and among NDF and TEPCO, and to create the condition for TEPCO to have the necessary ownership of the solutions that it will implement.

LICENSING PROCESS

Regulated activities in the decommissioning of the Fukushima Daiichi NPS, are licensed or approved by the Nuclear Regulatory Authority (NRA). The NRA provides oversight and regulatory control of the strategic and specific efforts to decommission the TEPCO's Fukushima Daiichi NPS. In order to employ appropriate management methods in accordance with the state of facilities, the NRA previously designated the Fukushima Daiichi NPS a "Specified Nuclear Facility". The NRA reviews and approves amendments to the "Implementation Plan Pertaining to Specified Nuclear Facilities at the Fukushima Daiichi NPS", and conducts inspections to ensure approved activities are in compliance with the Implementation Plan.

Acknowledgement 9

The IAEA Review Team acknowledges that TEPCO has a now well established monthly and weekly communication with NRA, organized within a transparent framework.

Advisory Point 9

In complex situations such as the post-accident situation of the Fukushima Daiichi site, some specific regulatory and licensing criteria may need to be defined when the criteria used in normal situations cannot readily be applied. The IAEA Review Team advises METI, NDF and TEPCO to maintain engagement with NRA to develop a common understanding of the safety requirements for the performance of the decommissioning of the site and to optimize the risk reduction strategy.

KNOWLEDGE MANAGEMENT

Effective realization of the full spectrum of knowledge management principles is essential to maintaining the necessary technical expertise and competences required for nuclear power programmes and other nuclear technology.

Appropriate technical expertise must be developed and kept available throughout the programme life-cycle. Advanced and specialized knowledge in nuclear engineering and science is required for the safe and effective licensing, maintenance and decommissioning of nuclear technology-based systems, along with the associated radioactive waste management, which may have long life-cycles in changing contexts.

The ability of organizations that operate or utilize nuclear technology to take safe decisions and actions can be affected by knowledge gaps or knowledge loss. Appropriate knowledge management methods and supporting technology are needed to establish and manage nuclear knowledge, competencies, information and records, work processes, data interpretation, and analysis and verification techniques.

Effective knowledge management systems help achieve these objectives.

Advisory Point 10

The IAEA Review Team encourages TEPCO to develop knowledge management systems that

encompass all facets of the relevant workforce (TEPCO and subcontractors) considering the specific requirements of the conditions and life-cycle stage of the site's facilities for the next several decades.

TRAINING AND HUMAN RESOURCES DEVELOPMENT

TEPCO created the Nuclear Education and Training Centre that operates at Fukushima Daini NPS. The education and training programme was designed by adopting the Systematic Approach to Training (SAT), which is globally recognized and practiced. All pertinent site work functions are broken down into knowledge and skill elements, and the required training points for each element are clearly specified. Lesson plans are developed by incorporating these required training points into teaching materials. The effectiveness of the programme is regularly evaluated at each organizational level in TEPCO. A group responsible for the planning function and a group managing the training delivery were established.

An education and training programme is provided, which is necessary for human resource development across the entire nuclear facility lifetime including decommissioning. Furthermore, education and training courses for each category of technology related to Fukushima Daiichi decommissioning and associated radioactive waste and spent fuel / fuel debris management work have been set up to maintain and improve the technological capabilities.

Acknowledgment 10

The IAEA Review Team endorses the creation of the Nuclear Education and Training Centre to facilitate the human resource development function, and which is now consolidated into an organization directly under the control of Director of the Nuclear Power & Plant Siting Division of TEPCO, thereby utilizing resources more efficiently. The IAEA Review Team also acknowledges that the education and training programme is designed following the Systematic Approach to Training.

Advisory Point 11

The IAEA Review Team recommends that TEPCO and the PMO utilize the integrated project management tool to maintain an estimate of the number and categories of workers required during different phases of the Fukushima Daiichi decommissioning project. This would include tracking worker demographics to identify recruitment and training requirements.

SAFETY AND RADIATION PROTECTION

As previously stated the role of the site operator to maintain safety remains paramount, with a solid foundation of a nuclear safety culture and leadership critical to achieving this. TEPCO is progressing well to reinforce safety culture; after holding the IAEA "Safety Culture Workshop" TEPCO adopted WANO's 10 Traits of a "Healthy Nuclear Safety Culture". Headquarters management, site executives, chief engineers and all employees in the nuclear department are engaged in the safety culture programme. A proven aspect in improving the safety performance of teams is having a more diverse team so that different styles of thinking are brought to bear on problems.

Japan is signatory of the ILO (International Labour Organization) Convention 115 on Radiation Protection since July 1973. This Convention applies to all activities involving exposure of workers to ionising radiations in the course of their work. All appropriate steps shall be taken to ensure effective protection of workers, as regards their health and safety, against ionising radiations. Rules and measures necessary for this purpose shall be adopted, and data essential for effective protection shall be made available.

Provision for workers' protection are available at Fukushima Daiichi NPS as required by the Ministry of Health, Labour and Welfare guidelines from August 2015. This guideline summarizes transparently the actions to be conducted by TEPCO and the primary contractors, namely:

1. Establishment of a system for occupational safety and health management undertaken by TEPCO and the primary contractors.
2. Implementation of risk assessment and measures to be taken for enhancement of safety and health education based on the results.
3. Consideration and implementation of effective exposure dose reduction measures from the stage of placing orders.
4. Healthcare measures, providing health guidance based on medical examination results.

The implementation of those provisions on site includes: prior radiological evaluation and safety assessment; the radiation protection programme; classification of areas; use of personal protective equipment; work planning and work permits; Individual and workplace monitoring; exposure assessment; health surveillance; information instruction and training as well as workers qualification and certification.

Detailed information and organizational arrangements are included in the Radiation Protection Programme (internal reference DA-53), the guidelines for dose exposure reduction management and the guidelines for organization and operation of ALARA committee. Those guidelines are in full practical implementation under the TEPCO's Risk Management Committees.

Measures for reduction of radiation dose have been conducted, such as preparatory work for removal of spent fuel, construction of radioactive waste storage facilities and paving of open areas. The target dose rate 5 μSv/h has been achieved in all areas, excluding areas surrounding Units 1-4 and the radioactive waste storage area.

As of November 2018, the work is performed with only light protective equipment (helmet, disposable dust mask, goggles, gloves and work boots) in approximately 96% of site premises.

Some full-face masks have also been improved to enhance safety and workability during work zones where dose rate or contamination is high. The improvements were the following: field of view was expanded by expanding the range of eye piece; exterior surface of the eye piece was hardened to prevent scratches and defogging treatment was applied to the interior surface of the eye piece to prevent fogging.

Dose rate monitors have been placed in the access control building, main anti-earthquake building, visitor route and other representative work locations, so as to enable workers to check dose rate. Large displays have been placed in areas where many workers gather, such as the access control building. The dose rate values measured as well as values measured with existing continuous dust monitors are displayed so that radiation environment at the work site can be remotely checked (real-time monitoring). The large displays show the latest measured values as well as the trend of past data and can also display alarms, which are set in advance.

To reduce exposure of workers working in high dose environments such as the reactor building, remote monitoring system is introduced and utilized. The remote monitoring system remotely monitors personal dose and work status of workers in real time and lets the supervisors and workers communicate with each other. This reduces exposure of supervisors and supporting people who are not directly engaged in work, such as work manager, safety manager and radiation manager. This approach allows an effective communication in environments where communication is difficult with workers wearing full-face masks, which leads to an improvement of safety.

Recommendation of the International Commission on Radiological Protection (ICRP) are being gradually adopted to improve safety of workers on-site. As from 2018, the value of the dose limit for equivalent dose to the lens of the eye was autonomously reduced to 50mSv/year. It was decided to monitor equivalent dose of the lens of the eye, if equivalent dose is expected to exceed 15mSv. However, for work with mainly β radiation, the area near the eye (forehead part inside full-face mask) is monitored regardless of exposure expected. After 2019, it is planned to adopt a dose limit of "5-year average of 20 mSv/year" for effective dose.

Individual monitoring of external exposure for TEPCO workers is done using glass dosimeters, in addition they are also using electronic dosimetry for operational monitoring. For Contractors workers, the individual monitoring of external radiation is provided by their own employer and TEPCO provides an electronic dosimetry for operational monitoring.

Individual monitoring of intakes of radionuclides is done when there is contamination found in the full face or half face masks. The fast scan whole body counter and a partially shielded chair are used for detection of fission products in the body.

Results of the occupational exposure for September 2018 shows an average effective dose of 0.27 mSv/month. The maximum dose reported during September 2018 was 8.00 mSv received by a worker during activities in Unit 1.

Acknowledgement 11 (Safety leadership and safety culture)

The IAEA Review Team recognises the safety leadership that TEPCO, who has primary responsibility as Operator and Licensee, has shown in the period since the last IAEA Review Mission in developing a safety culture at the Fukushima Daiichi site. They have made significant progress in addressing their understanding of the expectations and requirements of the nuclear safety culture in a decommissioning environment. In addition, the IAEA Review Team applauds the adoption of the WANO Traits of a Nuclear Safety Culture and the implementation of systems to measure their organizational performance, with review of the results of the safety culture programme.

Acknowledgment 12 (Occupational Radiation Protection Programme)

Measures for occupational safety and health management have been enhanced at the TEPCO Fukushima Daiichi NPS as required by the Ministry of Health, Labour and Welfare guidelines from August 2015. Radiation Protection Programme, Guidelines for dose exposure reduction management and Guidelines for organization and operation of ALARA committee has been reviewed and revised. Those guidelines are in full practical implementation under the TEPCO's Committees responsible for risk management.

The site working conditions are improved because of the paving action at the site, better work

planning by the ALARA Committee, improvement on the protective gear and real-time radiation monitoring. The workers dosimetry and health surveillance programme takes into consideration the demanding and difficult working conditions.

Advisory Point 12 (Safety leadership and safety culture)

The IAEA Review Team encourages TEPCO to promote the safety culture of all workers on site including its contractors, and to continue to consider the specific requirements of the conditions and life-cycle stage of the site's facilities that differ from a normal operating environment, and continue to develop a safety culture management system appropriate to radioactive waste management and decommissioning.

Advisory Point 13 (Occupational Radiation Protection Programme)

TEPCO is encouraged to provide for further optimization of radiation protection exposure by analysing the workers' exposure data for all facilities and types of operation, so as to identify optimization options and dose reduction factors. This is valuable information for current and future actions at the site.

INTERNATIONAL COOPERATION

International cooperation of Japan has been progressively developed over the years coming after the accident in March 2011 on a variety of Fukushima Daiichi decommissioning and waste management related issues. It includes cooperation with international organizations as well as bilateral cooperation on governmental and corporate levels. The international community can learn a lot from Japan's decommissioning effort and Japan can benefit from international experience and cooperation in support of its work towards decommissioning.

Acknowledgement 13

The IAEA Review Team acknowledges the development of bilateral cooperation on a number of important topics such as Research and Development, risk assessment and prioritization or communication, and the adoption of internationally recognized practices. The IAEA Review Team also acknowledges the proactive stance of Japan to share with international community the status of decommissioning activities.

Advisory Point 14

The IAEA Review Team advises Japan to further develop a broad array of international cooperation in all domains. Such international cooperation has the potential to bring significant benefits to the safe decommissioning of the Fukushima Daiichi site and to increase knowledge sharing with the international community. The IAEA Review Team encourages Japan to draw upon the global diversity of international good practices, and to integrate and adapt them to fit the unique Fukushima Daiichi site situation.

3.7. SPECIFIC TOPICS

MANAGEMENT OF CONTAMINATED WATER AND COUNTERMEASURES AGAINST GROUNDWATER INGRESS

TEPCO is implementing a comprehensive set of countermeasures to reduce the rate of arising of contaminated water, to prevent leakages and uncontrolled discharges into the sea, to process it and store it safely. Those measures are based on three policies: 1) Removing source of contamination, 2) Isolation from contamination sources, and 3) Preventing leakage of contaminated water.

The highly contaminated water from the reactor and turbine buildings is continuously treated and purified, and the water level inside the buildings has successfully been maintained at levels ensuring prevention of leakage out of the buildings. The seawater piping trenches of the Units 2, 3 and 4 have been closed and waterproofness achieved. The ingress of groundwater into the reactor and turbine buildings has significantly been reduced since the last IAEA Review Mission by stable operation of the groundwater bypass and the sub-drain, by the installation of the frozen-soil impermeable wall around the reactor and turbine buildings of the Units 1-4, and by paving the surfaces on the site to prevent ingress of rainwater into the soil.

Repair of the damaged part on the Unit 2 Reactor Building roof drain was completed in July 2018 and preparatory work to repair the damaged portion of the Unit 3 Turbine Building rooftop has started in November 2018. Planned completion of repair of the damaged buildings roofs should reduce the amount of rainwater entering into the buildings and mixing with the contaminated water stored there. Ongoing closing of buildings' openings will prevent potential flooding in case of a tsunami event. The construction of the impermeable sea wall and relocation of drainage channels has further improved the protection of the marine environment.

The operation of the purification systems for contaminated water is stable and reliable, and the water being stored on site is more than 900 tanks with average capacity of 1000 m^3 each. Works on improvement of the reliability of the water storage tanks by replacing the bolted tanks with welded tanks is advancing well. With regards to the water storage capacity, the site is now getting close to the limits of space available for additional storage tanks.

There are ongoing discussions and analyses of the potential options for disposal/discharge of the stored water. Five options are being considered: 1) ground injection, 2) controlled discharge into the sea, 3) discharge as steam, 4) discharge as hydrogen and 5) solidification followed by underground burial. It has been recognized that a pre-processing of the stored water might be needed prior to implementing some of the above mentioned potential solutions. Aspects related to the management of the water stored in the tanks are addressed in the Sub-chapter 3.3. of this final Mission report.

A detailed information on groundwater levels around buildings of the Units 1-4 is being maintained, as well as information on the levels of contaminated water inside the buildings, and the amounts and chemical and radiological properties of the processed water. That provides a good basis for monitoring and control of the migration of radioactivity. Sampling of water and measurements of concentrations of several radionuclides are being regularly performed at the drainage channels, inside the harbour area and from the sea outside of the harbour.

Japan continued reporting sea area monitoring results and that there have been no significant changes since the last report. These monitoring results continue to be published regularly by

NRA, TEPCO and Fukushima Prefecture. In particular, the discharges of treated and monitored groundwater continue to have no detectable effect on the levels of radioactivity in the marine environment, which were measured in these areas.

TEPCO is currently strengthening a quality management system for the environmental monitoring. Japan is actively participating in IAEA Interlaboratory comparisons for further data quality assurance.

Acknowledgement 14

The IAEA Review Team commends TEPCO for implementing the full set of the countermeasures against the groundwater ingress into the damaged facilities and against leakage of contaminated water from the buildings and from the site, thus contributing to reduction in the generation of contaminated water and to the protection of the workers, public and the environment, and the management of the site boundary dose.

Advisory Point 15

The injected water cooling of the fuel debris mixes with ingressed water and contributes to the generation of contaminated water. The IAEA Review Team encourages TEPCO to perform analyses of the needs for continuous cooling and, depending on the results, to consider further reducing the amount of injected water, ending injected water cooling at some point, or establishing a closed cooling loop.

SPENT FUEL REMOVAL AND FUEL DEBRIS RETRIEVAL

The Roadmap (revised in September 2017) recognises the challenges of removing spent fuel and retrieving fuel debris from Units 1, 2 and 3 and establishes an implementation plan to address the identified issues.

In line with the overall plan for risk and hazard reduction, Unit 1 and Unit 2 are both planned to start the removal of the spent fuel from the pools in FY2023. However more significant risks are to be managed in Unit 1 to enable the safe removal of the damaged fuel handling machine and crane. In managing these risks and uncertainties, maintaining the current schedule will be challenging.

The start of the fuel removal from the spent fuel pool of Unit 3 is planned for FY2018.

When the total inventory of fuel assemblies in Units 1 to 6 is considered, it may be that additional centralised storage capacity will be needed.

As the situation of every Unit is different, TEPCO is appropriately considering opportunities as well as the risks associated with both the spent fuel removal (see Figure 4) and the fuel debris retrieval (see Figure 5) and how these interact or may be conducted in parallel.

Removal of spent fuel assemblies

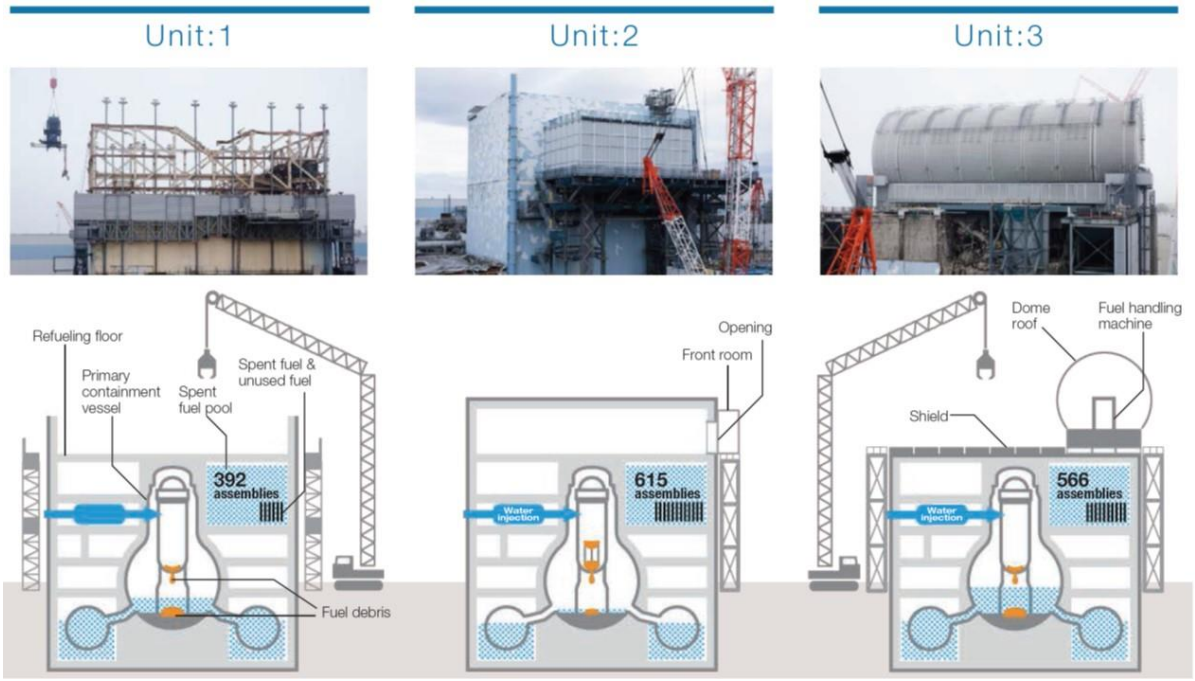

Figure 4. Current situation of spent fuel removal (courtesy of TEPCO).

Unit 1

The situation in Unit 1 is evolving and progress has been made to remove rubble from the reactor roof. According to the established plan, the roof structure and rubble will be removed gradually from the north side, which is more robust, before moving to the centre and the south side of the building.

The risk of further collapse of the ceiling crane has the potential to damage the spent fuel in the pool and to scatter a large amount of dust containing radioactive material. Mitigation and contingency measures have been identified and considered to carefully remove the material using suction equipment for small rubble, pliers and cutting tools for reinforcement bars and the steel frame. Special attention is paid to the dispersion of radioactive dust through the installation of water spraying equipment that are tested regularly, once a month, ready to prevent dispersion of any dust. Three different approaches had been considered to accomplish early removal of the pool fuel and fuel debris retrieval. The installation of upper cover on the operating floor was selected as the plan to enable early removal of the fuel and to reduce the risk of the fuel handling machine and the ceiling crane collapsing and affecting the fuel.

In addition, displacement of the well plug was confirmed during the operating floor investigation conducted from November 2016 to February 2017, which produces an increase in the dose rate of the surrounding area. It is under consideration to address the displacement of the well plug.

Unit 2

The operating floor of Unit 2 was not affected by the hydrogen explosion and the soundness of

the building was largely maintained. High levels of contamination were still found on the operating floor.

Measures were taken to suppress the scattering of the radioactive material and an opening for work access has been successfully installed on the exterior west wall of the reactor building in June 2018. Remotely operated robots are being used to inspect the situation on the operating floor and identify potential obstacles left behind that will cause problems for the subsequent activities. Robots are also being used to take measurements of dose rate, surface contamination and airborne material concentration.

To improve the environment around Unit 2, the reactor building and the turbine building will be decontaminated, prior to dismantling the upper part of the reactor building. The fuel handling equipment will be installed in order to start the fuel retrieval by FY2023. Options for building stabilization and covers that either would allow retrieval of both spent fuel and fuel debris from within the same structure, or that would allow spent fuel retrieval only are under consideration. The final decision will depend, among other factors, on gaining better knowledge and understanding of the fuel debris characteristics and the complexity and therefore time taken for the construction operations.

Unit 3

During the third Review Mission, it was found that decontamination of the operating floor in Unit 3 was difficult due to contamination ingrained in cracks, making it difficult to achieve the target level of 1 mSv/h. Activities in Unit 3 has progressed very well with the clearance of the operating floor, subsequent addition of the shielding floor, construction of the protective domed roof and installation of the fuel handling machine and crane. Installation work for the domed roof began on July 2017 and was completed in February 2018.

Although the fuel removal was planned to start by the middle of FY2018, activities were delayed due to some unexpected issues with the crane and fuel handling machine when they were installed on the operating floor. This situation has led to a valuable lesson learned for strengthening the functional specifications and acceptance testing within the supply chain. In addition, hands-on training of the workers on the remote operation has been implemented before starting the real operation, including specific training on the fuel handling machine and crane, transport container, fuel transfer from rack to transport container and training for the removal of small rubble that interferes with the lifting of the fuel assemblies.

To improve time efficiency in the fuel removal process, the removal work of the small rubbles which are in the pool will be carried out at night time, with fuel assembly removal activities taking place during the day time. Care will be paid to small rubble particles in the water pool that can affect the sealing of the transportation casks.

Consideration has been given to the order of removal of the fuel assemblies to minimise the risks during defueling operations. Fuel removal will start with the fresh fuel with no deformation due to collision with the rubble, followed by retrieval of spent fuel with no deformations and finally retrieving the failed fuel stored in the pool before the earthquake.

The risk exists that some of fuel assemblies may have been damaged by rubble. For the transportation of such fuel assemblies a new basket (internal part of the cask) will be designed, procured and put into operation.

The intent is for small rubble removal to be undertaken using the main Fuel Handling Machine

with different manipulators. Experience from the UK has shown that in situations where fuel pools have non-standard configurations or contain significant foreign material, the use of a Fuel Handling Machine can be complemented by small Remotely Operated Vehicles (ROVs). Such ROVs can aid with inspection, with cameras and lighting to provide a clearer picture and different angles within the pond itself, to support manipulator operations and with the removal or movement to enable easier retrieval with the FHM of small items of rubble.

Retrieval of Fuel Debris

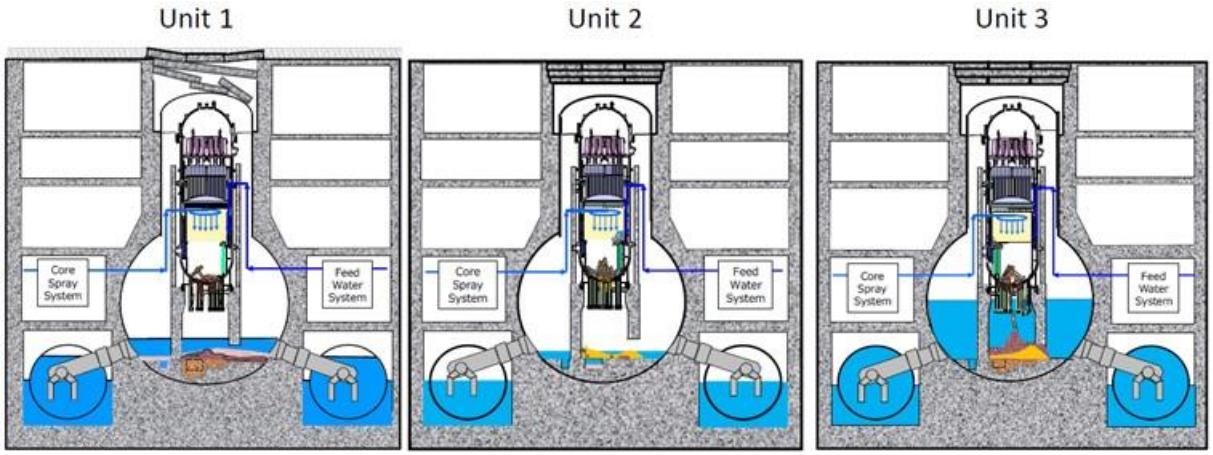

Figure 5. Current situation of fuel debris retrieval as of September 2018 (courtesy of TEPCO).

Different types of equipment and approaches are being used to conduct internal investigations inside the PCVs of Units 1-3, considering the environment and conditions of each individual unit. New muon-based detection technology has been used to better understand the distribution of fuel debris inside RPV, and than used to estimate this for PCV. It allowed improved determination of the position and form of the fuel debris. These measurements were conducted for Units 1-3, resulting in progress towards better understanding of fuel debris distribution since the last IAEA Review Mission in February 2015, but significant uncertainty still remains.

The IAEA Review Team recognizes the difficulties of obtaining information regarding the nature and position of the fuel debris. Significant R&D effort around fuel debris is in place in line with sharing worldwide the experiences and knowledge gained on fuel debris retrieval and management through international organizations. CLADS (Collaborative Laboratories for Advanced Decommissioning Science) in JAEA can play an important role in allowing experts from abroad to help and support Japan in the characterisation of this material and also using the results to further the international understanding of the behaviour of fuel in accident conditions. The international cooperation developed by METI, NDF and IRID is also bringing useful benefits.

<u>Unit 1</u>

So far it is accepted that there is almost no fuel in the core and almost all melted fuel has fallen into the lower part of the PCV. Surveys were conducted in April 2015 and in March 2017. Some main facts obtained by these surveys are listed below:

- Deposits were found at position elevated from PCV bottom;
- Sediments were observed at the bottom of PCV. Sediments are assumed to have certain weight since they did not stir up when images were taken;
- No damaged equipment and no significant damage to the existing structure;
- Dose rate in PCV outside the pedestal varied from 4.7 to 9.7 Sv/h;
- Dose rate increased when the dosimeter approached the bottom of PCV;
- Dose rate on the steel grating was approx. 4-12 Sv/h;
- It was observed that primary loop recirculation (PLR) lead wool mat have fallen. It can thus be estimated that the temperature on the steel grating of 1st floor might have exceeded 328°C in the past, which is the melting point of lead;
- Measured temperature outside the pedestal varies from 17.8 to 21.1°C;
- Access route to the bottom of a dry well (D/W) was investigated, but sediments are widely distributed at the bottom of D/W. Fuel debris was not observed in this survey.

Unit 2

So far it is accepted that the melted fuel is distributed across the core, the bottom of the RPV and the lower part of PCV, although the precise amount of fuel debris in each of three places is unknown.

Leakage from the suppression chamber does not support a higher level of water inside the PCV. The measured temperature inside the PCV is approximately 21°C, but at least part of the fuel debris may have a higher temperature because during the survey it was observed that what was assumed to be steam was rising from the lower part of the steel gratings.

In addition to PCV internal survey of Unit 2 conducted in March 2012 and in August 2013, more surveys were conducted in January and February 2017 and in January 2018. Some main facts obtained by this survey are as follows:

- The steel gratings inside pedestal had deformed or fallen out;
- A lot of sediments were seen inside the pedestal;
- No major damage was observed to the control rod drive mechanism (CRD) housing support near the entrance of pedestal;
- Abnormalities, such as cracks, were not observed on the wall surface in the pedestal of the pedestal platform;
- Deposits cover the whole of the bottom area inside the pedestal. Height of the deposit is mostly 30 to 60 cm from the floor, though in some places it is higher;
- A deposit at the bottom part of the pedestal includes not melted parts of fuel assemblies (a spacer) and pebbles.

The measured radiation level outside the pedestal is approximately 80 Gy/h, which is 10 times higher than radiation level inside the pedestal (7-10 Gy/h), where all the irradiated fuel debris presumably remains. It is not clear why this is the case and is the subject of further investigation.

Unit 3

So far it is accepted that some of the melted fuel has fallen to the bottom of the RPV, but part of the fuel debris still likely remains in the RPV, though most of the melted fuel have fallen to the bottom of the PCV with some molten substances solidified inside the pedestal.

Further PCV internal survey of Unit 3 were conducted in October 2015 and in July 2017. Some main facts obtained by both surveys are as follows:

- No damage was observed on the structure (only outside the pedestal) / wall surface in PCV within the range of the observation;
- No damage was observed in CRD rail and X-6 penetration within the range of the observation;
- Sediments were observed on the CRD rail and the steel grating outside the pedestal of the 1st floor;
- Water level in the PCV was approx. 6 m from the PCV bottom;
- Dose rate of the PCV gas phase was approx. 0.8-1 Sv/h. Radiation dose in the PCV was at the lowest among Units 1-3, which seemed to be an effect of shielding caused by a high level of stagnant water;
- The current understanding of the stagnant water in the PCV is it is not a severely corrosive environment, but rather has low corrosive environment;
- Presence of molten material that appears to have solidified was observed inside the pedestal;
- Sediment levels are high in the central part and lower further from the center.

Table 1 provides summary estimation of fuel debris distribution and condition.

	Unit 1	**Unit 2**	**Unit 3**
Core	A little amount of melted fuel may remain.	Stub-shaped fuel assemblies may exist in the peripheral area.	Some amount of melted fuel may remain.
RPV	Possibility that fuel fallen in the lower plenum remains at the bottom of RPV.	Some of the fuel has fallen to the bottom of the RPV.	Part of the fuel debris might still remain in the RPV. High density material at the bottom of PCV was confirmed.
PCV	Almost all melted fuel has fallen into the lower part of the PCV. Fuel debris solidified partially caused molten core-concrete interaction (MCCI), partially without causing MCCI.	Some of the melted fuel has fallen to the lower part of the PCV. Possibility that most of the fuel debris solidified without causing MCCI.	Most of the melted fuel has fallen to the lower part of the PCV. Possibility that the fuel debris partially solidified causing MCCI.

PCV condition	Possibility of diffusion of fuel debris to the D/W floor through the pedestal opening. Lower pedestal walls could be partially eroded by MCCI. Estimated that PCV has a damage. That conclusion is based on observed water leakage from sand cushion drain pipe.	Steam rising is observed during PCV internal survey. Dose measurements through X-6 penetration indicated an unexpected "hot spot" outside the pedestal zone. Suppression chamber was damaged and has hole(s), that could be a reason of the leakage of cooling water. No leakage from the send cushion drain pipe, no tendency of PCV breakage.	Sandy, pebbly and lumpy deposits confirmed in multiple locations within the pedestal. Possibility of diffusion of the fuel debris to the D/W floor through the pedestal opening.
Water level in containment	Approx. 2 m	Part of the fuel debris is not covered with water.	Approx. 6 m
Residual heat (November 2018)	68 kW	83 kW	82 kW

Dismantling of the upper part of the Units 1 and 2 Common Ventilation Stack

The IAEA Review Team was informed that dismantling of the upper part of the Units 1 and 2 Common Ventilation Stack (CVS) is included in the Roadmap. Damaged parts of the CVS at 45 m and 66 m above the ground were discovered during inspections. The decision taken was to dismantle the upper part of the stack reducing the height from 120 m to 60 m.

At the current time preparation for dismantling the CVS is in progress. It is being delivered by a local company having a mock-up close to the Naraha Center for Remote Control Technology Development. Though a review of the solution has been undertaken by those with the relevant international experience, the proposed solution is a bespoke remotely operated design and relatively complex. Completion of dismantling is scheduled for first half of 2019. This work will take place at height, in close proximity to the ongoing rubble removal and preparation for spent fuel removal activities in Units 1 and 2, and will benefit from careful risk assessment and integrated planning of site activities.

Acknowledgment 15 (Spent fuel)

The IAEA Review Team acknowledges the careful and deliberate approach to the spent fuel removal across the site. The team recognizes the many good practices such as the adaptation of safety controls to the conditions in each Unit, providing hands-on training of the workers, using dummy fuel and casks on the remote operation of the new FHM and crane in Unit 3 before starting the real operations, and measures taken to reduce dust arising during rubble and spent fuel removal operations for the radiological protection of the workers and the environment.

Acknowledgment 16 (Fuel debris)

The IAEA Review Team also acknowledges significant progress is being achieved in clarification of the fuel debris distribution inside the reactor building of Units 1-3 since the 3rd

Review Mission, and the step-by-step approach (from internal PCV investigation, fuel debris sampling and characterization, small scale retrieval to bulk retrieval) currently considered for the fuel debris retrieval.

Advisory Point 16 (Spent fuel)

The IAEA Review Team advises TEPCO to take measures to ensure enough storage capacity will exist among the common spent fuel pool and dry cask storage areas to accommodate all spent fuel on site from Units 1-6.

Advisory Point 17 (Spent fuel)

The IAEA Review Team advises that all the different categories and characteristics of fuel assemblies on the site be fully considered with regard to conditions affecting its safe management (retrieval, transport and storage). Substantial international experience is available in the management of both intact and damaged BWR spent fuel (e.g. USA, Germany, etc.) that may be drawn upon. While there are as yet no indications of fuel assemblies damaged by the accident, the plan should incorporate the ability to design and store, in the pool and casks, all anticipated fuel assembly conditions.

Advisory Point 18 (Fuel debris)

The IAEA Review Team advises that before the commencement of the fuel debris retrieval activities, there should be a clear implementation plan defined to safely manage the retrieved material. TEPCO should ensure that appropriate containers and storage capacity are available before starting the fuel debris retrieval. Sufficient characterization (e.g. estimation of criticality, hydrogen emission, neutron activity, thermal condition, parameters of neutron-multiplying medium, etc.) of the fuel debris environment will support successful safe debris retrieval and design of related facilities and equipment including containers and any treatment and storage facilities.

Advisory Point 19 (Fuel debris)

Whilst significant progress has been achieved in estimation of the fuel debris distribution inside the reactor building of Units 1-3, there is recognition that more must be done. The IAEA Review Team supports continuing efforts to more precisely understand the fuel debris distribution inside each unit, the associated level and distribution of radiation encountered.

MANAGEMENT OF RADIOACTIVE WASTE

The management of solid radioactive wastes is an on-going, complex challenge for the Fukushima Daiichi decommissioning project because of the accumulating large volumes and diverse types of wastes combined with the limited space to store and manage the wastes on site. Solid radioactive waste includes rubble (combustible), felled trees, used protective clothing, rubble such as concrete and metal, contaminated soil and secondary waste from water treatment such as adsorption towers or sludges. Very good progress is being made in managing these wastes in spite of the many challenges facing the project team.

The current volume of post-accident waste is reported to be in excess of 400,000 m^3 and more than 4,000 vessels and the volume is projected to increase to 770,000 m^3 and more than 7,000 vessels in ten years without additional countermeasures. However, with implementation of currently planned measures such as volume reduction, recycling and incineration the volume of stored waste could be significantly reduced to the order of 250,000 m^3. This is illustrated in Figure 6.

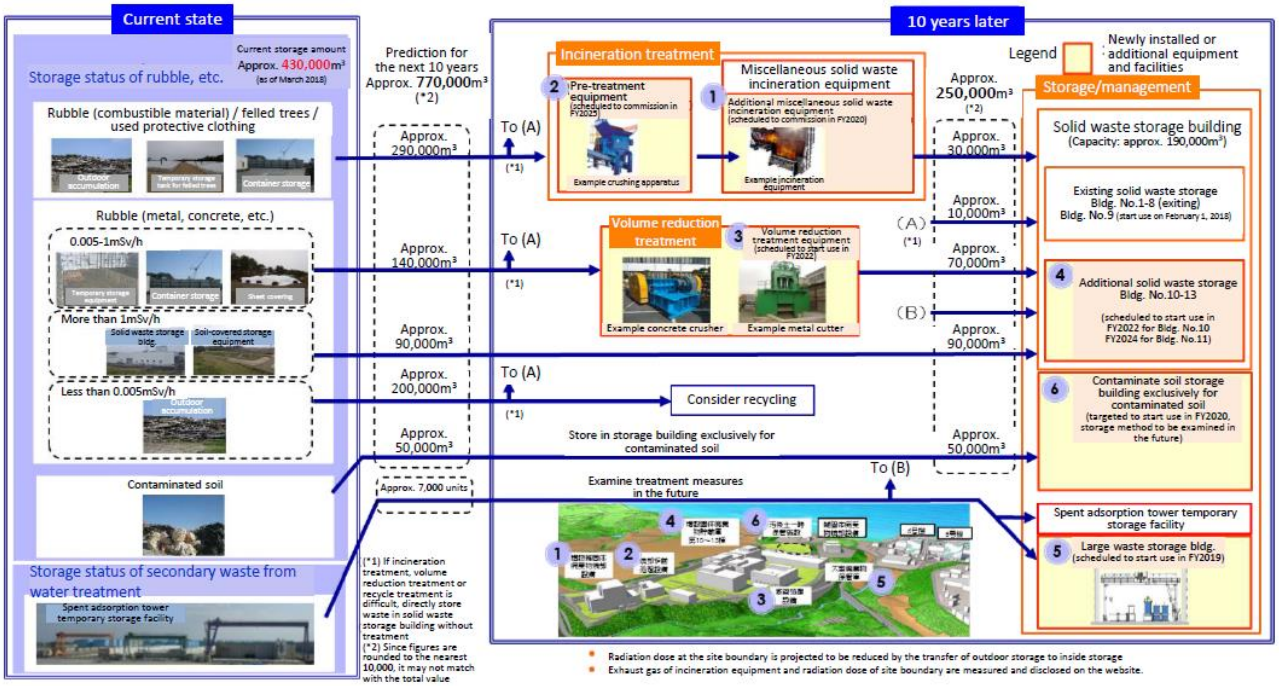

Figure 6. Illustration of expected stored waste volume reduction in 10 years (courtesy of TEPCO).

The management of these wastes is complicated because without further characterisation and disposal concept only temporary stabilization and storage measures can be implemented.

Countermeasures are being deployed to stabilize and reduce the volumes of wastes to allow for on-site storage until final disposal decisions can be made. In addition to the accumulating solid waste arising from the initial site decontamination and fuel retrieval preparations, there is a substantial volume of additional waste that will arise once decommissioning of the defueled units, and the existing and future support facilities begins in earnest.

The Roadmap specifies that the basic concept of solid waste management should be compiled in FY 2017 and that the prospects of a processing/disposal method and technology related to its safety should be made clear by around FY 2021. Strategies are also being developed for pre-accident waste such as activated metal, spent ion exchange resin and miscellaneous solid wastes that are currently stored in Waste Storage Buildings 1-8.

A new waste storage building (Building 9) has been constructed and is operational as of February 2018. Land has been cleared that can be used for additional waste storage buildings 10-13. Temporary storage facilities have also been constructed such as the large in-ground cells for storage of trimmed trees, rubble and soil.

An incineration facility has been constructed and is operational for the treatment of combustible

wastes such as the used protective clothing. The resulting ash is being stored in drum cans. TEPCO is making good progress on the construction of a second incineration facility for the treatment of felled trees. The second facility was reported as being 41% complete in July 2018.

Concrete rubble with very low surface dose rates is currently being crushed at temporary storage area C and being recycled for use as roadbed materials on the site. Plans are being developed for a new crushing capability for concrete waste.

Plans are also being developed for managing metal waste including a large metal cutting shear to size reduce metallic wastes. The project is evaluating the potential for a metal melting capability which could decontaminate metal and reduce the volume of metallic waste requiring disposal. Large volumes of metallic wastes could be recycled including contaminated water tanks, scrap metal including steel frames, reinforcing bar and metal containers. Storage facilities for contaminated soil have been established and more storage facilities are being prepared.

Progress is being made for the management and stabilization of secondary wastes resulting from water treatment such as adsorption towers, ALPS slurry, sludges and evaporator bottom slurry.

There are several thousand vessels from various treatment processes including SARRY and ALPS plus other mobile treatment processes. The adsorption towers primarily contain ion exchange resins like zeolites or crystalline silicotitanate resins. These are currently being stored in various locations. To supplement the storage capacity for the adsorption towers, a dedicated waste storage building is being planned for the storage of 744 SARRY and KURION adsorption towers. Safely storing the adsorption towers is the main objective at this time. Treatment or conditioning methods for the ion exchange media were not discussed with the IAEA Review Team.

The ALPS slurry (carbonate slurry, and iron co-precipitate slurry) wastes are stored in approximately 2800 high-integrity containers. These wastes have a high-water content and a high level of radioactivity. Radiolysis generates hydrogen gas which creates safety concerns and also increases the waste volume. The objective at this time is to stabilize the slurries and reduce the volume by the use of dewatering processes. This will reduce the hazard from hydrogen, help minimize the potential for volume expansion from hydrogen gas, and result in a more stable waste form for storage.

The decontamination apparatus sludge is contained in a sludge storage tank in a process building. The sludge volume is approximately 37 m^3 and is covered by water. The sludge will be retrieved, dewatered and stored on higher ground to reduce the risks from a potential tsunami.

For the treatment and stabilization of the sludges, significant progress has been made by TEPCO with the assistance by the IRID in defining the approach for the treatment. This includes the dewatering of the ALPS slurry and the retrieval, dewatering and packaging of the decontamination process sludges.

Significant progress in terms of creation of additional storage capacity and waste packaging has been made since the previous mission. However, significant waste management challenges remain such as the creating additional storage for the large volume of waste to be consigned for storage. The IAEA Review Team discussed with the Japanese counterparts the application of waste hierarchy principles to minimize the volume of waste consigned for disposal and how it could be incorporated into future radioactive waste management planning activities (see Figure 7) to utilize all available processing and disposition option.

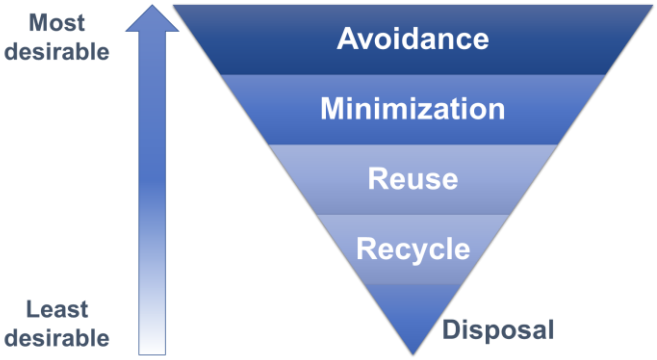

Figure 7. Waste hierarchy principles to minimize the volume of waste consigned for disposal.

Some of the waste processing technologies that are being adopted have a significant risk of schedule slippage. Delays could be experienced in many ways including in the design process, in research and development, in procurement, in factory acceptance testing, in construction and in installation and commissioning. In addition, treatment rates could be lower than planned due to unforeseen difficulties. In this respect, further review of the schedule appears warranted for the installation and commissioning activities.

The IAEA Review Team was briefed on the efforts being made by TEPCO to establish and maintain a solid radioactive waste inventory through routine documentation of the location, waste stream type and surface dose rate of the stored solid waste. However, recognizing the uncertainty associated with yet to be developed disposal waste acceptance criteria, it is worth considering routinely taking samples during waste collection and processing to allow the possibility for future detailed characterization when more information is available on the final disposition path, without having to resort to opening and inspection of the existing waste packages.

Acknowledgement 17

The IAEA Review Team is of the opinion that good progress has been made with this very complex series of decommissioning and waste management projects in the face of many significant challenges and constraints. Good progress has been made in establishing strategies to reduce the volume of radioactive wastes, create storage capacity and enhance the stability of wastes by using methods such as incineration and dewatering.

Advisory Point 20

The IAEA Review Team recommends that, in considering the overall duration of the Fukushima Daiichi decommissioning activities, the Roadmap and other planning documents address operational radioactive waste present on site at the time of the 2011 accident and the present arising of radioactive waste from the initial site decontamination and fuel retrieval preparations. In addition, the IAEA Review Team encourages to envisage the generation of waste arising from the decommissioning of 6 units and supporting facilities through the completion of decommissioning, recognizing that at this point in time, significant uncertainty exists in the decommissioning approach and thus the volumes involved. This will help ensure there is an adequate allocation of resources to manage, characterize, treat and dispose of these

radioactive wastes and that the work activities for these wastes can be properly sequenced with other activities.

Advisory Point 21

The IAEA Review Team encourages the NDF and TEPCO to continue to actively explore the application of waste hierarchy principles to minimize the volume of material consigned for disposal. Routine use of pre-treatment techniques of sorting, segregation and decontamination of solid material after collection will create opportunities for the recycling of material as well as providing the possibility to remove material from regulatory control. The IAEA Review Team encourages the Government of Japan to support TEPCO in such approach.

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Note: Not all documentation will be relevant to every situation, but the above represents a list of the principal IAEA documentation covering decommissioning, related waste management and other topics of the peer review. Other IAEA documentation applies to closely aligned fields such as radiation protection, emergency planning, transport and other aspects of waste and spent fuel management and disposal.

Several more IAEA publications (TECDOC and NE Series reports) relevant to the Mission topics are under completion or with Publishing Section for the final editing, e.g. "Characterization, Processing and Storage of Activated Materials from Reactor Cores and Structures", "Characterization of Radioactive Waste, Waste Forms and Waste Packages" and "Decommissioning After a Nuclear Accident: Approaches, Techniques and Implementation Considerations".

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APPENDIX I: MISSION PROGRAMME

IAEA INTERNATIONAL PEER REVIEW MISSION ON MID-AND-LONG-TERM ROADMAP TOWARDS THE DECOMMISSIONING OF TEPCO'S FUKUSHIMA DAIICHI NUCLEAR POWER STATION

The Mission was conducted between 5 and 13 November 2018.

The itinerary for the Mission is as follows:

Monday:	Meeting with METI/TEPCO and other organizations in Tokyo
Tuesday:	Transfer to Iwaki-city (morning), discussion with METI/TEPCO at Fukushima Daiichi NPS (afternoon)
Wednesday:	Site visit at Fukushima Daiichi NPS
Thursday:	Discussion with METI/TEPCO at Fukushima Daiichi NPS
Friday:	Discussion with METI/TEPCO at Fukushima Daiichi NPS (morning), visit of the JAEA Naraha Center for Remote Control Technology Development and transfer to Tokyo (afternoon)
Saturday:	Reserved for drafting the report in Tokyo
Sunday:	Reserved for drafting the report in Tokyo
Monday:	Discussion with METI/TEPCO (checking factual accuracy and pre-finalizing the preliminary summary report) in Tokyo
Tuesday:	Presentation of the preliminary summary report to METI and Press conference in Tokyo

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