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Review Report

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

(Fifth Review)

Vienna, Austria
Tokyo and Fukushima Prefecture, Japan

June – August 2021

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REVIEW REPORT TO THE GOVERNMENT OF JAPAN

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REVIEW REPORT

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EXECUTIVE SUMMARY

Ten years after the accident at Fukushima Daiichi NPS, significant progress has been achieved in managing the site and reducing the risks to the workforce and the environment, along side implementing a risk reduction strategy, and plan for the decommissioning. The site condition has further improved in the three years since the 4th review, but the environment is and will remain challenging. Any operation, however simple it seems, becomes highly complex. The IAEA Review Team appreciates the dedication of the Japanese teams to manage operations and make progress in such circumstances.

The stable situation of the site, with the more routine implementation of site management operations and the maturity reached on planning and executing decommissioning activities allow development in parallel of the two pillars of decommissioning and reconstruction. The IAEA Review Team appreciates the effort of the Japanese teams to engage with a network of universities and support the development of local people and supply chain.

The IAEA Review Team appreciates 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, water management and radioactive waste management activities.

Since the previous Review mission in November 2018, several progress and achievements of milestones of the Mid-and-Long-Term Roadmap could be highlighted: Government of Japan has taken a decision on the disposition of ALPS treated water and the target of reducing the amount of contaminated water generated was achieved by taking additional measures to reduce water ingress, the spent fuel pool of Unit 3 has been safely emptied, specific robotics have been designed and will soon be utilized to better understand the status of fuel debris by taking a first sample. On the organizational and institutional side, the re-organization of the FDEC (Fukushima Daiichi Decontamination and Decommissioning Engineering Company) is strengthening the project management and safety functions, and the pro-active engagement of local industries is bearing some fruits.

Based on the presentations made, the Review Team considers that the daily activities of the site are well managed and that the preparation and implementation of operations are thorough with proper attention given to safety culture and protection of the workers and of the environment. The Review Team believes that the stronger ownership of the decommissioning in FDEC is positive and provide an opportunity to engage with a wider range of organizations, in Japan and at the international level; such expert knowledge and experience can greatly benefit the decommissioning project.

While recognizing the improvement already made but considering the significant challenges ahead towards the safe decommissioning of the site, the Review Team encourages Japan to keep on strengthening the programme and project management as well as the in-house human resources development and knowledge management, and to promote a comprehensive and integrated planning up to the completion of the site decommissioning. The focus on the next 10 years should be complemented by the development of a more comprehensive approach for the next phases until completion, such as identification of options for the management of fuel debris after retrieval and storage, the life management of all assets and facilities of the site and the total requirements for solid waste storage to reach an end point after full dismantling of the six reactors of the site. In due time, when more information will have been gathered on fuel debris and some experience gained on their retrieval, an analysis of the potential options toward the

end state of the site would become feasible.

In ten years, the Japanese actors have brought a site under an emergency situation into an industrial decommissioning operation. This is an important step that should be congratulated and was necessary to enable addressing the challenges ahead of this unique and highly complex decommissioning project, as this is just the beginning. Success in the coming two or three decades will require disciplined programme and project management dealing with significant risks and uncertainties, a continued focus on safety culture and further scientific and technological developments with close coordination among concerned organizations including between relevant ministries. Sustained international cooperation across all these factors can contribute to the effective delivery of the project. The Review Team is of the opinion that all this is well recognized by the Japanese actors and that they are prepared to tackle these challenges.

ACKNOWLEDGEMENTS AND ADVISORY POINTS

FOLLOW-UP OF THE PREVIOUS IAEA REVIEW MISSIONS

Acknowledgement 1

The IAEA Review Team appreciates the consideration given to the Advisory Points from the previous Review missions and acknowledges the efforts of TEPCO, NDF and other Japanese organizations and institutions to effectively implement them into the arrangements and practices related to the decommissioning of the Fukushima Daiichi NPS. Particularly should be noted progress related to the 2018 Peer Review Advisory Points that were carefully considered, analysed and are implemented or under implementation by the Japanese organizations.

Acknowledgement 2

The IAEA Review Team appreciates the decision making of Government of Japan of a basic policy of disposition of the ALPS treated water following further purification as necessary and appropriate dilution. The decision on ALPS treated water disposition path was an important advisory point of previous reviews, and it will facilitate the implementation of the whole decommissioning plan.

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

Acknowledgement 3

The IAEA Review Team acknowledges the maintenance of the stable status of Fukushima Daiichi NPS since the last review and achievement of continuous risk reduction on the site to protect the people and the environment. The IAEA Review Team also acknowledges the efforts by Japan in the implementation and communication of the Roadmap activities and thorough regular revisions taking into account new findings, knowledge and lessons learned, as well as the funding scheme which brings stability and visibility to the project.

ORGANIZATION AND PLANNING

General view including relations between ministries and relevant organizations

Advisory point 1

As many organizations are involved in the decommissioning of Fukushima Daiichi, the IAEA Review Team advises to ensure close communication between TEPCO and NRA, as well as close coordination among these related organizations, in order to ensure safe and stable implementation of the decommissioning.

FDEC re-organization and new focus

Acknowledgement 4

The IAEA Review Team commends the FDEC for successfully performing its re-organization during challenging times (COVID-19 restrictions) towards more efficient project management-oriented organization, focusing on efficiency, safety and quality of the decommissioning works. In addition, the IAEA Review Team recognizes the ambition of FDEC to become an engineering company with its own design, engineering and procurement capacities.

Advisory point 2

The IAEA Review Team encourages FDEC to continue revising and improving its business processes to adapt them to the changing needs in the future, focusing on further strengthening of design, engineering, procurement and project management functions and on developing human resources in related domains.

Coordination of R&D

Acknowledgement 5

The IAEA Review Team acknowledges the streamlining of the coordination and collaboration process, such as placing directly under JAEA the relation with universities, the effective cooperation between IRID, TEPCO and the technology developers for robotics aimed at fuel debris operations and spent fuel pool's inspections, and the Decommissioning R&D Partnership Council coordinated by NDF.

Advisory point 3

The IAEA Review Team advises to develop a more structured form of collaboration and cooperation, which would improve the integration of the components of the R&D work performed or led by each organization into a common master plan to ensure timely and effective delivery.

Planning short-term, mid-term, long-term

Acknowledgement 6

The IAEA Review Team acknowledges the continued improvement that the Government of Japan, NDF, TEPCO and other organizations have made on revising and developing the strategy for the decommissioning of TEPCO's Fukushima Daiichi NPS. The principles and approach to risk reduction laid out in the Mid-and-Long-Term Roadmap take into account balancing of relevant factors to ensure the best overall approach to decommissioning towards "reducing risks systematically, under the concept of coexistence of reconstruction and decommissioning." The Decommissioning Action Plan issued by TEPCO provides a practical implementation path of the Mid-and-Long-Term Roadmap and of the Technical Strategic Plan issued by NDF.

Advisory point 4

The IAEA Review Team advises to develop planning scenarios for the entire decommissioning programme including all units; it would be advantageous to demonstrate that the planning provides sufficient flexibility and is robust against a range of scenarios. This could be achieved by optioneering against conceptual endpoints, for example, assessing if there will be a sufficient space for the processing and storage of all the material resulting from concurrent activities.

Advisory point 5

The IAEA Review Team recommends that TEPCO ensures that their plans for maintaining the safety and operability of the site infrastructure and assets are aligned with the projects that are delivering progress of the decommissioning plans. Managing an aging site infrastructure will become an increasing task with time and the systems required to keep the site, workforce and environment safe and operational are critical to ensuring the continued progress of the risk reduction activities.

FOCUS AREAS OF OPERATION

Water management

Acknowledgement 7

The IAEA Review Team recognises TEPCO's continued efforts to manage existing volumes of contaminated water on site and achieve further reduction in its generation through application of countermeasures. Of note is the successful removal of the stagnant water from the target buildings identified in the Roadmap.

Advisory point 6

The IAEA Review Team encourages TEPCO to perform an analysis of the site water balance considering the large volume of water that has been treated and stored, a significant proportion of which (around 70%) will require further purification. This analysis should also include an estimation of the ALPS treated water that will be generated in the future, and its anticipated schedule for its discharge to the sea.

Fuel removal from spent fuel pools

Acknowledgement 8

The IAEA Review Team recognizes the effort in training operators for remote operation in Unit 3 using only camera view and implementing a step-by-step approach , adjusting the training by incorporating lessons learned to enhance effectiveness. The Review Team appreciates the graded approach to start the actual operations from low risk to high level of difficulty in fuel removal (fresh fuel, spent fuel and fuel damaged before the accident), and the incorporation of operational experience and lessons learned, gained during Unit 3 removal activities, in an manual to be used for the subsequent spent fuel removal activities in Units 1 and 2.

Acknowledgement 9

The IAEA Review Team recognizes the efforts in enabling defueling of spent fuel pools at Units 1 and 2, implementing a step-by-step approach for rubble removal and dose rate reduction. The Review Team appreciates efforts in preventing dust release and in identifying approaches for damaged fuel removal and dose reduction at the refueling floor (Unit 2).

Advisory point 7

The IAEA Review Team advises to continue exploring technologies and approaches to remove difficult-to-handle damaged fuel.

Advisory point 8

The IAEA Review Team encourages to continue the successful approach for enhancing knowledge retention and transfer of operational experience and lessons learned gained in Unit 3 for the safe remote operation in Unit 2.

Fuel debris retrieval

Acknowledgement 10

The IAEA Review Team recognizes that significant R&D efforts have been accomplished to access PCV internals including the design, development, prototype and delivery of a "one of a kind robotic arm" for the trial fuel debris retrieval.

Acknowledgement 11

The IAEA Review Team recognizes the graded approach for starting fuel debris retrieval, gaining experience with trial and knowledge of fuel debris properties through characterization of small samples and development of a full-scale mock-up facility.

Advisory point 9

The IAEA Review Team advises, taking into consideration the complexity of fuel debris retrieval, to develop a strategy for the subsequent management of the interfering objects in PCV (Unit 1) that can be potentially highly radioactive.

Advisory point 10

While the IAEA Review Team commends the current focus of attention on fuel debris, the Team stresses the importance of undertaking a comprehensive characterization of the fuel debris to identify the key parameters that will enable the design of future strategies to manage this material from initial storage through to disposition, with an emphasis on the potential treatment and conditioning stages.

Advisory point 11

The IAEA Review Team considers that whilst significant progress has been achieved in estimation of the fuel debris distribution inside the reactor building of Units 1-3, there is recognition of the future challenges that will be encountered during the sampling, characterization, and scale up/ramp up phases. The IAEA Review Team advises TEPCO to develop a comprehensive feasibility and risk analysis of the retrieval options of fuel debris. With more information being gathered and experience gained in the coming years, the Review Team advises to steadily progress with an analysis of the potential options toward the end state of the site and their impacts on the full site management strategy.

Waste management

Acknowledgement 12

The IAEA Review Team welcomes the progress made by TEPCO in developing technical approaches for the management of the secondary waste arising from the treatment of contaminated water.

Acknowledgement 13

The IAEA Review Team appreciates TEPCO's progress made in identifying the existing waste streams as well as their appropriate disposition paths. This effort has informed the design and technology development efforts.

Advisory point 12

While the IAEA Review Team appreciates the plans TEPCO have developed for management of waste and potentially contaminated material generated through 2032, TEPCO is encouraged to extend these efforts to include all waste generated during the lifetime of decommissioning operations and an understanding of the anticipated end-point for each stream.

Advisory point 13

Given that decommissioning operations will generate a large volume of waste and potentially contaminated material requiring storage, TEPCO is encouraged to identify additional storage locations for material awaiting further processing and further strengthen traceability and characterization of the waste packages. In addition, the IAEA Review Team emphasizes the need to actively explore implementation of all opportunities afforded by implementation of the waste hierarchy and the circular economy principles to not only minimize the volume of waste that is generated during decommissioning operations but also to reduce the volume of waste consigned to disposal.

Site management

Acknowledgement 14

The IAEA Review Team acknowledges TEPCO for the measures against design basis and maximum reference earthquakes and against Outer-rise and Kuril trench tsunamis. The IAEA Review Team is also in the view that the construction of additional seawalls, which are in progress, is a good decision in anticipating the most extreme tsunami scenario from Kuril and Japan Trench.

Acknowledgement 15

The IAEA Review Team commends TEPCO for the progress in constructing a new drainage channel D to reduce the risk of flooding and also for monitoring radioactive concentration in the body of water around the Fukushima Daiichi NPS.

Acknowledgement 16

The IAEA Review Team recognizes TEPCO's efforts towards the organization of the site, to improve facilities for the workforce, such as canteen and checkpoints, while considering productivity but ensuring safety and security measures.

Advisory point 14

The IAEA Review Team encourages TEPCO to further develop the site management in order to optimize the utilization of the site space and workforce logistics while keeping the effort to reduce the risk systematically until completion of the decommissioning.

FUNCTIONS SUPPORTING THE SAFE AND EFFECTIVE DELIVERY OF THE DECOMMISSIONING PROGRAMME

Project management

Acknowledgement 17

The IAEA Review Team acknowledges the continued evolution and improvement in the project management and learning from other international programmes and internationally recognised practices in project management. This can be seen in changes made in FY2020. This includes the adoption of a stage gate process for decision making.

Advisory point 15

The IAEA Review Team advises TEPCO to continue to mature their project management methodologies, particularly managing uncertainties and interdependencies, and continuing to ensure that responsibilities and authorities are clear when determining the priorities and delivering programme at the Fukushima Daiichi site.

Advisory point 16

The IAEA Review Team encourages TEPCO to develop professionals in project management, to support the human resources requirements for the duration of the mid- and long-term plan.

Safety and occupational radiation protection

Acknowledgement 18

The IAEA Review Team acknowledges TEPCO for the strengthening of safety and occupational radiation protection since the last IAEA Review mission. Preliminary investigations of fuel debris and on-site decommissioning operations were completed with proper safety and occupational exposure control.

Acknowledgement 19

The IAEA Review Team recognizes TEPCO for the establishment of the D&D Safety and Quality Office in a higher management position in FDEC, which contributes to enhance both independency and effectiveness of internal inspection for safety and quality, and to promote safety behaviour as well. The operation of this new office also confirms commitment for safety leadership and culture.

Acknowledgement 20

The IAEA Review Team commends TEPCO for the implementation of dose constraints and optimization measures, for both external and internal occupational exposures, applying innovative technologies such as robotics, remote dismantling system and other remote system and sensing technology, and 3D remote radiation imaging and modelling system. The IAEA Review Team also recognizes TEPCO for the enhancement of occupational exposure monitoring programme implementing a real-time individual monitoring system that records the occupational exposure for each task and has the features of communication and alarm level setting. The monitoring programme also includes the dose to the lens of the eye monitoring initiative.

Advisory point 17

The IAEA Review Team encourages TEPCO and JAEA/CLADS to further develop the 3D remote radiation imaging system and 3D plant model system to become tools for radiation risk projection during planning of decommissioning operations.

Advisory point 18

The IAEA Review Team encourages TEPCO to further develop the real-time individual monitoring system and make the database a mean for experience feedback and optimization analysis for different tasks in decommissioning.

R&D and technology development

Acknowledgement 21

The IAEA Review Team recognizes the achievements in the area of R&D (basic, fundamental) and technology development in the areas of spent fuels, fuel debris, radiation measurement / 3D imaging, remote characterization technologies, processing and disposal of radioactive waste, materials in nuclear reactor, decontamination and characterization of reactor buildings.

Acknowledgement 22

The IAEA Review Team also recognizes the efforts in the development of full scale mock-up facilities to support the proof of concept, functional testing and deployment of one-of-a-kind technologies. The mock-up will also facilitate the training and skill set development of the workforce.

Advisory point 19

The IAEA Review Team advises that consideration be given to include the newly established D&D Safety and Quality Office in the R&D process. This office should engage early on in the R&D process to address any risk and safety issues with new technologies. In addition, active participation and contribution of the end users (TEPCO operators) with R&D organizations should be encouraged and maintained during the entire R&D process.

Advisory point 20

The IAEA Review Team encourages the end user (TEPCO) to develop a strategy for the smooth transition of "one of a kind" prototype technologies ranging from the testing and evaluation stages to the fully developed technologies ready for ramp up and full-scale operations, considering challenges, safety and schedule impact.

Knowledge management

Acknowledgement 23

The IAEA Review Team acknowledges the establishment of a formal knowledge management information platform to identify, accumulate and disseminate lessons learned to internal stakeholders at Fukushima Daiichi NPS. This collection of knowledge should be useful in the future for carrying out the same or similar activities or processes.

Advisory point 21

The IAEA Review Team encourages TEPCO to further develop the Knowledge Management platform to accommodate practical knowledge on decommissioning, including those gained from technical investigation and radiation protection internal practice and lessons learned from international experiences, where available, that might be useful in future planning and implementation of decommissioning activities or processes.

EXTERNAL RELATIONS FOR COOPERATION / COLLABORATION AND INFORMATION SHARING

Supply chain and localization

Acknowledgment 24

The IAEA Review Team acknowledges the programme developed by TEPCO to engage with local companies and to support the development of a local supply chain. The Review Team appreciates the proactive engagement shown by TEPCO along with local governments organizations and the pragmatic way to develop an approach taking into account the actual current industrial status of the local region. In particular, the IAEA Review Team believes it is important that TEPCO and local governments organizations continue to work with local supply chain to identify specialized areas and expertise that allow the local supply chain to develop their capability, diversification, and sustainability.

International cooperation and dissemination of knowledge

Acknowledgment 25

The IAEA Review Team acknowledges the commitment of Japanese organizations to engage with international counterparts, from research to industry, and to disseminate the scientific, safety and technological knowledge stemming from the decommissioning operation.

Advisory point 22

The IAEA Review Team advises FDEC and JAEA to further strengthen international cooperation in their respective domains, with two complementary aspects:

- benefit from solutions, resources and experience available internationally, which can contribute to the safe and effective decommissioning project;
- make available knowledge gained on the accident and facilitate access to fuel debris samples.

Public communication

Acknowledgment 26

The IAEA Review Team acknowledges the public outreach programme to disseminate relevant information regularly, both locally and at national level and the efforts to offer it in an easy to understand manner. The development of a virtual tour of the site is a useful mean to increase reach-out including internationally, complementing magazines and engagement with Social Networks.

Advisory point 23

The IAEA Review Team encourages TEPCO and METI to perform surveys and assessments to evaluate how the public outreach programme contributes to enhance public trust and confidence on Fukushima Daiichi decommissioning works.

1. BACKGROUND, OBJECTIVES AND SCOPE OF THE REVIEW

1.1. BACKGROUND

Following the accident at Fukushima Daiichi Nuclear Power Station (NPS) owned and operated by the Tokyo Electric Power Company (hereinafter "TEPCO") 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 "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, June 2013, June 2015, September 2017 and December 2019. 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.

The Nuclear Damage Compensation and Decommissioning Facilitation Cooperation (NDF) developed the "Technical Strategic Plan 2015 for Decommissioning of the Fukushima Daiichi Nuclear Power Station of Tokyo Electric Power Company" (hereinafter the "Technical Strategic Plan 2015") on 30 April 2015. It aimed at providing a firm technical basis for the Roadmap and was intended to serve as an aid for the smooth and steady implementation of the decommissioning work. Every year the Technical Strategic Plans have been updated and released in July 2016 (hereinafter the "Technical Strategic Plan 2016"), in August 2017 (hereinafter the "Strategic Plan 2017"), in October 2018 (hereinafter the "Technical Strategic Plan 2018"), in September 2019 (hereinafter the "Strategic Plan 2019") and in October 2020 (hereinafter the "Technical Strategic Plan 2020"), based on the status of the progress in the site conditions and technical development since the Technical Strategic Plan 2015 was developed[1].

Upon the request of the Government of Japan, the IAEA organized four missions of the International Peer Review of the Roadmap, which were implemented in the framework of the IAEA Nuclear Safety Action Plan, in April 2013, November/December 2013, February 2015 and in November 2018.

The first mission was conducted from 15 to 22 April 2013 with the main purpose of conducting an initial review of the Roadmap including assessments of decommissioning strategy, planning and timing of decommissioning phases and a review of several specific short-term issues and recent challenges, such as management of waste, spent fuel and fuel debris, management of associated doses and radiation exposure of the employees, and assessment of 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).

[1] The Technical Strategic Plans for each year are available on following sites:
The Technical Strategic Plan 2015: https://www.dd.ndf.go.jp/files/user/pdf/en/strategic-plan/book/20150624_Technology_strategy_plan_e.pdf
The Technical Strategic Plan 2016: https://www.dd.ndf.go.jp/files/user/pdf/en/strategic-plan/book/20170322_SP2016eFT.pdf
The Technical Strategic Plan 2017: https://www.dd.ndf.go.jp/files/user/pdf/en/strategic-plan/book/20171005_SP2017eFT.pdf
The Technical Strategic Plan 2018: https://www.dd.ndf.go.jp/files/user/pdf/en/strategic-plan/book/20181109_SP2018eFT.pdf
The Technical Strategic Plan 2019: https://www.dd.ndf.go.jp/files/user/pdf/en/strategic-plan/book/20191101_SP2019eFT.pdf
The Technical Strategic Plan 2020: https://www.dd.ndf.go.jp/files/user/pdf/en/strategic-plan/book/20201214_SP2020eFT.pdf

After the first mission, the Government of Japan and TEPCO took into consideration the advice given through the 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 Units 1-4, revised 27 June 2013" is available on the website of the Ministry of Economy, Trade and Industry (hereinafter referred to the "METI") (https://www.meti.go.jp/english/earthquake/nuclear/decommissioning/pdf/20180530_01b.pdf).

The second mission was conducted from 25 November to 4 December 2013. The objective of the second mission was to provide more detailed and holistic review of the revised Roadmap and mid-term challenges, including the review of specific topics decided and defined in the first mission, such as removal of spent fuel from storage pools, removal 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 decommissioning activities. The Final Report is available on 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 decommissioning missions conducted in 2013, review of the draft of the second revision of the Roadmap, review of the draft of the Technical Strategic Plans for decommissioning developed by 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 and institutional and organizational issues. The Final Report of the third peer review mission is available on https://www.iaea.org/sites/default/files/missionreport130515.pdf.

After the third mission, the Government of Japan revised the Roadmap on 26 September 2017 based on the feedback from the local community and the opinions of experts and the results of the feasibility assessment of the fuel debris retrieval process conducted by the NDF as well as the progress of decommissioning and contaminated water management. The revised Roadmap is available on https://www.meti.go.jp/english/earthquake/nuclear/decommissioning/pdf/20170926_01a.pdf.

The fourth mission was implemented from 5 to 13 November 2018. The objective was to provide an independent review of the planning and implementation of Fukushima Daiichi NPS decommissioning, aimed at assisting the Government of Japan in the implementation of the Roadmap revised on 26 September 2017. It included highlight of important progress in 17 areas covering 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 organizational issues as well as several specific topics. These covered water management including management of water treated by Advanced Liquid Processing System (hereinafter referred to the "ALPS") and stored in tanks in the site, spent fuel removal and fuel debris retrieval and solid waste management. The Final Report is available on https://www.iaea.org/sites/default/files/19/01/missionreport-310119.pdf.

After the fourth mission, the Government of Japan revised the Roadmap on 27 December 2019 based on the progress made since the revision of Roadmap in September 2017, including proposal for the method of fuel debris retrieval from the first unit from the NDF in its Technical Strategic Plan 2019, the progress of the measures for decommissioning and contaminated water management[2], and the gradual progress in the returning of residents and reconstruction efforts in the surrounding area of the TEPCO's Fukushima Daiichi NPS. The Roadmap is available on METI website (https://www.meti.go.jp/english/earthquake/nuclear/decommissioning/pdf/20191227_3.pdf).

On 10 February 2020 the Subcommittee on Handling ALPS Treated Water (hereinafter referred to the "ALPS subcommittee"), an advisory committee to the Government of Japan, concluded and submitted its report to the METI. The report outlines the potential available options for the disposition of the ALPS treated water. METI provided the IAEA the report as informing progress on the advisory point in the report of the fourth mission and requested IAEA to review the progress made in water management, including a review of the ALPS subcommittee report, in an official correspondence dated 10 February 2020 through the PM of Japan in Vienna. The review report is available on https://www.iaea.org/sites/default/files/20/04/review-report-020420.pdf.

The Government of Japan conveyed, in an official correspondence dated 2 June 2021 through the Permanent Mission of Japan in Vienna, its request to the IAEA to dispatch another review. The IAEA accepted the request in an official correspondence and Terms of Reference were signed by DDG-NE and Ambassador of the Permanent Mission of Japan in Vienna on 28 June.

Following this request, this fifth International Peer Review of Mid-and-Long-Term Roadmap towards the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Station, involving 12 experts, took place from June to September 2021.

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 Final report was submitted to METI (Ministry of Economy, Trade and Industry) on 27 August 2021 in Tokyo and published on the METI website and the IAEA website.

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 Review 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 Review was intended to:

- Provide advice and commentary on both the safety and technological aspects of decommissioning, waste management and other related activities;

[2] See "3-1. Measures for decommissioning and contaminated water management" in Chapter "3. Approach to risk reduction and ensuring safety associated with the implementation of mid- and long-term measures" of the Roadmap issued in 2019.

- 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 REVIEW

The scope of the Review covered following items:

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

Item 2: Follow-up of the fourth mission conducted in 2018 and the follow-up review conducted in 2020 (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 (NDF);

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

- countermeasures against groundwater ingress, measures for reducing generation of contaminated water and management of contaminated water;
- removal of spent fuel assemblies and 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 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).

It should be noted that the Agency's planned assistance to Japan regarding the discharge of ALPS treated water is a separate arrangement with Japan, and not part of this Review.

2. CONDUCT OF THE REVIEW

2.1. WEB-BASED INFORMATION EXCHANGE

The Review, involving 12 experts, was conducted from June to August 2021. Agenda of the Review is in Appendix I and the List of participants is in Appendix II.

After the ToR was signed by both the IAEA and Japan on June 28, the reference documents described in the ToR were promptly provided by the Japanese side for review. In addition, starting from June 30, ten online Review meetings with Japanese concerned organizations such as METI, MEXT, TEPCO, JAEA, NDF and IRID were held twice a week, spending more than three hours each time. Comprehensive and detailed topic-specific explanatory materials were provided in advance by the Japanese side.

The IAEA Peer Review Team members conducted desk-based initial reviews based on these materials mentioned above, and asked questions to obtain a clear understanding of the issues, while listening to the explanations from the Japanese side at the Review meetings. In addition, the IAEA Peer Review Team members requested to deliver additional explanations and supplementary documents as necessary, and the Japanese side responded by submitting materials and making additional presentations during the Review meetings.

From 2 to 6 August, an online Review Team meeting was held to discuss the results of the initial review, and prepare a draft report based on these results of the initial review. Some additional presentations were provided by Japanese counterparts to cover overall topics to be reviewed. Preliminary discussion (for facts checking) of proposed Acknowledgements and Advisory Points was held with Japanese counterpart during the meetings held on 5 and 6 August.

2.2. SITE VISIT

Under the special arrangement by the Government of Japan, two members of the IAEA Review Team visited the Fukushima Daiichi NPS and Tokyo from 23 to 27 August following specific rules due to the COVID-19 pandemic, and conducted a site visit to observe the the construction of sea wall and other work to address the risk of tsunami, water management measures including ALPS treated water, infrastructure for removal of spent fuel and waste management facilities, which are areas of particular importance, and exchanged opinions face-to-face with METI, TEPCO, NDF and NRA. They also visited TEPCO Decommissioning Archive Center in Tomioka town (open to the public on the accident and decommissioning) and The Great East Japan Earthquake and Nuclear Disaster Memorial Museum in Futaba town. Then, they completed the report based on the findings obtained through these activities.

2.3. HAND-OVER OF THE PRELIMINARY AND THE FINAL REVIEW REPORT

The Final report was submitted to METI on 27 August 2021 in Tokyo and published on the METI website and the IAEA website. On the same day, the IAEA Press conference and the METI press briefing were held in Tokyo.

3. MAIN FINDINGS, ACKNOWLEDGEMENTS AND ADVISORY POINTS

3.1. FOLLOW-UP OF THE PREVIOUS IAEA REVIEW MISSIONS

The Japanese counterpart prepared a detailed summary of responses to Advisory Points from the IAEA previous Review missions in 2013 (two missions), 2015 and 2018. All the Advisory Points were accepted and comprehensive works on advancing their implementation have been carried out.

Regarding the advice from the previous Review missions, Japan assessed 36 Advisory Points as fully completed. Others (19 from both 2013 Review missions and Advisory Points from 2015 and 2018 Review missions) are partially accomplished or under implementation considering mid-term to long-term run for their completion.

The IAEA Review Team concurs with the counterparts' summary of responses to Advisory Points from the previous Review missions. The IAEA Review Team recognizes an intensive effort by Japan to carefully address all Advisory Points and to work on their effective implementation.

Acknowledgement 1

The IAEA Review Team appreciates the consideration given to the Advisory Points from the previous Review missions and acknowledges the efforts of TEPCO, NDF and other Japanese organizations and institutions to effectively implement them into the arrangements and practices related to the decommissioning of the Fukushima Daiichi NPS. Particularly should be noted progress related to the 2018 Peer Review Advisory Points that were carefully considered, analysed and are implemented or under implementation by the Japanese organizations.

Acknowledgement 2

The IAEA Review Team appreciates the decision making of Government of Japan of a basic policy of disposition of the ALPS treated water following further purification as necessary and appropriate dilution. The decision on ALPS treated water disposition path was an important advisory point of previous reviews, and it will facilitate the implementation of the whole decommissioning plan.

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

The Fukushima Daiichi NPS is continuously being maintained in a stable and safe state. The decommissioning activities are planned and implemented in accordance with the revised Roadmap to provide for continuous risk reduction. While the situation remains complex and challenging, the IAEA Review Team concludes that since the last mission in November 2018 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 in brief include:

- Enhancement of project management to transition the organization from power plant operator to a decommissioning company;
- Enhancement of the internal governance of FDEC as two new offices (D&D Safety and Quality Office and Project Management Office) were set up to assist the site in implementing activities and in improving quality and safety;
- Enhancement of occupational exposure monitoring programme, including the dose to the lens of the eye monitoring initiative;
- By applying a comprehensive set of countermeasures, the contaminated water generation decreased to 140 m^3/day in 2020;
- Decision was made for controlled discharges of the ALPS treated water into the ocean;
- Treatment of stagnant water in buildings (other than reactor buildings of Units 1-3, Process Main Building and the High Temperature Incineration Building) has been completed in 2020;
- Fuel removal from storage pool of Unit 3 was completed in February 2021, preparations are underway for installation of large cover of Unit 1 reactor building to control scattering of dust during rubble removal and dose reduction activities are progressing on the refueling floor of Unit 2;
- Investigations for fuel debris retrieval progress in Units 1-3, Unit 2 was selected to be the first one to start the fuel debris retrieval and preparations for trial retrieval are ongoing;
- A portion of the exhaust stack common for Units 1 & 2 was dismantled in order to ensure safety margin in terms of its seismic resistance (the dismantling work started in August 2019 and was completed in May 2020);
- Progress towards elimination of temporary outdoor storage of rubble by putting in place volume reduction facilities and waste storage facilities;
- Continuous upgrade of countermeasures against big tsunamis;
- The "Mid-and-Long-Term Roadmap towards the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Station Units 1-4" was revised in December 2019;
- The "Mid-and-Long-Term Decommissioning Action Plan" was issued by TEPCO in 2020;
- Decommissioning Reserve Fund has been established based on the relevant 2017 Act and it is fully available to provide funding for the implementation of Fukushima Daiichi decommissioning;
- Development of an approach to gather during decommissioning information which can be useful to understand the progression of the accident and improve the safety of other nuclear power plants.

Acknowledgement 3

The IAEA Review Team acknowledges the maintenance of the stable status of Fukushima Daiichi NPS since the last review and achievement of continuous risk reduction on the site to protect the people and the environment. The IAEA Review Team also acknowledges the efforts by Japan in the implementation and communication of the Roadmap activities and thorough regular revisions taking into account new findings, knowledge and lessons learned, as well as the funding scheme which brings stability and visibility to the project.

3.3. ORGANIZATION AND PLANNING

3.3.1. General view including relations between ministries and relevant organizations

Originally TEPCO, as the owner of the Fukushima Daiichi NPS, held primary responsibility for its decommissioning. However, since this nuclear accident is of an unprecedented level in Japan and with many challenges, the Government has taken the lead in advancing the decommissioning plan by developing the Mid-and-Long-Term Roadmap for the decommissioning process.

As for the Government of Japan's management and supervision organization for the decommissioning of the Fukushima Daiichi NPS, the Inter-Ministerial Council for Contaminated Water, Treated Water and Decommissioning Issues (hereinafter "the Inter Ministerial Council") has been established under the Nuclear Emergency Response Headquarters headed by the Prime Minister, which is the de facto decision-making body for all policies related to the decommissioning of the Fukushima Daiichi NPS, including the handling of ALPS treated water. Under the Council is the "Decommissioning and Contaminated Water Countermeasure Team" headed by the Minister of Economy, Trade and Industry, an implementing body at the ministerial level with the participation of 10 relevant ministries and the Nuclear Regulation Authority (NRA).

The Inter Ministerial Council issued the 5th edition of "Mid-and-Long-Term Roadmap towards the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Station" ("Roadmap") in December 2019. The Roadmap is a policy level document which provides the main guiding principles and objectives for decommissioning of the Fukushima Daiichi NPS, taking into account the progress achieved and current situation on the site. To achieve the goals set forth in the Roadmap, NDF and TEPCO have developed following annual plans.

The Ministry of Economy, Trade and Industry (METI) is the ministry in the Government of Japan responsible for the decommissioning of Fukushima Daiichi NPS. Organizationally, NDF is under the Ministry of Economy, Trade and Industry. In addition to compensating for the Fukushima accident and providing funds to TEPCO, NDF's main task is to formulate strategies for the development of decommissioning technologies to address the challenges and issues in its annual "Technical Strategic Plan for Decommissioning of the Fukushima Daiichi Nuclear Power Station of Tokyo Electric Power Company Holdings, Inc." and the latest version was published in October 2020.

NRA is the responsible nuclear regulatory authority, and although organizationally it is an external bureau of the Ministry of the Environment, it is an independent organization that can enact its own regulations equivalent to ministerial ordinances. In order to carry out the decommissioning of Fukushima Daiichi, TEPCO needs to obtain the necessary permissions or approval from the NRA based on the regulatory requirements. NRA also publishes the "Measures for Mid-term Risk Reduction at TEPCO's Fukushima Daiichi NPS" (hereinafter "the Risk Map") which shows the appropriate conditions of the Fukushima Daiichi NPS in approximately 10 years, and indicates the areas and major efforts to reduce risks to achieve the state. The latest version of the Risk Map was issued in March 2021.

In accordance with the provisions of the Nuclear Regulation Act, TEPCO shall submit an implementation plan for the entire decommissioning process as well as an associated risk assessment, facility design and equipment, and security measures to the NRA for approval as necessary. TEPCO shall also report the status, plan and policy related to decommissioning implementation, status of R&D and organizational structure to ensure appropriate and steady

implementation of the decommissioning to the competent Minister through the NDF every fiscal year. Furthermore, TEPCO prepares an annual Mid-and-Long-Term Decommissioning Action Plan which spells out the main work process for the entire decommissioning in order to achieve the objectives set in the Roadmap and the Risk Map of the NRA.

To withdraw the funds from the Reserve Fund for Decommissioning, in which TEPCO is obliged to deposit the amount specified by NDF that is approved by the Minister of Economy, Trade and Industry, TEPCO and NDF are to jointly prepare the Withdrawal Plan and to submit it to the METI for approval every fiscal year. After the approval, TEPCO withdraws the funds from the Reserve Fund, to cover the decommissioning costs in accordance with the Plan.

The Ministry of Education, Culture, Sports, Science and Technology (MEXT) is in charge of academia and basic research, and in the field of nuclear energy, the Japan Atomic Energy Agency (JAEA) is organizationally under the MEXT. For the decommissioning of Fukushima Daiichi, MEXT is conducting basic and fundamental research on decommissioning through JAEA/CLADS, including some collaboration with domestic and overseas universities and research institutes, as well as analysis of radioactive materials.

IRID serves as a centre for the development of technologies to be used directly in decommissioning work, for example, robotics, and is developing such technologies funded by METI in collaboration with many private companies.

NDF runs a coordinating body for decommissioning technology development called the Decommissioning R&D partnership council, which aims at coordinating not only applied technology development related to METI, but also basic research by MEXT and JAEA.

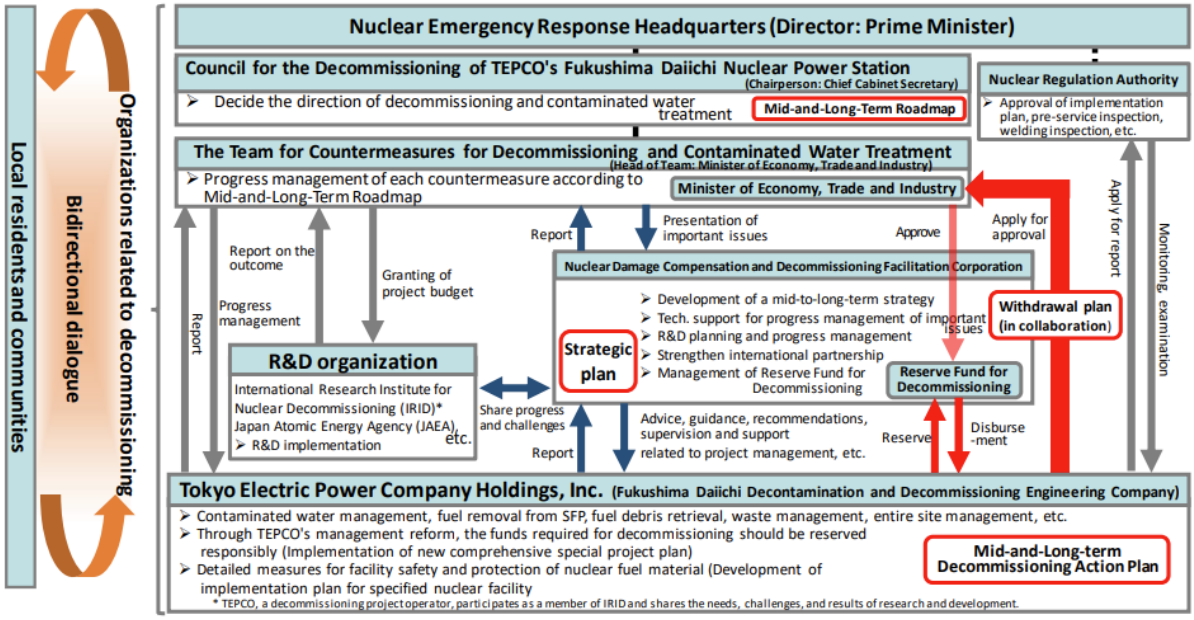

Figure 1. Relations between ministries and other relevant organizations (courtesy of NDF).

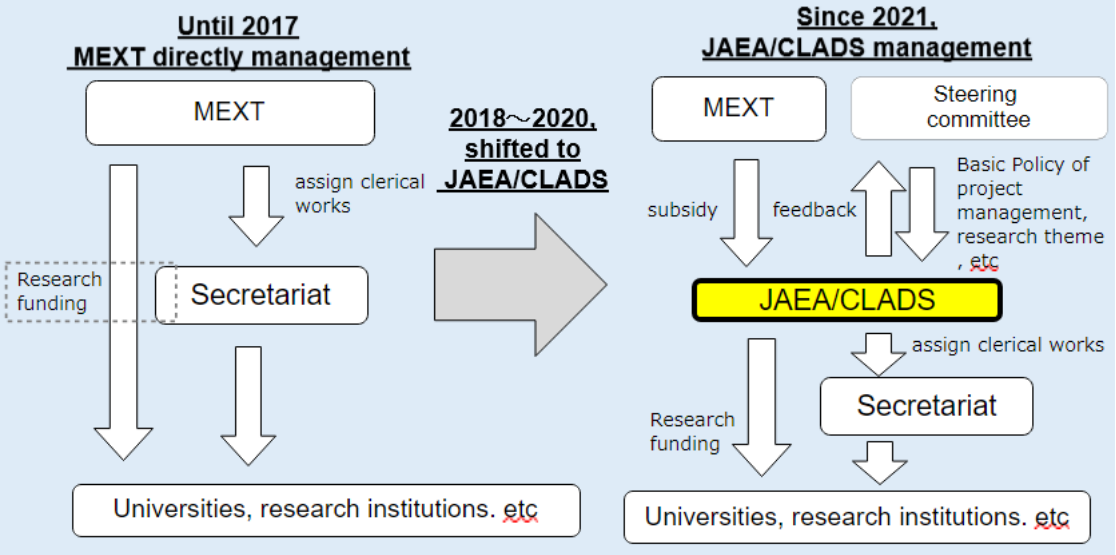

Figure 2. Change in JAEA/CLADS management (courtesy of MEXT).

NRA is exercising its role of independent regulator, and has dispatched resident inspectors on the Fukushima Daiichi NPS. In this respect, NRA has a good technical understanding of the situation and of the constraints of the decommissioning project.

Advisory point 1

As many organizations are involved in the decommissioning of Fukushima Daiichi, the IAEA Review Team advises to ensure close communication between TEPCO and NRA, as well as close coordination among these related organizations, in order to ensure safe and stable implementation of the decommissioning.

3.3.2. FDEC re-organization and new focus

As part of its internal process, FDEC is regularly updating the objectives of the organization, taking into account progress made, challenges encountered or anticipated. It contributes to define or adjust priorities on a regular basis and provides an overall image of the activities to be implemented. Consistent with higher level plans and objectives issued by the Government of Japan, this internal review mechanism addresses technical aspects and include considerations on supporting the reconstruction of Fukushima region.

The aim of the 2020's re-organization of FDEC was to shift the focus from operation and maintenance works, performed previously, to project works such as decommissioning. In addition, to revise to "project execution organization" to be more suitable for project management than a standard power station operation organization could be. The main goals of the FDEC re-organization were (1) to strengthen project management functions; (2) to strengthen safety and quality management functions, and (3) to promote "Genba Genbutsu" (hands-on approach). For that purpose, two new offices were set up to assist in implementing activities and in improving quality and safety: D&D Safety and Quality Office and Project Management Office. Modern standard project management tools have been introduced, such as Primavera P6, making possible an improvement of the efficiency of process management, overall coordination and reporting by managing the process data in a unified system. The project management training has been enhanced as well. Progress has already been made and more progress is expected to come steadily in the coming years.

In addition to above-mentioned, FDEC declared its intention to become a true engineering company. Its management is making steady progress in this direction, setting the goal of enhancing its intelligent customer capabilities, looking for the best partner on a given topic, and progressively taking over some of the design, engineering and procurement tasks. FDEC is aiming at further strengthening its engineering policy, achieving "in-house production" and pursuing "initiatives to take control of currently outsourced operations" through continuous "Kaizen" (improvement) efforts with contractors.

The main part of the FDEC re-organization happened in April 2020, that coincided with the first COVID-19 measures, thus introducing some difficulties in the initial phase. Later, the implementation of the projects continued well, in accordance with the "Mid- and Long-Term Decommissioning Action Plan" (DAP), with a good coordination of contractors' work and contributing to risk reduction initiatives.

In the next 10 years, FDEC is expected to make efforts to achieve goals such as minimizing the quantity of generated contaminated water, completing the fuel removal from the spent fuel pools in Units 1, 2, 5 and 6, dismantling temporary storage facilities for rubbles, etc., so as to reduce risk much further and carry out the decommissioning operations in a safe and sustainable manner. During the following 10 years the focus will also be on preparations for fuel debris retrieval. At the same time, FDEC needs to carefully consider how decommissioning can contribute towards reconstructing Fukushima and towards serving the community in the future. FDEC commits to undertake initiatives for the human resources development and enhancement of skills of the personnel and the contractors, so the decommissioning works can be performed confidently, and can also be transferred to the next generations.

Acknowledgement 4

The IAEA Review Team commends the FDEC for successfully performing its re-organization during challenging times (COVID-19 restrictions) towards more efficient project management-oriented organization, focusing on efficiency, safety and quality of the decommissioning works. In addition, the IAEA Review Team recognizes the ambition of FDEC to become an engineering company with its own design, engineering and procurement capacities.

Advisory point 2

The IAEA Review Team encourages FDEC to continue revising and improving its business processes to adapt them to the changing needs in the future, focusing on further strengthening of design, engineering, procurement and project management functions and on developing human resources in related domains.

3.3.3. Coordination of R&D

A comprehensive multi-agency approach has been implemented and achieved in support of Fukushima Daiichi decommissioning. Multiple organizations are contributing and collaborating to achieve measurable R&D results and advancing the decommissioning mission of Fukushima Daiichi. Under the leadership and funding of METI (Ministry of Economy, Trade and Industry) and MEXT (Ministry of Education, Culture, Sports, Science and Technology), and with some coordination provided by NDF (Nuclear Damage Compensation and Decommissioning Facilitation Corporation), research organization such as, JAEA/CLADS

(Japan Atomic Energy Agency / Collaborative Laboratories for Advanced Decommissioning Science), IRID (International Research Institute for Nuclear Decommissioning), and research centers such as Naraha Center for Remote Control Technology Development, and Okuma Analysis and Research Center, and end user (TEPCO) are producing meaningful R&D results for the Fukushima Daiichi decommissioning efforts.

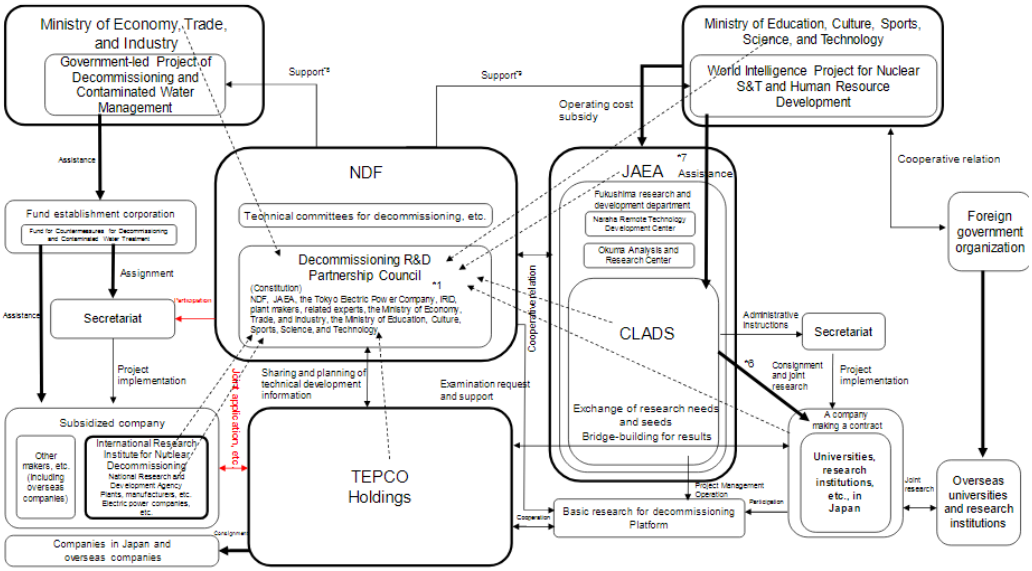

Figure 3. R&D relations to support decommissioning of Fukushima Daiichi (courtesy of NDF).

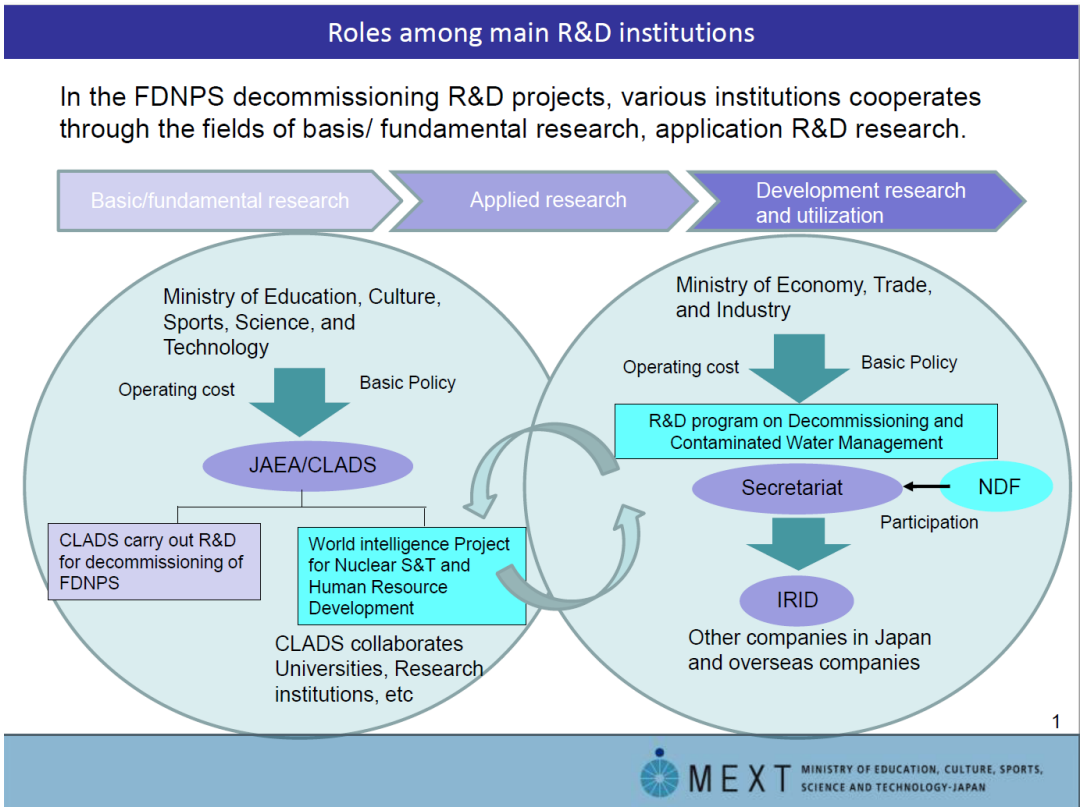

Figure 4. Role among main R&D institutions (courtesy of MEXT).

Some notable cooperation involves NDF, IRID and TEPCO to support the retrieval of fuel debris, and under the supervision of METI, NDF and TEPCO have jointly developed an R&D masterplan 'R&D medium-to-long-term plan' in this and waste management fields. It shows a good level of cooperation from the end user to the equipment and system designer. The handling of the contribution of universities has been streamlined, giving JAEA a direct role of coordination of the R&D supported by the MEXT. NDF is facilitating information exchange between all actors through the Decommissioning R&D Partnership Council.

In addition, to the extensive R&D efforts, MEXT has also recognized and is addressing the human capital and workforce training issues that will be critical in the completion of Fukushima Daiichi decommissioning.

Acknowledgement 5

The IAEA Review Team acknowledges the streamlining of the coordination and collaboration process, such as placing directly under JAEA the relation with universities, the effective cooperation between IRID, TEPCO and the technology developers for robotics aimed at fuel debris operations and spent fuel pool's inspections, and the Decommissioning R&D Partnership Council coordinated by NDF.

Advisory point 3

The IAEA Review Team advises to develop a more structured form of collaboration and cooperation, which would improve the integration of the components of the R&D work performed or led by each organization into a common master plan to ensure timely and effective delivery.

3.3.4. Planning short-term, mid-term, long-term

The Government of Japan issued the 5th edition of the "Mid-and-Long-Term Roadmap towards the Decommissioning of TEPCO's Fukushima Daiichi NPS" in December 2019. That policy level document provides main guiding principles and objectives for decommissioning of the Fukushima Daiichi NPS, taking into account the progress achieved and current situation on the site and includes a clear approach to risk reduction and ensuring safety associated with the implementation of mid and long term measures.

In response to the revision of the "Roadmap", the Nuclear Damage Compensation and Decommissioning Facilitation Corporation (NDF) published its "Technical Strategic Plan 2020 for Decommissioning of the Fukushima Daiichi Nuclear Power Station of Tokyo Electric Power Company Holdings, Inc." in October 2020. That Technical Strategic Plan presents a technical strategy from the mid- and long-term perspective that overviews the overall efforts made by the Fukushima Daiichi NPS in order to steadily carry out decommissioning works in accordance with the new targets.

In March 2020 announced the first "Mid-and-Long-Term Decommissioning Plan 2020", selecting the main work processes to be implemented during the period of 10 years to reach the established milestones of the Mid-and-Long Term Roadmap. The decommissioning work will be based on DAP programmes and projects and they are implemented with a strong emphasis

to project management. As per project management practice, it includes intermediate goals and some scenarios to reach these intermediate goals.

In March 2021 TEPCO issued the update "Mid-and-Long-Term Decommissioning Action Plan 2021". The document describes the progress made in decommissioning works in FY2020, addresses newly identified challenges and provides revised schedule of activities, based on the Fukushima Daiichi decommissioning Roadmap and the NRA issued Risk Map.

Programme managers will review monthly progress of the programme/project operations, they also review schedule and additional changes of DAP based on new information and knowledge obtained as the decommissioning work progresses and update it at the end of fiscal year. FDEC will strategically review the policies for these measures and brush up the DAP.

IAEA Review Team observes that the schedules for the complex decommissioning programme will likely be subject to significant change as a result of the current uncertainties and encourages FDEC to clearly state what assumptions are being made with each revision of the DAP. The "lead and learn" strategy adopted in the areas where there is significant uncertainty is welcomed, but should be complemented with mid- and long-term planning.

FDEC is also preparing mid- and long-term plans for technological development and procurement, which will allow to build processes to allow execution side (programmes / projects) and the supervision / support side (Project Management Office, hereinafter PMO) to efficiently revise the DAP. The strategic and implementation planning is supported by an extensive research and development programme involving numerous Japanese and international organizations. The IAEA Review Team encourages the consideration of a means of understanding how the outcomes of the R&D programme are targeted against the DAP schedule, such that they can be adopted in time, with the requisite time for development from R&D to industrial scale deployment.

The Review Team wishes also to bring to attention another important aspect of future planning and operation: the management of the aging of the infrastructure on the site. Many of the facilities recently built are expected to have several decades of operation. This includes current storage solutions for several streams of waste to be conditioned or treated in the future.

Acknowledgement 6

The IAEA Review Team acknowledges the continued improvement that the Government of Japan, NDF, TEPCO and other organizations have made on revising and developing the strategy for the decommissioning of TEPCO's Fukushima Daiichi NPS. The principles and approach to risk reduction laid out in the Mid-and-Long-Term Roadmap take into account balancing of relevant factors to ensure the best overall approach to decommissioning towards "reducing risks systematically, under the concept of coexistence of reconstruction and decommissioning." The Decommissioning Action Plan issued by TEPCO provides a practical implementation path of the Mid-and-Long-Term Roadmap and of the Technical Strategic Plan issued by NDF.

Advisory point 4

The IAEA Review Team advises to develop planning scenarios for the entire decommissioning programme including all units; it would be advantageous to demonstrate that the planning provides sufficient flexibility and is robust against a range of scenarios. This could be achieved by optioneering against conceptual endpoints, for example, assessing if there will be a sufficient space for the processing and storage of all the material resulting from concurrent activities.

Advisory point 5

The IAEA Review Team recommends that TEPCO ensures that their plans for maintaining the safety and operability of the site infrastructure and assets are aligned with the projects that are delivering progress of the decommissioning plans. Managing an aging site infrastructure will become an increasing task with time and the systems required to keep the site, workforce and environment safe and operational are critical to ensuring the continued progress of the risk reduction activities.

3.4. FOCUS AREAS OF OPERATION

3.4.1. Water management

TEPCO continues the implementation of a comprehensive set of countermeasures to reduce the rate of generation of contaminated water, prevent leakages and uncontrolled discharges into the sea. These measures are based on three policies: (i) removal of contaminated water, (ii) keep groundwater away from contamination sources and (iii) prevention of leakage of contaminated water. The IAEA Review Team notes the success of these measures which have resulted in the reduction of the generation of contaminated water below the target of 150 m^3/day in FY2020 with a goal to further reduce the volume to 100 m^3/day or less within FY2025. The principal measures and the major progress achieved in the management of contaminated water is summarized below.

Changes in contaminated water management (image)

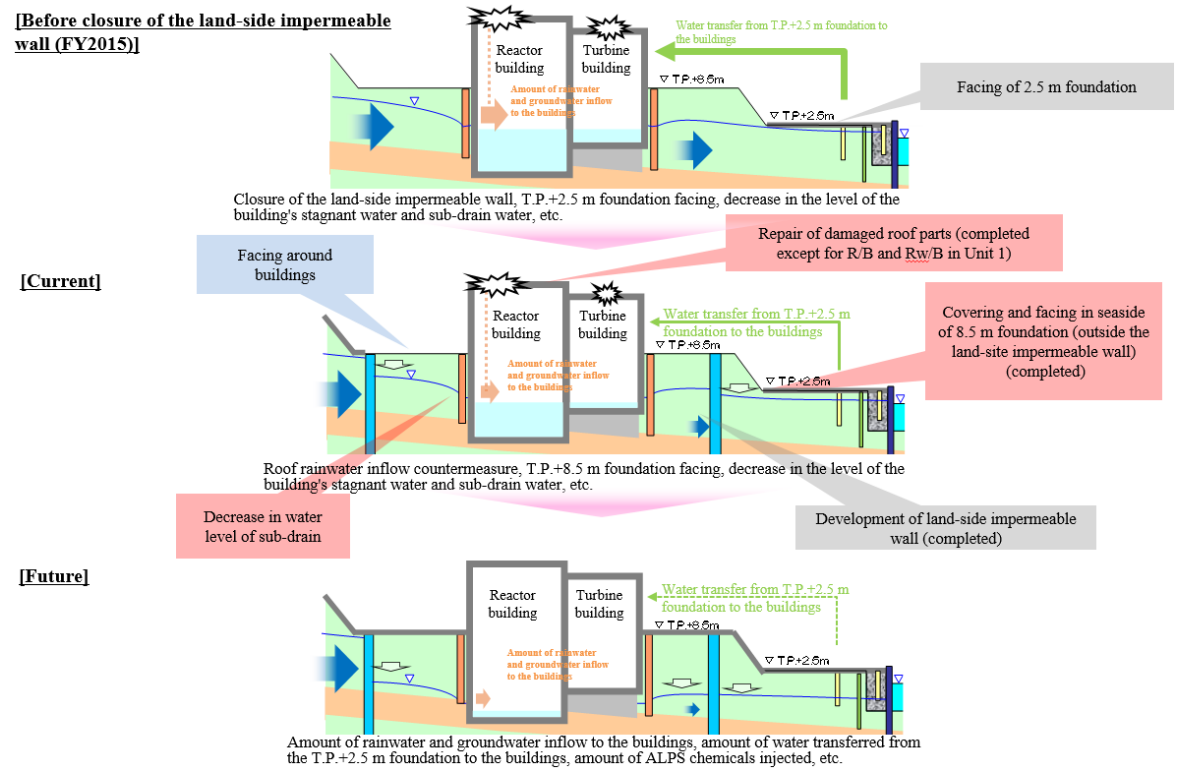

Figure 5. Changes in contaminated waste management (courtesy of TEPCO).

Prevention of rainwater ingress into several of the damaged buildings has been achieved during 2020 by installation of roof covers and repair of damaged portions. TEPCO's goal is to extend these measures to reactor building (R/B) and Radwaste building in Unit 1 by FY2023. As rainfall is considered to be the largest contributor to the groundwater infiltrating the site, TEPCO have covered the site foundations with paving (facing) 1.45 million m^2 (94%) of the site assessed as impactful and are currently working to complete this endeavor. Facing in the area of the seawall is 100% complete while the facing in the area around Units 1-4 is currently 25% complete with a target to achieve 50% area covered during FY2023.

To date a total of 636,000 m^3 of groundwater has been pumped from an extensive system of sub drains. The treatment facility to purify the collected groundwater prior to discharge has been expanded to be able to process 2000 m^3/day. The pumping capacity of the wells has been improved, twelve of the existing wells have been enlarged and four more wells have been put into operation. The IAEA Review Team notes the routine inspection and maintenance to ensure that the sub-drain system continues to operate optimally. The operating water level in the sub-drains has been gradually decreased as a consequence of the decrease in the level of stagnant water in the buildings, which demonstrates the effectiveness of the impact of TEPCO's multiple countermeasure strategy.

The IAEA Review Team notes the continued efforts underway to reduce the volume of stagnant water in buildings on site. Due to the effectiveness of the multi-layered contaminated water strategy, the inflow rate (groundwater and precipitation) into the buildings has decreased from 400 m^3/day, before implementation of countermeasures to approximately 140 m^3/day (FY2020) and a target of 100 m^3/day (FY2025). The IAEA Review Team appreciates TEPCO's efforts to achieve a ten-fold reduction of amount of stagnant water in the buildings (from ~120,000 m^3 in March 2011 to around 12,000 m^3 in March 2021). To prevent egress of contaminated water the level of stagnant water in the buildings continues to be deliberately kept lower than the groundwater. The IAEA Review Team notes the achievements made since 2018 which include the pumping and treatment of stagnant water from Unit 1 to expose the turbine building floor, the separation of the connection between Units 1 & 2 and Units 3 & 4, and completion of treatment of stagnant water inside several buildings. Stagnant water still remains in the reactor buildings of Units 1-3 which is subject to circulating injection cooling. However TEPCO's goal is to further reduce the volume of alpha-nuclide containing stagnant water in the reactor building to half of the FY2020 level by FY2024. Due to the high dose, installation of new pumps to do this will first need the clearance of obstacles (e.g. existing pumps) and this will be accomplished using a flexible structure arm (muscular robot) currently under development and testing.

Stagnant water also remains in the Process Main Building (PMB) and the High Temperature Incinerator building which contain high-dose zeolite sand bags as well as a layer of sludge containing a high concentration of alpha radionuclides. TEPCO's current plan is to remove the stagnant water in such a way as not to overwhelm the upstream treatment system (SARRY) by maintaining a uniform radionuclide feed through mixing. The challenge of removal of these high dose sludges and zeolite sandbags using remote systems is under investigation. A study in 2019 mapped the zeolite sandbag dose rates in the PMB which led to assessment of four potential retrieval options. TEPCO's current plans call retrieval of the solid components and stagnant water treatment operations to commence in FY2023.

The stagnant water is treated using cesium adsorption and a desalination system. This reverse osmosis (RO) treated water from the desalination system is reused for injecting into the reactor building for cooling of the fuel and fuel debris, thereby ensuring no new water is added to the system. TEPCO in recognition that there is a likelihood for an increase in radionuclide release during fuel debris retrieval is planning to augment the filter system of the existing SARRY system to ensure the efficiency of purification system, particularly alpha radionuclides, remains optimal.

As of April 2021, the on-site tank capacity is approximately 1,370,000 m^3. Since 2018 the majority of the old flange type tanks have been emptied and decommissioned by size reduction

and emplaced in containers for on-site storage. Just four flange-type tank units remain in operation as temporary ALPS sample tanks as in order to replace them would necessitate temporarily shutting down the entire ALPS treatment system. The IAEA Review Team concurs that the priority of maintaining continuous ALPS water treatment outweighs the risk posed by maintaining operation of these four flange-type tanks given that TEPCO are actively pursuing reliability improvement measures to maintain them safely.

All ALPS treated water is now (March 2019) stored in welded tanks to minimize the potential for leakage. Additional measure such as construction of dykes surrounding the tanks ensure that any leakage, should it occur, will be contained. TEPCO is currently conducting a seismic assessment for the welded-tanks however mitigation measures are already in place such as not fixing the tanks to their foundations. TEPCO also conduct routine inspections of the tanks to give reassurance of their integrity.

As of November 2020, there is approximately 1.23 million m^3 of ALPS treated water store on the Fukushima NPS, approximately 71% of which will require repurification through the ALPS treatment system to reduce the radioactive contaminants apart from tritium to below regulatory discharge limits. The IAEA Review Team encourages the Government of Japan to follow through with their stated policy of discharge to the sea of the ALPS treated water following purification and appropriate dilution.

The IAEA Review Team also notes that space for accommodating additional storage tanks on site is limited and the continued operation of measures to treat the contaminated water generated on site will be dependent on the successful implementation of the Government of Japan's policy to discharge the ALPS treated water inventory to sea. The IAEA Review Team considers it imperative that TEPCO continue, given the large volume of water, to actively analyse the water balance for the entire period of decommissioning of the Fukushima NPS to ensure that adequate flexibility is retrained to allow uninterrupted operation of water treatment for as long as it is necessary.

During the site visit and subsequent meetings in Tokyo, explanations were provided on the status of preparation for the release of ALPS treated water (space allocation on the site, use of ALPS for further purification when needed, basic concept for sampling and dilution).

Acknowledgement 7

The IAEA Review Team recognises TEPCO's continued efforts to manage existing volumes of contaminated water on site and achieve further reduction in its generation through application of countermeasures. Of note is the successful removal of the stagnant water from the target buildings identified in the Roadmap.

Advisory point 6

The IAEA Review Team encourages TEPCO to perform an analysis of the site water balance considering the large volume of water that has been treated and stored, a significant proportion of which (around 70%) will require further purification. This analysis should also include an estimation of the ALPS treated water, that will be generated in the future and its anticipated schedule for its discharge to the sea.

3.4.2. Fuel removal from spent fuel pools

During 4th peer-review mission it was recognized the difficulties to access spent fuel pools (SFP) in Units 1-3 due to the extensive accident rubbles and contamination, with the special case of Unit 1 with the risk of further collapse of the ceiling crane and the scattering of large amount of dust containing radioactive material.

TEPCO has continuously reviewed the action plan for fuel removal from SFP Units 1-3 and adequate it to ensure safety and workers and environment protection against radiation exposure. As each unit presents unique conditions, TEPCO appropriately considers options for managing risks of spent fuel and fuel debris retrieval.

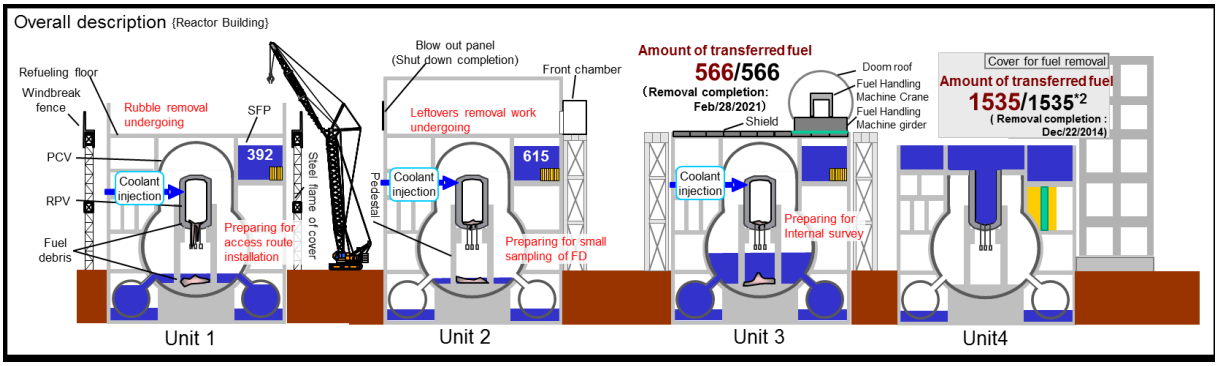

Figure 6. Status of spent fuel and fuel debris in Units 1-4 in July 2021 (courtesy by TEPCO).

Plans for fuel removal in Unit 1 were changed from the previous Review Mission and a large cover will be installed to cover the Reactor Building prior to install the FHM after rubble removal. This presents advantages from the perspective of reliability of dust scattering measures during refueling floor operations and controlling of rainwater inflow into the buildings.

Unit 1 presents the additional challenge to avoid overhead crane on the south side to collapse on the SFP. Measurements such as SFP gate covers and supporting the overhead crane from below were taken (completed in November 2020) to reduce the risk of decrease in water level and potential fall into the SFP of roof steel frames, by small rubble, etc., impacting on the integrity of SFP. Rubble removal on the refueling floor will be formulated from the North side where there is no risk of collapse, followed by the removal of rubble from the center and south side. Prior to the removal of the north side roof steel frame, some of the rubble in the central part will be removed. By removing some of the rubble from the central part in advance, it will be possible to confirm the condition of the roof steel frame in the central part at an early stage and obtain information that will contribute to the planning of safe removal of rubble in the future. Dust scattering will be controlled through vacuuming the roof blocks.

To control the release, radioactive substances scattered during the removal of rubble inside the large cover will be collected by the exhaust filter of the ventilation system, and the air inside the cover will be discharged to the outside. Dust monitoring points will be set up at the inlet and outlet of the ventilation system to measure the concentration of radioactive substances inside the large cover and before being released into the atmosphere. In addition, as a further measure, monitoring will be enhanced by setting dust monitoring points on the outer circumference of the large cover.

Approximately 400 FAs are present in SFP at Unit 1. 100 FAs out of 400 FAs are fresh FAs. Out of approximately 300 spent FAs, 70 FAs were damaged prior to the earthquake (66 FAs

(7x7) and 1 FAs (8x8) with risk of diffusion of pellets from damaged fuel cladding tubes and additional 3 unsound fuel assemblies).

In Unit 2 plans for fuel removal were also revised and changed from the previous Peer Review Mission. To reduce dust scattering and worker exposure, the method of not dismantling the upper part of the reactor building and built a gantry for fuel removal was adopted.

Exhaustive internal investigation of SFP was carried out with the remotely operated unmanned heavy machinery and a small robot to check the presence of any problems that might hinder fuel removal or fuel cooling in the future. As a result of the investigation, although there were some issues, those had been anticipated in advance and did not cause hindrance. With respect to clearing of objects remaining on the refueling floor, which was started on August 23, 2018, was completed on November 25, 2020, including carrying out the 47 containers storing the remaining objects. It was confirmed that there was an overall 20% decrease in the dose rates after comparing with the previous air dose rate measurements by moving and clearing up of objects remaining on the refueling floor (about 10%), natural decay (about 10%, within a span of about 2 years from FY2018⇒FY2020).

615 FAs are present at SFP in Unit 2. The removal of interfering objects (transformer bases, service tunnel, objects lying under the ground) for installation of the gantry is underway.

Unit 3 SFP contained 514 spent fuel assemblies and 52 new fuel assemblies (total 566 assemblies), and all the fuel assemblies have been successfully retrieved by February 28, 2021, starting on April 15, 2019. Small rubble, deposited inside the spent fuel pool due to the explosion of the building, was removed by means of suction, grasping, etc. using a manipulator and other tools. Fuel removal was started with low-risk fuel first, considering the level of difficulty in fuel removal (fresh fuel, spent fuel and fuel that was deformed due to collision with rubble and spent fuel that was damaged before the accident). All operations had to be conducted remotely, and operators were trained accordingly to perform operation safely and effectively through camera vision.

18 FAs with handle deformities (10 FA moderated and 8 FA deformed) were removed. A few fuel assemblies could not be pulled out due to rubble that had entered the gaps. Multiple methods were developed to eliminate rubble interferences between fuel rack and fuel assemblies (e.g. device causing vibrations in fuel rack and fuel rack cutting device). As a result, changing the state of the rubbles between the fuel rack and the fuel assembly made it possible to retrieve the fuels (with a chisel tool). Spent fuel was transported to the common pool at the site using on-site transportation casks. Knowledge gained from fuel removal in Unit 3 was incorporated into a manual for fuel removal activities in Units 1 and 2.

Acknowledgement 8

The IAEA Review Team recognizes the effort in training operators for remote operation in Unit 3 using only camera view and implementing a step-by-step approach , adjusting the training by incorporating lessons learned to enhance effectiveness. The Review Team appreciates the graded approach to start the actual operations from low risk to high level of difficulty in fuel removal (fresh fuel, spent fuel and damaged fuel before the accident), and the incorporation of operational experience and lessons learned, gained during Unit 3 removal activities, in ~~a~~an manual to be used for the subsequent spent fuel removal activities in Units 1 and 2.

Acknowledgement 9

The IAEA Review Team recognizes the efforts in enabling defueling of spent fuel pools at Units 1 and 2, implementing a step-by-step approach for rubble removal and dose rate reduction. The Review Team appreciates efforts in preventing dust release and in identifying approaches for damaged fuel removal and dose reduction at the refueling floor (Unit 2).

Advisory point 7

The IAEA Review Team advises to continue exploring technologies and approaches to remove difficult to handle damaged fuel.

Advisory point 8

The IAEA Review Team encourages to continue the successful approach for enhancing knowledge retention and transfer of operational experience and lessons learned gained in Unit 3 for the safe remote operation in Unit 2.

3.4.3. Fuel debris retrieval

During 4th Peer Review mission the significant R&D effort on fuel debris was recognized and actions taken for sharing experiences and knowledge gained on fuel debris retrieval and management worldwide through international organizations were appreciated.

Fuel debris retrieval is a very complex and unique task. Although considerable efforts have been applied to more precisely understand fuel debris distribution and the situation inside each unit to design safe fuel debris retrieval strategies, there is still an enormous amount of work ahead during the sampling, characterization, and scale up/ramp up phases.

Test for coolant injection shutdown in Units 1-3 were conducted in 2019 and 2020 for optimization of emergency response procedures and revision of the Implementation Plan. During coolant injection shutdown, no major increase in temperature as well as no impact on dust concentration, noble gas concentration, etc. were observed in the three Units (1-3). Additional coolant injection shutdown tests are planned with extended shutdown time.

Fuel debris retrieval is expected to start in Unit 2, commencing with fuel debris retrieval trial to gain experience before expanding the scale of retrieval in stages. A series of operations will be carried out in a "step-by-step" manner, starting with trial retrieval of fuel debris, subsequently verifying/confirming the methods based on the results of trial retrieval and then expanding the scale of fuel debris retrieval in stages.

To proceed with fuel debris retrieval, it is important to understand the distribution of fuel debris and grasp the situation of existing structures. Trial retrieval of fuel debris refers to retrieving small amounts of fuel debris using the investigation equipment used for internal investigation of PCV. To access the fuel debris and to retrieve powder-like fuel debris is plan with a robot arm from inside Unit 2 PCV, using a metal brush or vacuum container type collection device.

The retrieved fuel debris will be transported to an off-site analysis facility where it will undergo characterization. Trial retrieval is important for fuel debris characterization and will contribute as well towards enhancement of safety in future operations of fuel debris retrieval by verifying and confirming developed devices.

After checking and confirming the methods based on the results of trial retrieval, the scale of fuel debris retrieval will be expanded in stages and a series of operations will continue to be performed from placing the debris into containers, transporting them, and then storing them under stable conditions. The scale of retrieval will be increased gradually in a step-by-step manner. The retrieved fuel debris will be stored safely under dry conditions within the Fukushima Daiichi premises. Necessary information and experience will be acquired for further expanding the scale of fuel debris retrieval while limiting the risks by controlling the volume of fuel debris to be handled.

Acknowledgement 10
The IAEA Review Team recognizes that significant R&D efforts have been accomplished to access PCV internals including the design, development, prototype and delivery of a "one of a kind robotic arm" for the trial fuel debris retrieval.

Acknowledgement 11
The IAEA Review Team recognizes the graded approach for starting fuel debris retrieval, gaining experience with trial and knowledge of fuel debris properties through characterization of small samples and development of a full-scale mock-up facility.

Advisory point 9
The IAEA Review Team advises, taking into consideration the complexity of fuel debris retrieval, to develop a strategy for the subsequent management of the interfering objects in PCV (Unit 1) that can be potentially highly radioactive.

Advisory point 10
While the IAEA Review Team commends the current focus of attention on fuel debris, the Team stresses the importance of undertaking a comprehensive characterization of the fuel debris to identify the key parameters that will enable the design of future strategies to manage this material from initial storage through to disposition, with an emphasis on the potential treatment and conditioning stages.

Advisory point 11
The IAEA Review Team considers that whilst significant progress has been achieved in estimation of the fuel debris distribution inside the reactor building of Units 1-3, there is recognition of the future challenges that will be encountered during the sampling, characterization, and scale up/ramp up phases. The IAEA Review Team advises TEPCO to develop a comprehensive feasibility and risk analysis of the retrieval options of fuel debris. With more information being gathered and experience gained in the coming years, the Review Team advises to steadily progress with an analysis of the potential options toward the end state of the site and their impacts on the full site management strategy.

3.4.4. Waste management

The Roadmap stipulates that the amount of solid waste generated by decommissioning is reduced as much as possible in order to ease the burden on solid waste management operations. The IAEA Review Team acknowledges this principle and the efforts made to understand and quantify the existing waste inventory and progress made to date with construction of new storage facilities and addition of volume reduction technologies such as incineration, metal

cutting and concrete crushing. TEPCO are also considering augmenting these technologies with additional capabilities such as metal melting, which will not only make a substantive contribution to their waste volume reduction goals but also facilitate the possibility of new recycle and reuse opportunities. The Roadmap states that through the implementation of waste hierarchy principles, efforts should be made to avoid creating new waste streams through judicious introduction of new material to the Fukushima NPS that may become contaminated and to further reduce the volume of existing waste through utilization of recycle and reuse opportunities wherever possible. The IAEA Review Team supports this approach and considers such actions important as both on-site storage capacity and processing capabilities are a finite and valuable asset that are key to enabling the efficient decommissioning of the Fukushima NPS.

TEPCO have estimated the amount and type of solid waste that will be generated and require processing over the coming ten years (through 2032) and documented this in the regularly updated Solid Waste Storage Management Plan. As described in the Roadmap, both the large volume and diversity of the radionuclides associated with the waste will pose challenges for characterization, processing and storage both in terms of technologies deployed, their associated throughput capacity and the interdependencies between all the management stages.

Understanding the characteristics of the waste will also play a key role in the planning for suitable disposal facilities. The IAEA Review Team notes the challenges of characterization and traceability of the waste generated in the immediate aftermath of the accident. A large number of packages of these "initial waste", while stored safely, require further characterization. Looking forward, the IAEA Review Team encourages TEPCO to extend the forecast of waste arising as well as its broad characteristics, through to the end of decommissioning operations accepting that the fidelity of the estimates will decrease post-2032 but will, nevertheless, provide important data to inform the overall site decision making and waste management strategy. It is important that the estimate of waste arisings should not only include the waste coming directly from the dismantling operations themselves but also new secondary waste streams that will be generated, for example during the fuel debris retrieval operations, as well as decommissioning of the infrastructure associated with the treatment, conditioning and temporary storage facilities. The IAEA Review Team believes that a complete understanding of all waste to be generated will aid in the identification of the decision points related to the need and timing of additional or new processing technologies, adequately sized storage capacities and potential disposal concepts. In addition, it will allow a holistic perspective that may lead to operational efficiencies and overall reduction of waste in the long-term. The IAEA Review Team acknowledges the important integration role that NDF will play in ensuring that the plans for the characterization, processing and storage of solid waste at Fukushima NPS and its ultimate disposal are in line with the national waste management policy and strategy.

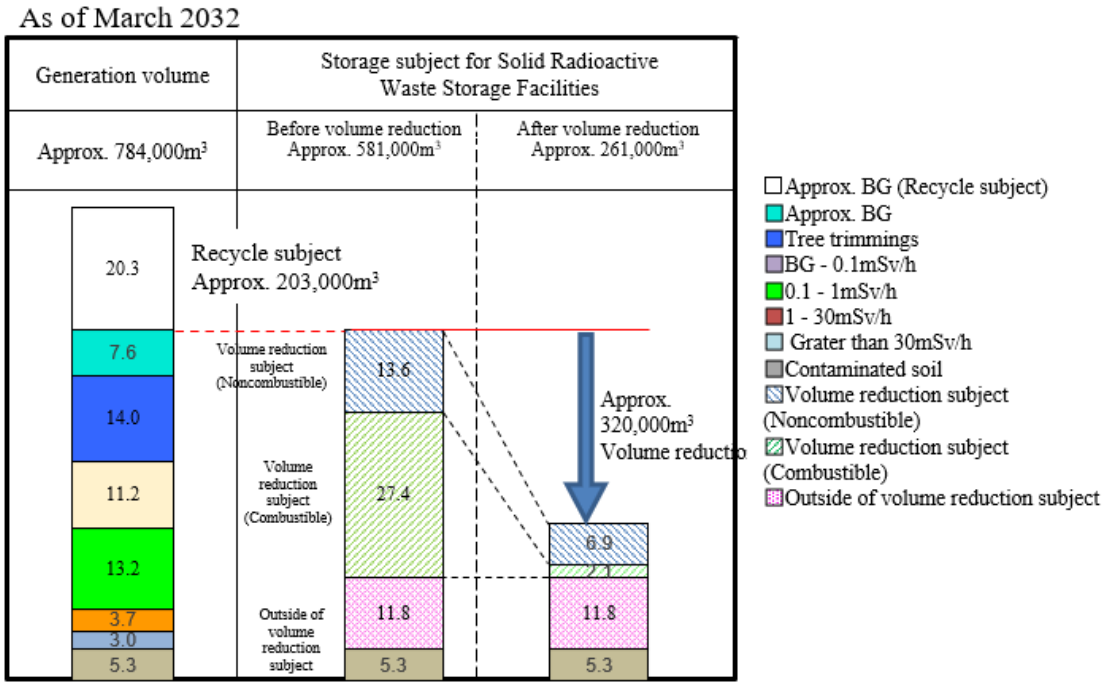

Figure 7. Forecast of volume of waste generated at Fukushima NPS through 2032 (courtesy of TEPCO).

The IAEA Review Team notes the FY2028 Roadmap milestone to eliminate temporary storage areas outside for rubble and other waste and appreciates TEPCO's plans to collect, size reduce and repackage for indoor storage rubble type waste and incinerate combustible type waste such as the felled trees.

The IAEA Review Team appreciates the recent progress made by TEPCO in addressing the high activity secondary waste generated from the treatment of contaminated water. The approach described by TEPCO for the stabilization of the ALPS slurry currently stored in HICs is thorough and accompanied by a detailed understanding of the characterizations of the material to be treated, and supported by a research programme and mock up demonstrations. The IAEA Review Team notes that there is a large body of international experience related to the management of highly contaminated sludges and slurries and encourages TEPCO and JAEA to continue their international collaborative efforts to leverage and learn from this experience.

Since the 4th Review in 2018, TEPCO have also made substantive progress in addressing the high activity secondary waste arising from operation of water treatment facilities in the immediate aftermath of the accident and stored in tank D within the PMB. Although relatively small in volume (~37 m^3), this is nevertheless a challenging, high dose waste consisting of both a liquid and sludge fraction in a difficult to access area. The IAEA Review Team noted TEPCO's comprehensive and systematic approach to the design of a retrieval and treatment concept that combines remote operations using manipulators with centrifuge technology to dehydrate the sludge and placement in a specially designed storage container that accommodates gas venting and liquid drainage thereby mitigating two of main risks associated with storage of highly active sludge type material.

Acknowledgement 12
The IAEA Review Team welcomes the progress made by TEPCO in developing technical approaches for the management of the secondary waste arising from the treatment of contaminated water.

Acknowledgement 13
The IAEA Review Team appreciates TEPCO's progress made in identifying the existing waste streams as well as their appropriate disposition paths. This effort has informed the design and technology development efforts.

Advisory point 12
While the IAEA Review Team appreciates the plans TEPCO have developed for management of waste and potentially contaminated material generated through 2032, TEPCO is encouraged to extend these efforts to include all waste generated during the lifetime of decommissioning operations and an understanding of the anticipated end-point for each stream.

Advisory point 13
Given that decommissioning operations will generate a large volume of waste and potentially contaminated material requiring storage, TEPCO is encouraged to identify additional storage locations for material awaiting further processing and further strengthen traceability and characterization of the waste packages. In addition, the IAEA Review Team emphasizes the need to actively explore implementation of all opportunities afforded by implementation of the waste hierarchy and the circular economy principles to not only minimize the volume of waste that is generated during decommissioning operations but also to reduce the volume of waste consigned to disposal.

3.4.5. Site management

The site management for Fukushima Daiichi NPS covers overarching efforts, including among others preparing the site in response to latest findings on associated earthquake ground motion and tsunami, security enhancement of the site, and optimizing the use of site. These works are under the first principle laid down by the Roadmap (revised in December 27, 2019) in order to reduce the risk systematically, within the concept of "coexistence of reconstruction and decommissioning." Hence, site conditions should be managed for good working environment.

As the first practice of site management, TEPCO has completed their efforts in anticipating design basis and maximum reference earthquakes, including the examination of structural soundness of each building and the use of portable equipments and performing drill and exercise to use these equipments. TEPCO has also completed construction of seawalls anticipating Outer-rise and Kuril trench tsunamis, and is in the progress to construct additional seawalls (13-16 m high) assuming the tsunami based on "a model of a huge earthquake along the Japan Trench and the Kuril Islands Trench", which the Cabinet Office (a national advisory body) published on 21 April 2020. The Cabinet Office (a national advisory body) has also assessed the tsunami as highly imminent. TEPCO has relocated and fix the Mega Float that may create significant damage in case of tsunami. Furthermore, TEPCO is in the progress of sealing all openings of each buildings and treatment and relocation to the hill of stagnant water in buildings, and is considering relocation to the hill of sludge from decontamination device.

TEPCO has also remotely dismantled upper part of exhaust stack common for Units 1 & 2, which was posing a risk in case of earthquake.

The second practice of site management is regarding the utilization of the site space. In the North part of the facility, TEPCO has develop a layout and is in progress of constructing new buildings for miscellaneous solid waste incinerator, incinerator pretreatment facility, volume reduction facility, additional solid radioactive waste storage facilities, and large waste storage facility. Adjacent to this area, TEPCO has remotely dismantled upper part of exhaust stack common for Units 1 & 2. The existing bottom part of the stack and the wastes generated from the dismantling need some space as well. In the South part, the spaces are mostly used for contaminated water treatment and storage. TEPCO is also in the progress of retrieving fuel debris, which in the near future requires some spaces to store these fuel debris wastes.

The next practice of site management is concerning the arrangement of workers area. As part of safety management, TEPCO has enhanced the security system in the site with renovation of the administrative building completed with physical protection checkpoints, contamination inspection checkpoints, and protection area parking space. In addition, TEPCO also established a new surrounding area physical protection fence and the vehicle gate, and also some temporary changing places. TEPCO is giving consideration to save unnecessary time to access this area.

Other practice of site management is dealing with flood prevention. TEPCO is currently constructing a new drainage channel D, in addition to the existing channels, to reduce the risk of flooding and increased contaminated water around the Unit 1 to 4 buildings area due to rainstorm. Drainage channel D is planned to collect rainwater drainage from the area on the west side of the Fukushima Daiichi NPS. Hence, the concentration of radioactive materials in the drainage channel D is assumed to be very low. Moreover, TEPCO performs periodic radioactive concentration measurements at the end of the drainage channels, inside the Open channel for water intake of Unit 1 to 4, and inside and outside the harbor.

Acknowledgement 14
The IAEA Review Team acknowledges TEPCO for the measures against design basis and maximum reference earthquakes and against Outer-rise and Kuril trench tsunamis. The IAEA Review Team is also in the view that the construction of additional seawalls, which are in progress, is a good decision in anticipating the most extreme tsunami scenario from Kuril and Japan Trench.

Acknowledgement 15
The IAEA Review Team commends TEPCO for the progress in constructing a new drainage channel D to reduce the risk of flooding and also for monitoring radioactive concentration in the body of water around the Fukushima Daiichi NPS.

Acknowledgement 16
The IAEA Review Team recognizes TEPCO's efforts towards the organization of the site, to improve facilities for the workforce, such as canteen and checkpoints, while considering productivity but ensuring safety and security measures.

Advisory point 14

The IAEA Review Team encourages TEPCO to further develop the site management in order to optimize the utilization of the site space and workforce logistics while keeping the effort to reduce the risk systematically until completion of the decommissioning.

3.5. FUNCTIONS SUPPORTING THE SAFE AND EFFECTIVE DELIVERY OF THE DECOMMISSIONING PROGRAMME

3.5.1. Project management

The project management capability and structure within FDEC continues to develop and mature. A significant organizational change was made in April 2020 with the aim of strengthening the project management functions; creating a Project Management Office (PMO) and Decommissioning Safety and Quality Office. The PMO takes oversight of the totality of the decommissioning works and budget execution and reports it to the Program Supervision and Support Office (PSO) working directly under the NDF President, and in turn receives guidance from the PSO. This re-organization defined the responsibilities and authorities of programme managers and project managers and shifted the company to a system that enables smooth execution of projects by specifying the chain of command, enhancing communication and ensuring timely coordination. FDEC started progress review meetings to share the progress, issues, risks, budgetary impact, etc. of each project with the top management at an early stage, risk monitoring meetings and trial operations of change management. In addition, they are establishing the use of Primavera P6, introduced for the purpose of improving the efficiency of schedule management, coordination and reporting, by managing the schedule data of all projects with a unified system.

Since many unprecedented activities have to be undertaken in a post-accident environment, the fluctuation range of schedule and costs will be controlled in combination with risk management and change management tools. For the "schedule", the project sets more specific goals (baseline schedule) and margins on the premise of observing the goals promised to the society (external milestones). With respect to the baseline schedule, the aim is to keep the actual results within "+10%" and manage possible risks to schedule accordingly become apparent. For "costs", the aim is to keep the actual results within "±10%" of the numerical plan, and manage possible risks to budget accordingly. The IAEA Review Team observes that more significant variability than this has been experienced on unique decommissioning projects and FDEC should continue its focus on risk management and to communicate the risks and uncertainties associated with their complex programme and projects.

Each project identifies various risks (nuclear safety, project, work safety) that would greatly affect the cost, schedule, safety, etc., as a risk matrix, and decides on the response policy. In order to achieve the project goals, FDEC will not only build the mechanism of risk matrix, but will also increase each individual's sensitivity to risk identification, and improve the understanding of the everchanging site, understand the social situation, and continuously enhance technological capabilities. In addition, feedback will be accumulated on whether or not the response policy as identified in the risk matrix was appropriate and that will be reflected it in the next-generation projects. FDEC will regularly monitor the risk reduction status in order to reduce the probability of occurrence and the extent of impact of events that may have a negative impact on the progress of the project.

Since each project is an activity with uncertainty, changes in schedule, cost, and safety occur due to new knowledge, changes in site conditions, or external factors. When a change occurs, each project will apply a series of change management processes in which the appropriate approver approves the change at an appropriate time and informs the relevant departments in a timely manner based on appropriate criteria, thereby maintaining the integrity of the project.

Management constantly assesses the risk monitoring results and the progress of decommissioning work, and allocates management resources (people, goods, money, time, and site) to optimize schedules, costs, and quality, while reducing risks, thereby making risk management effective. All risks need to attain an acceptable level. Company risk management meetings, which include PMO, D&D Safety and Quality Office and D&D Communication Centre, have been introduced to prioritize risks. After reviewing the priorities pertaining for the reduction of nuclear risk at the project risks, operation and maintenance risks, nuclear safety, work safety, radiation, environmental risks, and reputation risk, step-by-step decisions are made whereby the management directs the operations for a programme and the PGM directs the operations for each project.

FDEC has adopted a stage gate approach for managing the programmes and projects, including plans, processes, cost and risks, as part of its drive to strengthen the project management function.

Contents of each stage and the judgment of the gate

	Start-up		Planning			Implementation and management	Knowledge creation
	Gate 1	**Gate 2**	**Gate 3**	**Gate 4**	**Gate 5**	**Gate 6**	**Gate 7**
Stage Description	PG Mmission	Planning for PG	Planning for PJ	How to proceed with PJ	Establishment of baseline	Monitoring & Correction	Completion approval
Gate Decision Items	・Are the missions of each PG consistent with the medium-to long-term Road Maps?	・Definition of PJ missions and expected outcomes for each PG	・Expected outcome of each PJ	・Policy for achieving the PJ ・Order scope ・Contract Method ・Prospective vendor ・Outcome verification methods	・Baseline	・Report of deviations from baseline	・Verification of outcomes ・Succession to the next process ・Identify improvement points

Figure 8. Introduction to Stage Gate method (courtesy of TEPCO).

In addition, the risks at the execution stage are reviewed regularly and management directs corrections as necessary. In this way, decisions are made after accurately identifying risks.

FDEC will continue to develop risk management methods, such as setting a scale for the extent of impact, and improve risk management by turning experience into systematized knowledge. There is awareness that further refining of the project management and of the procedures in place is needed, especially in the part of enhancing safety and quality. More time and efforts will be required until the full effects of organizational restructuring are obvious. Strengthening of TEPCO's project management functions is in place and their methodologies and tools should be further matured, particularly managing uncertainties and interdependencies.

Allocation of responsibilities and clear structure of authorities have been established for the effective project management when determining the priorities and delivery of decommissioning programme. This will need to be supported by further development of professionals in the project management to address requirements of the overall decommissioning programme.

Acknowledgement 17
The IAEA Review Team acknowledges the continued evolution and improvement in the project management and learning from other international programmes and internationally recognised practices in project management. This can be seen in changes made in FY2020. This includes the adoption of a stage gate process for decision making.

Advisory point 15
The IAEA Review Team advises TEPCO to continue to mature their project management methodologies, particularly managing uncertainties and interdependencies, and continuing to ensure that responsibilities and authorities are clear when determining the priorities and delivering programme at the Fukushima Daiichi site.

Advisory point 16
The IAEA Review Team encourages TEPCO to develop professionals in project management, to support the human resources requirements for the duration of the mid- and long-term plan.

3.5.2. Safety and occupational radiation protection

The first principle stated in the Roadmap (revised in December 27, 2019) regarding systematic risk reduction has been implemented by TEPCO both in organizational and technical level. In organizational level, TEPCO has established D&D Safety Quality Office directly under the CDO, out of the framework of Head Office and NPS, with the main tasks on planning, formulating and monitoring the measures to strengthen safety and quality of the entire FDEC, including promoting safety behaviour.

In technical level, TEPCO has developed and implemented many innovative technologies such as robotics, remotely controlled technology for dismantling the upper part of the contaminated exhaust stack, remote system and sensing technology, and 3D remote radiation imaging and modelling system. These efforts are also in response to the previous mission report on the issue of optimization.

TEPCO has also managed work, utilizing a real-time individual radiation monitoring system, which remotely monitors the external exposure during tasks and has the features of alarm level setting based on planned dose. Furthermore, TEPCO has initiated a system to perform dose monitoring for lens of the eyes of workers.

Besides TEPCO, in coordination with other Japanese organization, is doing its best to collect through the decommissioning work data and information which can help understanding the progression of the accident and the assessment of emergency measures taken at that time. This information is analysed and could be useful for currently operating similar plants as well as for the design of new nuclear power plants. TEPCO is designing a plan to identify useful data and collect them as far as reasonably possible.

Acknowledgement 18
The IAEA Review Team acknowledges TEPCO for the strengthening of safety and occupational radiation protection since the last IAEA Review mission. Preliminary investigations of fuel debris and on-site decommissioning operations were completed with proper safety and occupational exposure control.

Acknowledgement 19
The IAEA Review Team recognizes TEPCO for the establishment of the D&D Safety and Quality Office in a higher management position in FDEC, which contributes to enhance both independency and effectiveness of internal inspection for safety and quality, and to promote safety behaviour as well. The operation of this new office also confirms commitment for safety leadership and culture.

Acknowledgement 20
The IAEA Review Team commends TEPCO for the implementation of dose constraints and optimization measures, for both external and internal occupational exposures, applying innovative technologies such as robotics, remote dismantling system and other remote system and sensing technology, and 3D remote radiation imaging and modelling system. The IAEA Review Team also recognizes TEPCO for the enhancement of occupational exposure monitoring programme implementing a real-time individual monitoring system that records the occupational exposure for each task and has the features of communication and alarm level setting. The monitoring programme also includes the dose to the lens of the eye monitoring initiative.

Advisory point 17
The IAEA Review Team encourages TEPCO and JAEA/CLADS to further develop the 3D remote radiation imaging system and 3D plant model system to become tools for radiation risk projection during planning of decommissioning operations.

Advisory point 18
The IAEA Review Team encourages TEPCO to further develop the real-time individual monitoring system and make the database a mean for experience feedback and optimization analysis for different tasks in decommissioning.

3.5.3. R&D and technology development

Significant R&D and technology development efforts has been accomplished as part of Fukushima Daiichi decommissioning, as described in sub-chapter 3.3.3. Examples of some of the technologies that have been developed include the design, development, prototyping and delivery of a "one of a kind robotic arm" for fuel debris retrieval sampling and characterization, the development and field deployment of a remote system for the successful dismantling and removal of the Upper Part of Units 1&2 Exhaust Stack, the development of remote systems (submersible and standard crawling robots) for the investigation of outside the pedestal (Unit 1), investigation of inside the pedestal (Unit 2), and investigation of inside the pedestal (Unit 3), the development of six (6) ROVs which can move on a wide range of the water surface in the primary containment vessel (PCV). These ROVs were developed and deployed for a variety of applications including the visual inspections, deposit three-dimensional shape measurements, deposit thickness, Neutron flux measurement, and small amount of deposit sampling/retrieval. Important steps have also been taken in the development of a full scale mock-up facilities at nearby research centers. These mock-up facilities will provide important information on the functional test of the one-of-a-kind technologies, as well as facilitate the training of the workforce; therefore, increasing safety and reducing risk.

Other advanced technologies have been introduced, such as augmented reality. The concept of "smart glass" which adds virtual information visible through these glasses to the bottle of samples taken for analysis has significantly improved productivity and quality.

Looking to the future, new technologies will have to be developed in order to meet the future challenges that will be encountered during the complex decommissioning process of Fukushima Daiichi and brought to routine operation scale. Key organizations and the end user (TEPCO) should engage early on in the R&D process to address any risk and safety issues with "one of a kind" technology development and deployment and identify a clear path identified for the smooth transition of new prototype technologies to routine operation at scale. This will be ranging from the testing and evaluation stages to system development and integration of the technology in the working environment so that the fully developed technologies be ready for ramp up and full-scale operations. Finally, Japan should also continue partnering with international organizations to identify technologies that can be applied to the decommissioning of Fukushima Daiichi.

Acknowledgement 21
The IAEA Review Team recognizes the achievements in the area of R&D (basic, fundamental) and technology development in the areas of spent fuels, fuel debris, radiation measurement / 3D imaging, remote characterization technologies, processing and disposal of radioactive waste, materials in nuclear reactor, decontamination and characterization of reactor buildings.

Acknowledgement 22
The IAEA Review Team also recognizes the efforts in the development of full scale mock-up facilities to support the proof of concept, functional testing and deployment of one-of-a-kind technologies. The mock-up will also facilitate the training and skill set development of the workforce.

Advisory point 19
The IAEA Review Team advises that consideration be given to include the newly established D&D Safety and Quality Office in the R&D process. This office should engage early on in the R&D process to address any risk and safety issues with new technologies. In addition, active participation and contribution of the end users (TEPCO operators) with R&D organizations should be encouraged and maintained during the entire R&D process.

Advisory point 20
The IAEA Review Team encourages the end user (TEPCO) to develop a strategy for the smooth transition of "one of a kind" prototype technologies ranging from the testing and evaluation stages to the fully developed technologies ready for ramp up and full-scale operations, considering challenges, safety and schedule impact.

3.5.4. Knowledge management

Since the last review Mission report, TEPCO has put in place a formal knowledge management (KM) strategy as part of human resource development mentioned in the Roadmap (revised in December 27, 2019), even if the Roadmap does not explicitly point out KM. The KM process starts by identifying, integrating and organizing experience obtained during decommissioning project execution at Fukushima Daiichi. Currently the knowledge is collected and organized

using a list/one-sheet per case format. The knowledge obtained is organized and registered in a dedicated central database. The knowledge is subsequently disseminated among the various TEPCO organizations (Design Management Division, Procurement Division, Fuel Management Division, Human Resources Development Division, etc.) through core technology courses, and work operation guides. A draft concept on future functionally of the KM platform will include major categories (QMS) and medium categories (knowledge type) to facilitate the logical classification of the information and searchability of the database. Currently the KM system is internal to TEPCO and only accessible to Fukushima Daiichi organizations and workers.

Aware of the need to manage information under completion of the decommissioning, TEPCO has developed a systematic information management system which is collecting and storing all necessary design, construction and operation data.

Acknowledgement 23

The IAEA Review Team acknowledges the establishment of a formal knowledge management information platform to identify, accumulate and disseminate lessons learned to internal stakeholders at Fukushima Daiichi NPS. This collection of knowledge should be useful in the future for carrying out the same or similar activities or processes.

Advisory point 21

The IAEA Review Team encourages TEPCO to further develop the Knowledge Management platform to accommodate practical knowledge on decommissioning, including those gained from technical investigation and radiation protection internal practice and lessons learned from international experiences, where available, that might be useful in future planning and implementation of decommissioning activities or processes.

3.6. EXTERNAL RELATIONS FOR COOPERATION / COLLABORATION AND INFORMATION SHARING

3.6.2. Supply chain and localization

TEPCO, METI and the local governments organizations are pro-actively engaging with the local industries, in line with the policy of "coexistence of decommissioning and reconstruction". The re-organization of FDEC and its objectives to move towards an EPC role gives TEPCO more opportunities to develop a local supply chain. Local companies and local people are already well represented in support functions which do not require a "nuclear grade" qualification, and in civil engineering work which is not specific to nuclear facilities such as the construction of the sea walls to protect from tsunami. TEPCO, in cooperation with local governments and industrial organizations is actively engaging local companies: regular presentations are made on needs of the decommissioning projects, and are attracting interest. In addition, policies are put in place to support local companies to develop additional skills to be able to become a supplier. A success example is the role of prime contractor that a local company was awarded to develop and operate the robotic system used to dismantle remotely the upper half of the stack on the site. However, there is yet not many such examples. In order to foster capacity building, TEPCO is teaming up with well-established nuclear suppliers to create joint ventures to manufacture locally some equipment needed for the decommissioning project. In addition to direct local employment opportunities in these JVs, it is expected that local companies can become suppliers or partners of these JVs and progressively go up the

value chain. The policies also take into account that such local companies must not become over-dependent of the Fukushima decommissioning project, and are considering extending support for them to develop and diversify more widely, leveraging their newly acquired skills. In addition, technologies for decommissioning have been included in the "Fukushima Innovation Coast Framework" designed to stimulate innovation and new technologies development in the region.

Acknowledgment 24

The IAEA Review Team acknowledges the programme developed by TEPCO to engage with local companies and to support the development of a local supply chain. The Review Team appreciates the proactive engagement shown by TEPCO along with local governments organizations and the pragmatic way to develop an approach taking into account the actual current industrial status of the local region. In particular, the IAEA Review Team believes it is important that TEPCO and local governments organizations continue to work with local supply chain to identify specialized areas and expertise that allow the local supply chain to develop their capability, diversification, and sustainability.

3.6.3. International cooperation and dissemination of knowledge

The Japanese organizations involved in planning, research and technology development for the decommissioning are well aware that they can benefit from solutions and knowledge outside of Japan. There are some good examples of initiating collaboration and placing orders abroad, one of them being the robotic arm developed in UK and adapted to collect the first samples of fuel debris.

There is also a commitment to disseminate lessons learned and knowledge acquired with several successful examples.

It is important to keep and further strengthen this international engagement. The re-organization of FDEC and its positioning on strengthening its EPC role offers an opportunity to actively identify resources and experience available outside of Japan which could benefit the decommissioning programme. In terms of dissemination, the information being gathered from the plant to better understand the accident progression as well as access to fuel debris sample analysis when it will become available are prime candidates for international dissemination and collaboration.

Acknowledgment 25

The IAEA Review Team acknowledges the commitment of Japanese organizations to engage with international counterparts, from research to industry, and to disseminate the scientific, safety and technological knowledge stemming from the decommissioning operation.

Advisory point 22

The IAEA Review Team advises FDEC and JAEA to further strengthen international cooperation in their respective domains, with two complementary aspects:

- benefit from solutions, resources and experience available internationally, which can contribute to the safe and effective decommissioning project;
- make available knowledge gained on the accident and facilitate access to fuel debris samples.

3.6.3. Public communication

TEPCO has developed a comprehensive outreach programme that is facilitating public communication. Taking into account travel restrictions either due to COVID-19 or simply to the time and distance needed to go to the plant, TEPCO has developed a comprehensive virtual tour of the Fukushima site with comments in Japanese and in English, which is regularly updated. For those who can visit, TEPCO has reviewed the access procedures and the content of the visit to reduce the time and therefore increase the visiting capacity. Further optimization and fine tuning are on-going. TEPCO Decommissioning Archive Center located in Tomioka town on the former PR centre of Fukushima Dai-Ni Nuclear Power Station, offers a wealth of information from what happened in March 2011 to the current situation of the site and decommissioning technologies; it also shows testimonies of residents and workers. Fukushima prefecture has established the Great East Japan Earthquake and Nuclear Disaster Memorial Museum focused on the triple events of earthquake, tsunami and nuclear accident, explaining the fate of evacuees and introducing the promotion for the reconstruction of the region; it features live testimonies to pass on the memory.

TEPCO is publishing on a regular basis newsletter and a magazine, with local residents as a primary audience, to present the progress of decommissioning with an effort to make technical information accessible and to provide a perspective from the workers engaged in the project.

TEPCO is also using internet social media to communicate on the situation of the decommissioning, seeking and getting cooperation with public influencers including artists and sportsmen.

Acknowledgment 26
The IAEA Review Team acknowledges the public outreach programme to disseminate relevant information regularly, both locally and at national level and the efforts to offer it in an easy to understand manner. The development of a virtual tour of the site is a useful mean to increase reach-out including internationally, complementing magazines and engagement with Social Networks.

Advisory point 23
The IAEA Review Team encourages TEPCO and METI to perform surveys and assessments to evaluate how the public outreach programme contributes to enhance public trust and confidence on Fukushima Daiichi decommissioning works

4. CONCLUSIONS

The IAEA Review Team was impressed by the progress made since the last review in November 2018 on all aspects including water management, removal of fuel from spent fuel pools, better understanding of fuel debris, new waste management facilities, further improvement of the site including measures against extreme tsunami and earthquakes, considering the complexity that faces the operator at the Fukushima Daiichi NPS site, which should not be underestimated. The IAEA Review Team also appreciates the build-up of an overall organization geared towards delivering safe and effective decommissioning. The re-organization of the FDEC, which now includes an office for project management and an office for safety and quality is a prime example of this mindset.

The IAEA Review Team acknowledges the commitment of the Japanese actors to put actions to the words "coexistence of reconstruction and decommissioning". As part of this review, the IAEA Review Team took note of the pro-active stance to engage with and support local industries and local suppliers and of the outreach and communication programme. The IAEA Review Team was also informed of progress made outside the plant, including the lifting in 2020 of the evacuation orders for parts of both Okuma Town and Futaba Town, which are the towns where the Fukushima Daiichi NPS is located.

While the project is entering a phase of industrial decommissioning, i.e. runs with the tools of any standard industrial project in terms of organization, the challenges to overcome remain plentiful, from the safe disposition of ALPS treated water or the removal of fuel from pools of Units 1 and 2 to the assessment of options and implementation for characterization, retrieval, storage and management towards a disposition path of the fuel debris. This will require comprehensive long-term planning covering the whole duration of the decommissioning work and the full waste inventory, a steady attitude of rigor and innovation, of scientific developments and pragmatism, of systematic human resources development and information and knowledge management, of continuous engagement with the nuclear regulatory authority and with the local communities. The project can continue to learn much from the international experiences, and conversely the project is also contributing significantly to the international experience of nuclear material retrieval and knowledge of accident progression, which others will learn from.

The IAEA Review Team wishes to thank all Japanese counterparts for the quality and thoroughness of all the discussions held during the review.

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SF-1	Fundamental Safety Principles: Safety Fundamentals	2006
GSR Part 1	Governmental, Legal and Regulatory Framework for Safety: General Safety Requirements	2010
GSR Part 2	Leadership and Management for Safety	2016
GSR Part 3	Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards	2014
GSR Part 4	Safety Assessment for Facilities and Activities (Rev. 1)	2016
GSR Part 5	Predisposal Management of Radioactive Waste: General Safety Requirements	2009
GSR Part 6	Decommissioning of Facilities: General Safety Requirements	2014
GSR Part 7	Preparedness and Response for a Nuclear or Radiological Emergency: General Safety Requirements	2015
GSG-1	Classification of Radioactive Waste: General Safety Guide	2009
GSG-3	The Safety Case and Safety Assessment for the Predisposal Management of Radioactive Waste	2013
SSG-15	Storage of Spent Nuclear Fuel	2012
SSG-40	Predisposal Management of Radioactive Waste from Nuclear Power Plants and Research Reactors	2016
SSG-45	Predisposal Management of Radioactive Waste from the Use of Radioactive Material in Medicine, Industry, Agriculture, Research and Education	2019
SSG-47	Decommissioning of Nuclear Power Plants, Research Reactors and Other Nuclear Fuel Cycle Facilities	2018
RS-G-1.7	Application of the Concepts of Exclusion, Exemption and Clearance: Safety Guide	2004
WS-G-2.5	Predisposal Management of Low and Intermediate Level Radioactive Waste: Safety Guide	2003
WS-G-2.6	Predisposal Management of High Level Radioactive Waste	2003
WS-G-5.1	Release of Sites from Regulatory Control on Termination of Practices: Safety Guide	2006
WS-G-5.2	Safety Assessment for the Decommissioning of Facilities Using Radioactive Material: Safety Guide	2008
WS-G-6.1	Storage of Radioactive Waste: Safety guide	2006

Nuclear Energy Series

NW-G-1.1	Policies and Strategies for Radioactive Waste Management	2009
NW-G-2.1	Policies and Strategies for the Decommissioning of Nuclear and Radiological Facilities	2011
NW-T-1.8	Mobile Processing Systems for Radioactive Waste Management	2014
NW-T-1.14	Status and Trends in Spent Fuel and Radioactive Waste Management	2018
NW-T-2.1	Selection and Use of Performance Indicators in Decommissioning	2011
NW-T-2.5	An Overview of Stakeholder Involvement in Decommissioning	2009
NW-T-2.6	Decommissioning of Pools in Nuclear Facilities	2015
NW-T-2.7	Experiences and Lessons Learned Worldwide in the Cleanup and Decommissioning of Nuclear Facilities in the Aftermath of Accidents	2014
NW-T-2.8	Managing the Unexpected in Decommissioning	2016
NW-T-2.10	Decommissioning After a Nuclear Accident: Approaches, Techniques and Implementation Considerations	2019
NF-T-3.6	Management of Damaged Spent Nuclear Fuel	2009
NG-T-2.3	Decommissioning of Nuclear Facilities: Training and Human Resource Considerations	2008
NP-T-3.16	Accident Monitoring Systems for Nuclear Power Plants	2015

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SRS No. 31	Managing the Early Termination of Operation of Nuclear Power Plants	2003
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TRS No. 389	Radiological Characterization of Shutdown Nuclear Reactors for Decommissioning Purposes	1998
TRS No. 395	State of the Art Technology for Decontamination and Dismantling of Nuclear Facilities	1999
TRS No. 399	Organization and Management for Decommissioning of Large Nuclear Facilities	2000
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TRS No. 408	Application of Ion Exchange Processes for the Treatment of Radioactive Waste and Management of Spent Ion Exchangers	2002
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TRS No. 440	Dismantling of Contaminated Stacks at Nuclear Facilities	2005
TRS No. 441	Management of Problematic Waste and Material Generated During the Decommissioning of Nuclear Facilities	2006
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TECDOC-1476	Financial Aspects of Decommissioning	2005
TECDOC-1478	Selection of Decommissioning Strategies: Issues and Factors	2005
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TECDOC-1537	Strategy and Methodology for Radioactive Waste Characterization	2007
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TECDOC-1602	Innovative and Adaptive Technologies in Decommissioning of Nuclear Facilities: Final report of a Coordinated Research Project, 2004-2008	2008
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TECDOC-1702	Planning, Management and Organizational Aspects in Decommissioning of Nuclear Facilities	2013
TECDOC-1817	Selection of Technical Solutions for the Management of Radioactive Waste	2017
TECDOC-1876	Modelling of Marine Dispersion and Transfer of Radionuclides Accidentally Released from Land Based Facilities	2019

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NEA/IAEA/EC	International Structure for Decommissioning Costing (ISDC) of Nuclear Installations	2012
IEM Report	IAEA Report on Decommissioning and Remediation after a Nuclear Accident, International Expert Meeting, 28 January – 1 February 2013, Vienna, Austria	2013

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.

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List of Abbreviations

ALPS	Advanced Liquid Processing System
CLADS	Collaborative Laboratories for Advanced Decommissioning Science
D&D	decommissioning and dismantling
FA	fuel assembly
FDEC	Fukushima Daiichi Decontamination and Decommissioning Engineering Company
FY	fiscal year
IAEA	International Atomic Energy Agency
IRID	International Research Institute for Nuclear Decommissioning
JAEA	Japan Atomic Energy Agency
KM	knowledge management
METI	Ministry of Economy, Trade and Industry
MEXT	Ministry of Education, Culture, Sports, Science and Technology
NDF	Nuclear Damage Compensation and Decommissioning Facilitation Corporation
NPS	Nuclear Power Station
NRA	Nuclear Regulation Authority
PCV	primary containment vessel
PMB	Process Main Building
PMO	Project Management Office
R&D	research and development
SARRY	Simplified Active Water Retrieve and Recovery System
SFP	spent fuel pool
TEPCO	Tokyo Electric Power Company

APPENDIX I: REVIEW AGENDA

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

The Review was conducted between 30 June and 27 August 2021.

General Agenda was as follows:

30 June: Opening and introductory meeting of the IAEA Review Team with the Japanese counterparts;

5 July – 6 August: Meetings of the IAEA Review Team with the Japanese counterparts (2 per week) and internal meetings of the IAEA Review Team (1 per week);

2-6 August: Meeting of the IAEA Review Team to prepare the report and presentation of the findings to the Japanese counterparts;

All meetings above were conducted using web-based solutions.

23-27 August: Review mission to Japan, site visit of Fukushima Daiichi, further meetings at the Fukushima Daiichi NPS and in Tokyo, hand-over of the (Preliminary summary of Final Review) report;

27 August: Hand-over of the Final Review report.

APPENDIX II: LIST OF PARTICIPANTS

IAEA REVIEW TEAM:

1. XERRI, Christophe Team Leader	Director Division of Nuclear Fuel Cycle and Waste Technology (NEFW) Department of Nuclear Energy, IAEA
2. WESTON, Rebecca Deputy Team Leader	Executive Director, Sellafield Ltd Sellafield, United Kingdom
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7. LAGOS, Leonel	Director of Research Florida International University Applied Research Center Miami, USA
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9. MA, Jizeng	Unit Head Occupational Radiation Protection Unit, NSRW, IAEA
10. ROBBINS, Rebecca	Predisposal Team Leader Waste Technology Section, NEFW, IAEA
11. YAGI, Masahiro	Senior Nuclear Engineer Decommissioning and Environmental Remediation Section, NEFW, IAEA
12. KHAPERSKAIA, Anzhelika	Topical reviewer (spent fuel and fuel debris) Nuclear Fuel Cycle and Materials Section, NEFW, IAEA

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MINISTRY OF EDUCATION, CULTURE, SPORTS, SCIENCE AND TECHNOLOGY (MEXT)	
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NUCLEAR DAMAGE COMPENSATION AND DECOMMISSIONING FACILITATION CORPORATION (NDF)	
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