

Technical Strategic Plan 2018
for Decommissioning of the Fukushima Daiichi
Nuclear Power Station of
Tokyo Electric Power Company Holdings, Inc.

Overview

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Nuclear Damage Compensation and Decommissioning
Facilitation Corporation

NDF

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1 Introduction

Since 2015, the Nuclear Damage Compensation and Decommissioning Facilitation Corporation (hereinafter referred to as the “NDF”) has annually developed the “Technical Strategic Plan for Decommissioning of the Fukushima Daiichi Nuclear Power Station of Tokyo Electric Power Company Holdings, Inc.” (hereinafter referred to as the “Strategic Plan”). The purpose of this development is to provide a technical basis for contributing to the implementation and revision of the Government-developed “Mid-and-Long-Term Roadmap towards the Decommissioning of TEPCO’s Fukushima Daiichi Nuclear Power Station” (hereinafter referred to as the “Roadmap”).

1) Enhancement of structure and system toward appropriate and steady implementation of decommissioning

Seven years have passed since the accident at the Fukushima Daiichi NPS. In this period, it has made some progress in various activities such as building land-side impermeable wall as a part of contaminated water management, removing spent fuel from the spent fuel pool, and improving work environment in the site. Moreover, from a mid-and-long-term perspective, study and R&D activities toward both fuel debris retrieval work and waste management have progressed. Additionally, Roadmap was revised, policy on fuel debris retrieval was determined, and basic policies on the solid waste was developed.

As the phase of decommissioning moves, Tokyo Electric Power Company Holdings, Inc. (hereinafter referred to as “TEPCO”) has been enforcing project management structure, to handle mid-and-long-term issues systematically, with steadily addressing present issues. In addition, to more steadily ensure decommissioning in terms of funding, an amendment of the NDF Act was passed in May 2017 and enforced in October 2017. Based on this Act, NDF has increased responsibility for management of reserve fund for decommissioning (hereinafter referred to as Reserve Fund). In this responsibility, in every fiscal year, it was determined that 1. TEPCO deposits the amount required by NDF to implement decommissioning appropriately and steadily as well as approved by competent minister (Minister of Economy, Trade and Industry), 2. Based on the “Withdrawal plan for reserve fund” (hereinafter referred to as “Withdrawal plan”), jointly prepared by NDF and TEPCO and approved by competent minister, TEPCO will withdraw reserve fund and implement decommissioning. (Fig. 1)

Under the system of the reserve fund, NDF will 1) appropriately manage the fund for decommissioning, 2) manage the implementation structure of decommissioning properly and 3) manage the decommissioning work appropriately and NDF increased responsibility now as an organization to manage and oversee TEPCO’s decommissioning activities. In particular, based on “The Policy for Preparation of Withdrawal Plan for Reserve Fund for Decommissioning” (hereinafter referred to as “The Policy for Preparation of Withdrawal Plan”), NDF will propose work target and main works to be included in the Withdrawal Plan. In addition, NDF will assess the validity of TEPCO’s performance from the standpoint of project accomplishment, considering engagement and communications with local communities in the process of joint creation of Withdrawal Plan with TEPCO. Through these proposal and assessment, NDF supports an appropriate and steady implementation of decommissioning.

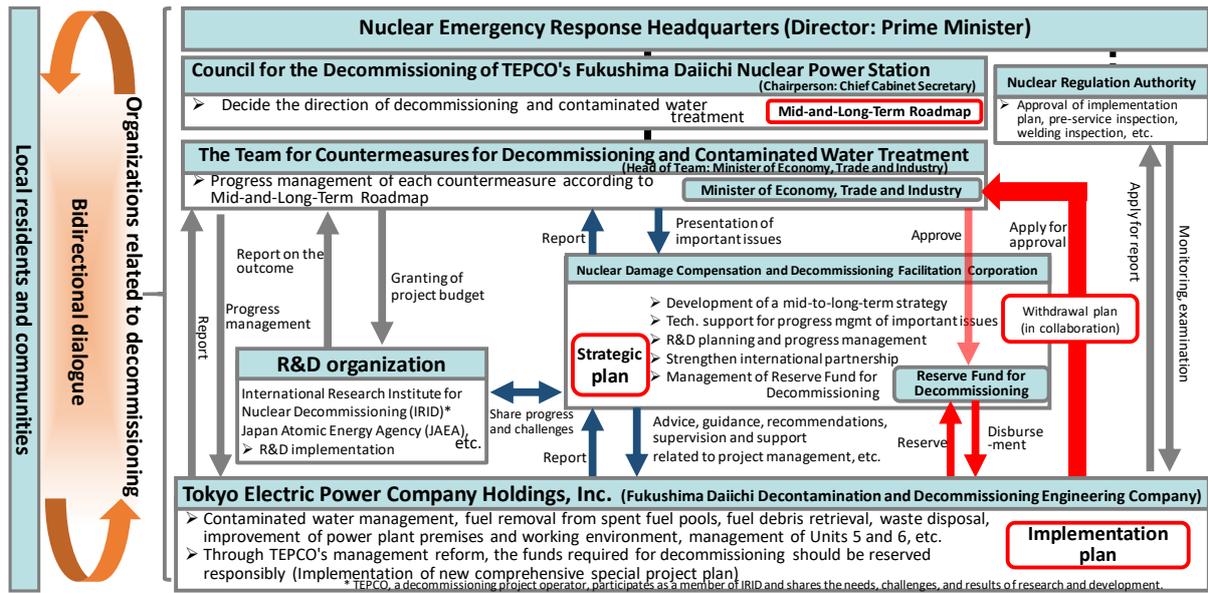


Fig. 1 Division of roles of related organizations in decommissioning of the Fukushima Daiichi NPS

2) Strategic Plan

In the previous Strategic Plans, fuel debris retrieval and waste management have been focused as the mid-and-long-term decommissioning strategies that NDF should address, and those measures have been considered. However, in elaborating fuel debris retrieval work, it will be necessary to consider not only these issues but also the relationship and consistency with measures for contaminated water and fuel removal from the spent fuel pools. Therefore, the Strategic Plan should also include measures for contaminated water and fuel removal from the spent fuel pools and present the mid-and-long-term direction, overlooking total approach for decommissioning of the Fukushima Daiichi NPS. The issues extracted from these considerations as items to address for the near term, will be reflected on the Policy for Preparation of Withdrawal Plan, which NDF will propose to TEPCO (Fig.2).

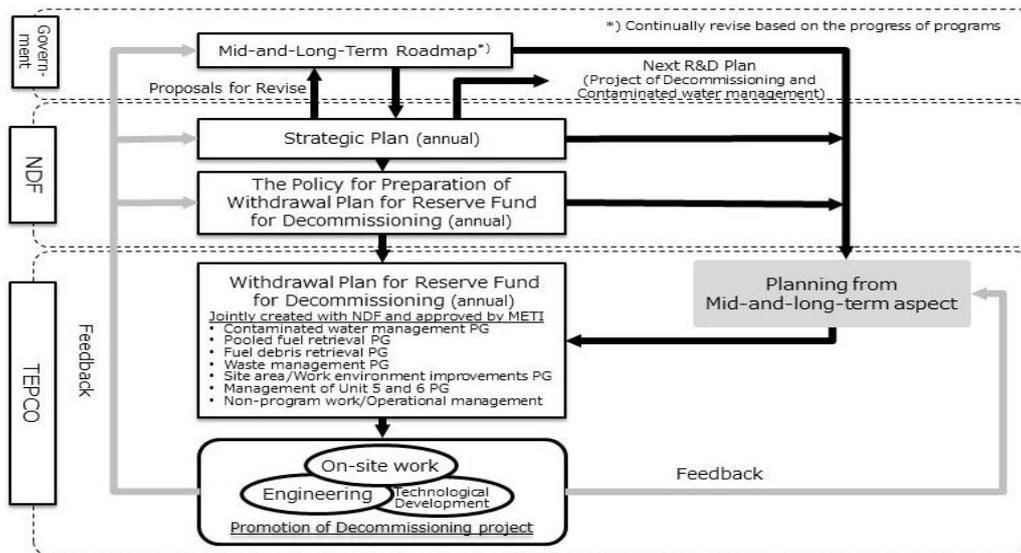


Fig. 2 Positioning of the Strategic Plan based on the system of the Reserve Fund

2 Decommissioning of the Fukushima Daiichi NPS as risk reduction strategies

1) Basic concept of the decommissioning of the Fukushima Daiichi NPS

Concerning to the Fukushima Daiichi NPS decommissioning, the basic concept is to continuously and quickly reduce the radioactive risk caused by the accident that does not exist in the usual NPS.

2) Progress status of the decommissioning of the Fukushima Daiichi NPS

The Fukushima Daiichi NPS has the necessary safety measures in place that are required by the NRA in “the matters for which measures should be taken” (hereinafter referred to as “Matters to be addressed”) and is maintained in a state with a certain level of stability. In addition, as a result of various risk reduction measures taken so far, risk reduction has been continuously achieved as follows:

(1) Contaminated water management

Measures have been taken based on the three principles on the issue of contaminated water (“Removing” contamination sources, “Redirecting” fresh water from contamination sources, and “Retaining” contaminated water from leakage).

As a measure of “Removing” contamination source, radioactive materials are removed from contaminated water with multi-nuclide removal equipment. As a measure of “Redirecting” fresh water from contaminated sources, freezing operation of all the areas of the land-side impermeable walls started by August 2017. In March 2018, the installation completed except for deep areas. Consequently, the completion of the land-side impermeable wall and reinforce of the sub-drain system led to the decrease of the groundwater inflow into the buildings. Total amount of the contaminated water attributed to rainwater and groundwater decreased due to decreased inflow into the buildings and sharp decrease in the amount of the water transferred from the groundwater-drains to the buildings. In addition, the effect of the land-side impermeable wall appeared in the decreased pumping amount both in the sub-drains and groundwater drains. As a result of “Retaining” contaminated water from leakage, the concentration of radioactive materials in the surrounding sea area is constantly low.

In treating stagnant water in the buildings, the amount of stored water has been decreasing steadily by lowering water level within turbine buildings with the goal of completing the treatment in 2020. The level of stagnant water in the Unit 1 Turbine Building was reduced to the lowest floor level in March 2017. In the Unit 2 - 4 turbine buildings, the level of the stagnant water lowered to the lowest floor’s intermediate ceiling, which was exposed in December 2017. For the condensers of Unit 1 – 3, where the highly radioactive stagnant water was stored at the time of accident, draining completed by December 2017 and so forth, thereby radioactive substances contained in the stagnant water sharply decreased. A new circulation system for the contaminated water management started the operation in February 2018 to reduce the concentration of the radioactive materials in the stagnant water. Decreasing both the amount of

the stagnant water and the concentration of the radioactive materials accelerate the reduction of the inventory of the radioactive materials in the stagnant water.

Moreover, the water treated by the multi-nuclide removal equipment is stored in the welded type tanks, so that the risk is managed in sufficiently low level. Comprehensive discussion including social standpoints such as mitigation of reputational damages have been made in the government's subcommittee on the water treated by the multi-nuclide removal equipment.

(2) Fuel removal from spent fuel pools

In Unit 1, to remove fuel from spent fuel pools at the operating floor, rubble removal in the north of the operating floor was started in January 2018.

In Unit 2, as a part of preparation of fuel removal from spent fuel pool, opening to provide access to the operating floor was made, then investigation on dose or contamination in the operation floor was started by using robots and heavy machinery in July, 2018 (scheduled in November 2018).

In Unit 3, a cover for fuel removal from the pool was installed in February 2018. Once started the trial operation for fuel handling equipment, several troubles have occurred. TEPCO is examining and reviewing the start of fuel removal in the spent fuel pool which was scheduled in November 2018.

(3) Fuel debris retrieval

In Unit 2, internal investigation of Primary Containment Vessel (hereinafter referred to as the "PCV") was conducted in January 2018, continued from January and February 2017. It was confirmed that deposits, which seemed to be fuel debris, are accumulated in the bottom of pedestal, according to the result of analysis of the images obtained.

In Unit 3, based on results of investigation in July 2017 using a remotely operated underwater survey vehicle (ROV), three D shape reconstruction was conducted, to grasp whole image within the pedestal. It was found out that swivel platform came off the track, and partly buried in the deposit, showing relative position of structures.

(4) Waste management

In February 2018, operation of solid waste storage building No. 9, which has about 40% of storage capacity of the existing solid waste storages (buildings No.1 – 8), was started. In the storage facility with shielding function, it became possible to store the highly radioactive rubbles arisen from removal in the operating floor of Unit 1 and dismantling of upper part of reactor building of Unit 2. In addition, sampling and analysis has been progressing for the purpose of characterization. Storage management plan was revised in June 2018 based on the results of revision of prediction of generation of solid waste.

(5) Other specific measures

The surrounding road of Unit 1 to 4 buildings and part of east side of turbine buildings were determined as "ordinary clothing area", where the workers are allowed to enter and work in general workwear or in on-site safety workwear with disposable dust-proof mask. By this, ordinary clothing area expanded to approximately 96% of the Fukushima Daiichi NPS site.

3) Basic concept of reducing risk of radioactive materials

i. Quantitative grasping of risk

In the Strategic Plan, the method based on the Safety and Environmental Detriment score (hereinafter referred to as “SED”) developed by Nuclear Decommissioning Authority (hereinafter referred to as “NDA”) is used to express the magnitude of risk (risk level) of radioactive materials. In this method, risk level is expressed as the product of “Hazard Potential”, which is used to indicate the level of impact of internal exposure caused by intake of radioactive substance into the human body, and “Safety Management” which is used as an index to indicate the likelihood of occurrence of the event.

ii. Identification of risk source and risk assessment

The major risk sources of the Fukushima Daiichi NPS are indicated in Table 1. Moreover, the risk levels of each risk source expressed using Hazard Potential and Safety Management are shown in Fig. 3.

In the Roadmap, management of these risk sources is classified into the three broad categories: 1. Highly contaminated water and fuels in the spent fuel pools, etc., relatively high risks given high priority, 2. Fuel debris, etc., immediate risks unlikely, risks may grow if neglected, 3. Solid waste, etc. increased risk unlikely in the future, but appropriate decommissioning efforts necessary. Their priorities are set, and appropriate measures are proceeded. Risk reduction strategies for each of these sources will be described in Section 3.

Table 1 Major risk sources in the current risk map

Fuel debris		Fuel debris in the RPVs/PCVs in Units 1-3
Spent fuel	Fuel in SFPs	Fuel assemblies stored in the spent fuel pools (SFPs) in Units 1-3
	Fuel in the common pool	Fuel assemblies stored in the common pool
	Fuel in dry casks	Fuel assemblies stored in dry casks
Contaminated water etc.	Stagnant water in the buildings	Contaminated water accumulated in the reactor buildings and turbine buildings in Units 1-4, main process building, and high temperature incinerator building.
	Stored water in flanged tanks	Strontium-treated water, residual concentrated salt water
	Stored water in welded tanks	Strontium-treated water, treated water by ALPS
Secondary waste from water treatment systems	Waste adsorption columns	Storing adsorbent used in the cesium adsorption apparatus, the second cesium adsorption apparatus, high-performance ALPS, mobile-type strontium removal equipment, second mobile-type strontium removal equipment and mobile-type treatment equipment, etc.
	HIC slurry	Slurry produced during the treatment by the multi-nuclide removal equipment stored in high integrity containers (HIC)
	Waste sludge	Precipitation from the decontamination instruments
	Concentrated liquid waste, etc.	Concentrated liquid waste generated by evaporative concentration of concentrated salt water and carbonate slurry collected from concentrated liquid waste
Rubble, etc.	Solid waste storage facility	Rubble with high-dose (30mSv/h and above) stored in the solid waste storage facility
	Soil covered temporary storage, etc.	Rubble stored in Soil covered temporary storage facility, Temporary storage tent and Outdoor container storage (1~30mSv/h) , and Felled tree stored in Temporary storage pool
	Outdoor storage, etc.	Rubble stored in Outdoor seat covered storage (0.1~1mSv/h), Rubble stored in Outdoor storage (Under 0.1mSv/h), and Felled tree stored in Outdoor storage
Contaminated structures, etc. in the buildings		Structures, pipes, components, and other items inside the reactor buildings, PCVs or RPVs that are contaminated with radioactive materials dispersed due to the accident; and activated materials from operation before the accident

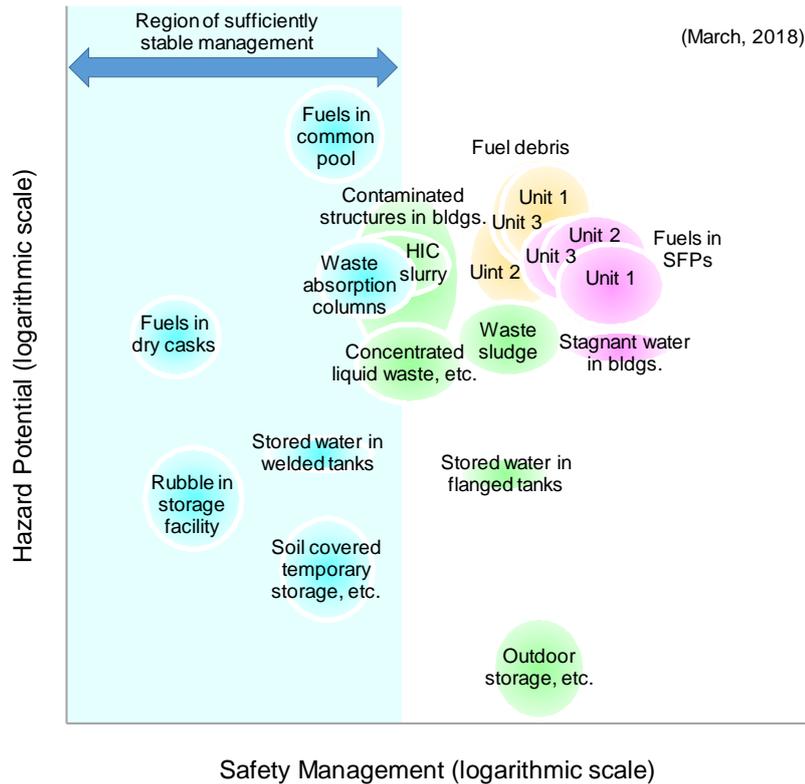


Fig.3 Example of risk levels assigned to the risk sources at the Fukushima Daiichi NPS

iii. Approach to risk reduction strategies and future direction

(1) Interim goal of risk reduction strategies

Risk reduction strategies include reduction in Hazard Potential and Safety Management in the SED. The examples of reduction in Hazard Potential include decrease in inventory and decay heat associated with radioactive decay, and changing the form of liquid and gas into the form that is hard to move. To process contaminated water to change into the secondary waste is an example of form change.

The examples of reduction in Safety Management include transfer of fuel in the pools to the common pool, and placement of rubbles stored outside to the storage. Of the various risk reduction measures, the reduction in Safety Management is considered generally to be easily achieved. Therefore, the interim goal of risk reduction strategies is to bring the risk levels into the “Region of sufficiently stable management” (pale blue area) indicated in Fig. 3.

(2) Basic approach to risk reduction

The decommissioning of the Fukushima Daiichi NPS is a project with inherent considerable uncertainty. To date, internal status of the Unit 1 to 3 is estimated to some extent by simulation of the development process of accident, estimation of location of fuel debris by measurement of muon, projection of inspection equipment into PCV, dose measurement in the buildings and others. However, to eliminate uncertainty, many resources, especially a considerably long time, are required. To realize prompt risk reduction, it is necessary to make integrated decisions

taking flexible and prompt approach, based on the directions determined with previously obtained experience and knowledge and with experiment- and analysis-based simulation, placing safety at the top priority, even though a certain extent of uncertainty remains. At this time, it is important to flexibly address the issues with experiences, reflecting the internal information, technical feasibility and other information obtained in advance in a certain Unit on the subsequent works and the works in other Units. As the viewpoint to make integrated decisions like this, NDF summarizes the following five guiding principles.

(Five guiding principles)

- Safe Reduction of risks posed by radioactive materials and ensuring work safety
- Proven Highly reliable and flexible technologies
- Efficient Effective utilization of resources (e.g. human, physical, financial and space)
- Timely Awareness of time axis
- Field-oriented Thorough application of Three Actuals (actual field, actual things and actual situation)

These guiding principle are the viewpoint necessary to discuss priority of approaches and total optimization.

(3) Order of priority

It is important to be aware of position of each project and their mutual relationship in their respective fields in managing progress of overall project based on the five guiding principles. In the decommissioning of the Fukushima Daiichi NPS that aspires to a continuous and prompt risk reducing, it is important to aim at choosing the best option among the various possible options, with the integrated viewpoint of looking at the entire site on a long-term basis and considering time axis. Taking into account such point of view, TEPCO and NDF have just introduced project management mechanism.

(4) Addressing temporary increase of risk level associated with the decommissioning operations.

The implementation of the decommissioning work is striving for prompt risk reduction from the mid-and-long-term viewpoint. However, it requires careful consideration of the possibilities that the performance of decommissioning work may temporarily change the risk levels and may increase the radiation exposure of workers. This possibility of a temporary increase in the risk level and a rise in workers' exposure arising from the decommissioning work must be addressed by ensuring measures to prevent and restrict them. It is imperative to limit the increase in the risk level during the decommissioning work within the permissible range by thorough preparations for the work. In particular, the radiation safety of workers should be ensured in

accordance with the concept of ALARA (to suppress radiation exposure As Low As Reasonably Achievable).

Note that the basic stance of promptly implementing the decommissioning must be firmly maintained because if the decommissioning work is delayed excessively, existing high risks will remain over the long term and their risk levels can gradually increase as the buildings and facilities deteriorate over time. For this reason, regard to the selection of the method of work, the design and production of equipment and safety systems, and the development of work plans for the decommissioning work, cautious and comprehensive decision making is required for the early implementation of the decommissioning in consideration of many constraints such as time, cost and worker's exposure needed for associated preparations and work, while giving priority to limiting the risks involved in the decommissioning work.

Moreover, the decommissioning of the Fukushima Daiichi NPS as a risk reduction project should be promoted, gaining the broad understanding and support by wide range of public including local residents. Therefore, it is important to implement an easy-to-understand mechanism of monitoring of risks such as how the overall risks at the NPS have been continuously reduced through the decommissioning work.

3 Technological strategies toward decommissioning of the Fukushima Daiichi NPS

1) Fuel debris retrieval

i. Sectoral target

- (1) Retrieve fuel debris safely after thorough preparations including safety measures, and bring it to the state of stable storage that is fully managed.
- (2) Toward determination of fuel debris retrieval method for the first implementing unit in FY 2019, and start of fuel debris retrieval work for the first implementing unit within 2021, necessary approaches will be taken, according to policy on fuel debris retrieval.

<Policy on fuel debris retrieval>

① Step-by-step approach

We will adopt a step-by-step approach wherein we will set the method of fuel debris retrieval to be started first in order to reduce risks at an early stage and will adjust our direction flexibly based on information that comes out as retrieval proceeds.

Fuel debris retrieval, the investigation inside the primary containment vessel, and the investigation inside the reactor pressure vessel will be performed in a coordinated, integrated manner. The fuel debris retrieval starts from a small-scale task and the scale of retrieval will be stepped up as we review our operations flexibly based on new findings obtained from the nature of the fuel debris and working experience.

② Optimization of entire decommissioning work

We will examine fuel debris retrieval as a comprehensive plan aimed at total optimization, from preparation to cleanup through retrieval work, discharge, processing and storage, including coordination with other construction work at the site.

③ Combination of multiple methods

We will combine optimum retrieval methods suitable for the part of each unit where fuel debris is expected to be present, instead of making an assumption that all the fuel debris is to be taken out using a single method.

At present we will examine how to combine methods from an accessibility standpoint, assuming that access is made to the bottom of the primary containment vessel from the side and that access is made to the inside of the reactor pressure vessel from the upper part of the vessel.

④ Approach focused on partial submersion method

Given the technical difficulty of stopping leaks at the upper of the primary containment vessel and expected radiation doses during work, the full submersion method is technically difficult at present, so we will base our efforts on the partial submersion method that is more feasible.

However, given the advantages of the total submersion method, such as being effective in providing shielding against radiation, we might consider adopting the full submersion method in the future depending on the progress of R&D.

⑤ Prioritizing fuel debris retrieval by access to the bottom of the primary containment vessel from the side

According to an analysis, fuel debris is expected to be present in both the bottom of the primary containment vessel and the inside of the reactor pressure vessel of each unit, although their distribution varies among the units. In view of rapidly mitigating risks from fuel debris while minimizing any increase in risks that might be caused by retrieval, we will

prioritize retrieval of fuel debris in the bottom of a primary containment vessel by access from the side by taking the following into account:

- The bottom of the primary containment vessel is most accessible and a certain amount of knowledge about it has already been accumulated through the investigation inside the primary containment vessel;
- There is a possibility that fuel debris retrieval could be started earlier;
- Fuel debris retrieval could be performed at the same time as spent fuel removal

ii. Sectoral strategies

(1) Approach to risk reduction in fuel debris retrieval work

It is hard to consider that the fuel debris immediately appears as a risk, but it is a risk source that risk may grow in case of dealing with waste. Currently, it is maintained in a state with a certain level of stability. However, on a long-term, the possibility of changes in the form and physical property due to aging degradation is considered. For this reason, as indicated in (1) of Sectoral goal, fuel debris should be retrieved safely after thorough preparations such as safety measures and bring it to the state of stable storage that is fully managed as soon as possible. To realize this, in the Strategic Plan, securing of safety during the operations of fuel debris retrieval and technical requirements that are defined including feasibility of fuel debris retrieval method and stable storage of fuel debris have been considered while organizing the issues logically. In the future, consideration should be made according to these technical requirements to implement fuel debris retrieval work safely when expanding the scale with a step by step approach in accordance with policy on fuel debris retrieval.

(2) How to proceed discussion toward determination of fuel debris retrieval method for the first implementing unit

In the Roadmap revised in September 2017, policy on fuel debris retrieval has been just determined based on the contents of strategic proposals in Strategic Plan 2017. Moreover, it is stated that “regarding the method of fuel debris retrieval for the first implementation unit to begin the operation, the fuel debris retrieval work for the first implementing unit will start within 2021 by determining the method of containing, transfer and storage (by FY2019) after due consideration of the results of the preliminary engineering work and R&D”. Fig. 4 shows the investigating flow (draft plan) to determine the fuel debris retrieval method for the first implementing unit, based on the R&D achievements and results of internal investigation of PCVs. 1: It is necessary to prepare a scenario (operation process plan) during the preliminary engineering work implemented by TEPCO (see next section), based on the consideration on the concept of fuel debris retrieval system for each unit and on the evaluation of its applicability on site. 2: After this, the first implementing unit and the retrieval method will be determined, by considering multiple whole scenarios combining the scenarios of each unit and the plan for surrounding areas and by identifying the whole scenario which is considered to be comprehensively the most reasonable.

To select the first implementing unit, consideration should be made for the particularity of unprecedented undertaking of fuel debris retrieval work in the environment with many uncertainties, and the benefit of getting experiences and information of handling of fuel debris early, also taking into account the viewpoints of reliability of internal information, work environment such as involvement of necessary preparatory works and risk assessment of each unit, etc.

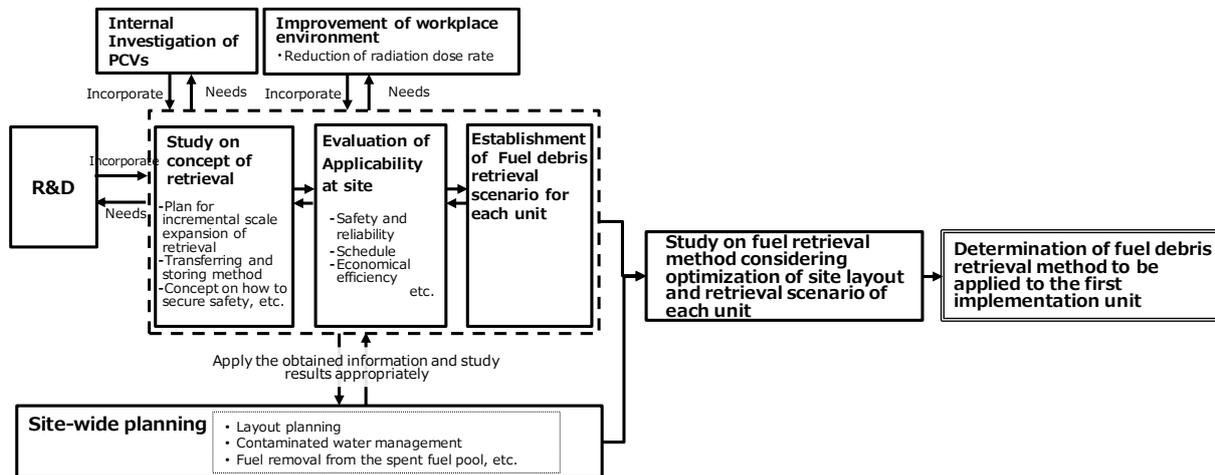


Fig. 4 Investigating flow toward determination of fuel debris retrieval method (draft plan)

(3) Proceeding method of preliminary engineering and creation of concrete plan of each task

In the preliminary engineering work conducted by TEPCO, by confirming the applicability of operations on site in light of the situation of each unit about operations and system concept for each step of fuel debris retrieval proceeded step-by-step, and it will be specified as a scenario for fuel debris retrieval for each unit. In particular, details of preliminary engineering work should be fully planned and investigated to obtain the necessary information, aiming at milestones, which is the determination of fuel debris retrieval method of the first implementing unit within FY 2019.

From this point of view, considerations meeting the following items are expected to be conducted in the preliminary engineering work:

- The whole related operations ranging from internal investigation in the preliminary stage of fuel debris retrieval and preparations to the improvement in the surrounding environment to fuel debris storage should be included in the scenario.
- In each step, the information that should be gained in advance should be organized in order to secure safety and engineering reliability on the equipment for retrieval.
- Clarification of prerequisites as well as evaluation on its uncertainties and forecast concerning a development of the scenario should be conducted.
- Sufficient safety evaluation should be implemented for the major troubles and others assumed at present.

As a result of these considerations, the following items are expected to be obtained, as the achievement of preliminary engineering work:

- Image of operation process to fuel debris retrieval for each unit and identification of technical issues to solve
- Engineering schedule incorporating the period of solving the technical issues (scenario for each unit)

As a result, it will be possible to create the overall scenario, combining the obtained scenario for each unit and fuel debris retrieval from the pools and contaminated water management. And the candidate of the first implementing unit will be selected according to this overall scenario.

(4) Continued internal investigation and accelerated/prioritized R&D

It is necessary to draw up a roadmap for solving the technical issues extracted so far and identified in the process of implementing preliminary engineering work, through further internal investigation and accelerated/prioritized R&D.

As the PCV internal investigation conducted so far has obtained various information, further detailed internal investigation is planned to collect data such as the distribution of deposits and fuel debris inside the PCV. In the future internal investigation, it should be thoroughly identified what kind of data is necessary as part of assembling the whole project in preparing for retrieving fuel debris, which is progressing step by step. Then to implement the scenario for the goal of each phase is needed.

In addition, according to the fuel debris retrieval policy based on the partial submersion method, by advancing the side access to the bottom of the PCV, R&D tasks that newly needs have become clear are to be proceeded to extract through preliminary engineering work, as well as accelerating and prioritizing R&D including establishing a containment function (gas phase) on the assumption of the existence of α -nuclides and technology to manage the water level in the PCV. It is also important to take a step-by-step approach to flexibly adjust the direction including the method of retrieving fuel debris, depending on the outcome of R&D and the situation on site to which the scenario is applied.

iii. Technical issues for promoting sectoral strategies and future plans

Fuel debris retrieval work should proceed step by step according to the fuel debris retrieval policy. After presenting the step-by-step concept in (1), the main issues are described in (2) to (5) including the approach to comprehensively understand internal reactor condition, the technical requirements related to safety assurance shown in the Strategic Plan, the technical requirements concerning the fuel debris retrieval method, and the technical requirements on the stable storage of fuel debris, together with further considerations required as the scale grows.

(1) Concept of the step-by-step approach

In the fuel debris retrieval policy, internal investigation and fuel debris retrieval work will be performed in a coordinated, integrated manner. Starting with small-scale fuel debris retrieval,

the scale of retrieval will be gradually expanded, reviewing the work flexibly, based on the nature of fuel debris and new findings obtained from work experience, etc.

Details of work elements pertaining to fuel debris retrieval for each unit are under consideration, an example of which is described as follows. Note that these do not necessarily apply to all of Units 1 to 3 across the board.

a. Internal investigation

For the condition inside of the PCV and damages of the internal structure, investigation and observation are to be made provided that the internal environment has not changed. This will provide information for checking the distribution and accessibility of fuel debris at the bottom of the PCV and information for judging the safety of fuel debris retrieval work, which are used for examining the fuel debris retrieval method.

Furthermore, the nature of fuel debris inside of the PCV, including the shape, existing state, composition, and mechanical/chemical properties, etc. are identified through sampling and analysis.

As fuel debris sampling inevitably involves moving fuel debris, it aims to improve the accuracy of determining the feasibility of the fuel debris retrieval method and to improve the reliability of the protective measures for ensuring safety, by collecting important data that assists evaluation of ensuring safety in the subsequent stage such as information pertaining to the transportation for temporarily storage of retrieved fuel debris and stable storage, information pertaining to the transition state of fuel debris to the gas/liquid phase and potential criticality, etc.

b. Fuel debris retrieval

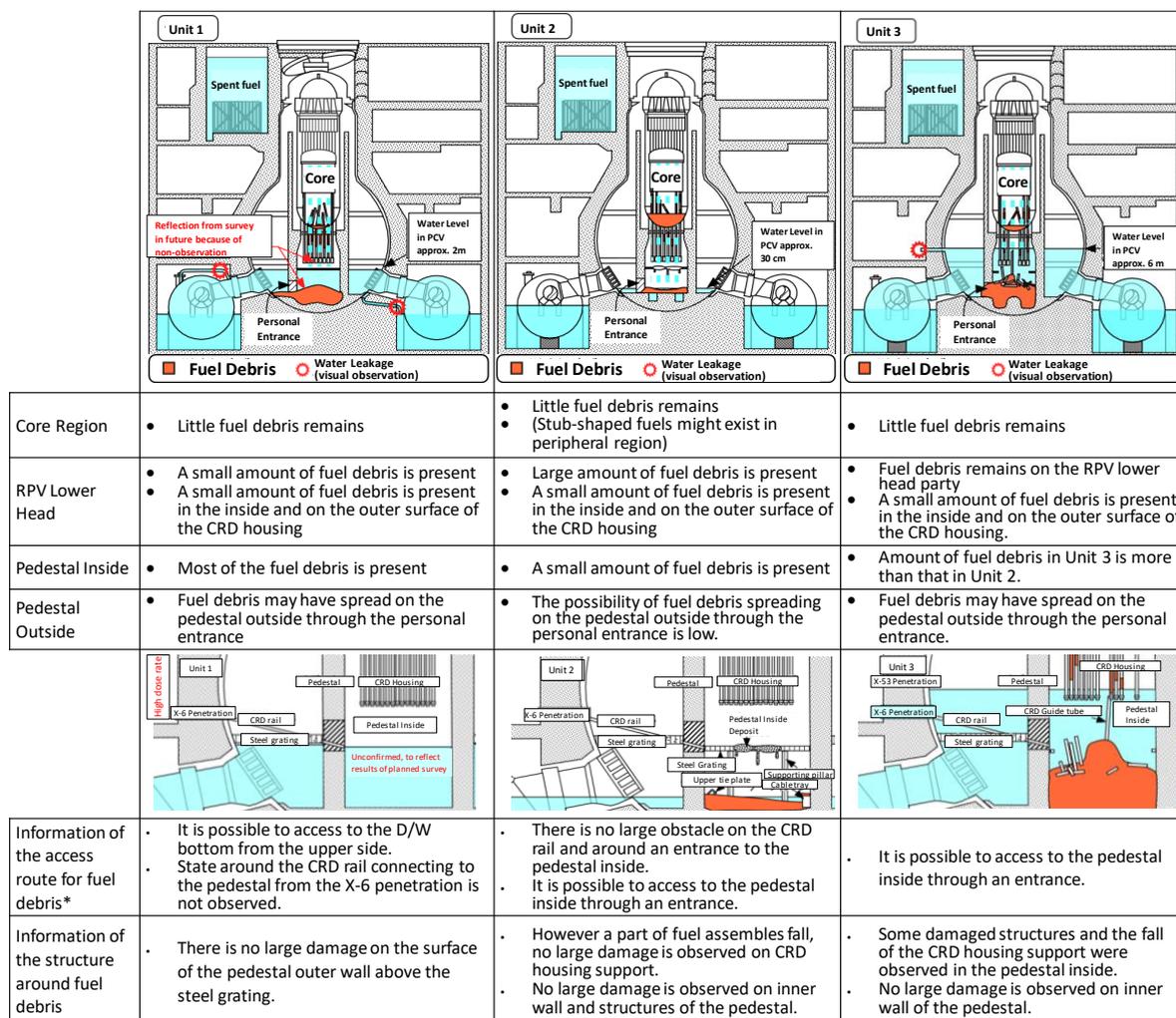
In the initial stage of fuel debris retrieval work, fuel debris will be taken out to the extent that the condition of the site is not significantly changed. In order to improve the efficiency of work throughout the fuel debris retrieval period, various kinds of information to identify the work and equipment used for large-scale retrieval scheduled thereafter should be collected and verified, including to confirm the effectiveness and evaluate the work efficiency of the fuel debris retrieval work and equipment, to evaluate the effect on safety when extending the scale of fuel debris retrieval and to check in advance the conditions for collecting, transferring and storing.

Based on the data obtained from the operation until the small-scale fuel debris retrieval, installing equipment is to be made that can handle the target amount of fuel debris taken out per day and more efficient fuel debris retrieval work will be performed after studying the fuel debris retrieval equipment and the system for ensuring safety.

(2) Comprehensive understanding of reactor conditions by continuing internal investigation, etc.

The comprehensive analysis and the evaluation results are as shown in Fig.5, that including actual measured value of plant parameters, etc. severe accident progress analysis, information

by PCV internal investigation, which are obtained at the time of accident as well as the access route to fuel debris and the situation of the surrounding structure and the distribution of fuel debris of the Unit 1 to 3 based on the knowledge obtained by examination, etc.



- It is thought that a route to the pedestal inside from the X-6 penetration is important for fuel debris retrieval from a small-scale task by side access method. The contents observed by previous internal investigation are mentioned as information to judge whether troubles are caused by falling objects on the route.
- In the access route for the fuel debris retrieval in the PCV (large-scale task), an access route through an equipment hatch is planning in the project of retrieval method and system.
- Due to high dose rate around the X-6 penetration of Unit 1, it may use the same access route of the large-scale task, in case it is difficult to improve work environment. Next internal investigation of Unit 1 is scheduled to develop by accessing from X-2 penetration.

(Prepared by Achievement Report 2017 and June 2018 of "Decommissioning and Contaminated Water Management Fund (Advancement of comprehensive grasping of inner reactor)" provided by IRID, The Institute of Applied Energy)

Fig. 5 Estimated fuel debris distribution, access route and surrounding structure of Unit 1 – 3

The following investigation and study for each unit should be considered steadily.

【Unit 1】

- Grasping distribution of structures or deposits outside the pedestal (including sampling) [scheduled in the first half of FY2019]

【Unit 2】

- Grasping mobility of deposits at the bottom of the pedestal when force is applied [scheduled in the second half of FY2018]
- Grasping distribution of structures or deposits inside the pedestal (including sampling) [scheduled in the second half of FY2019]
- Considering to increase sampling volume [scheduled in FY2020]

【Unit 3】

- Considering availability of internal investigation technology that was developed and proved by the project of decommissioning and contaminated water management project, in parallel to study water level reducing in PCV
- Considering necessity of further investigation in utilizing underwater ROV that was used in the former investigation

	FY2018		FY2019		FY2020	FY2021	
	1st	2nd	1st	2nd			
Unit 1	<p>Grasping distribution of structures or deposits outside the pedestal (including sampling)</p>		<p>Grasping distribution of structures or deposits inside the pedestal (including sampling)</p>		Determine the method of fuel debris retrieval for the first implementation unit	Start of fuel debris retrieval for the first implementation unit	
Unit 2	<p>Grasping mobility of deposits at the bottom of the pedestal when force is applied</p>		<p>Investigation equipment by arm-type access</p>				Consider to increase sampling volume
Unit 3	Considering availability of internal investigation technology that has been demonstrated in parallel to study water level reducing in PCV Considering necessity of further investigations in utilizing ROV that was used in the previous investigation						

Drawings in the balloons are quoted by the material from IRID, TEPCO

Fig. 6 Further internal investigation schedule and image of investigation equipment

Prior to implementing further internal investigation in detail, giving due consideration will be required for continuous ensuring safety, including maintaining containment function and prompt recovery of containment function in the abnormal event as well as measures against exposure and dust management, in consideration of maximum use of existing penetration into internal PCV that has been used in the former investigations as larger equipment will be used.

(3) Technical issues and future actions for ensuring the safety of fuel debris retrieval work

For ensuring the safety at the each stage of the fuel debris retrieval, it is important to study reasonable protective measures according to the scale of fuel debris retrieval work while taking

actions to reduce the uncertainties of the PCVs' internal conditions during the conceptual design phases. In the Strategic Plan, as the concept of ensuring the safety during the fuel debris retrieval work is being constructed, the key technical issues for ensuring the safety of fuel debris retrieval are carefully selected and studied as follows.

① Establishing the containment function (Gas phase)

When retrieving the fuel debris, the dispersion of radioactive fine particles (α -dust) containing α -nuclides may occur due to the works such as fuel debris cutting and drilling, and it may create a concern for increasing the concentration of radioactivity in the PCVs gas phase. Therefore, a function for containing the gas phase with protective measures should be provided that suppress the dose impact of workers and public within the allowable value, by minimizing the spread of α dust from PCV.

Accordingly, it is reasonable to upgrade the scale of the retrieval work while verifying the validity of the containment function built in the subsequent stage by grasping the tendency of dust dispersion at the each stage of scale expansion. For example, internal PCV investigations and the small-scale retrieval planned in the near future, α -dust emission can be controlled by reducing the amount to be retrieved, and selecting a retrieval method that does not involve cutting and drilling, while maintaining the current inert atmosphere (slightly positive pressure state due to nitrogen gas charge) inside the PCVs. Based on both the results of monitoring changes in the state of α -dust emission from the retrieval work and the evaluation of the effects on the surroundings, it will likely be shifted to the larger size of the fuel debris retrieval work gradually, using such as the cutting and drilling equipment. If it is evaluated that the expansion of the retrieval work may induce effects on the surrounding environment, further study is required for the means to strengthen the containment function by equalization or negative pressurization inside the PCVs as well as constructing a secondary containment function outside the PCVs.

② Establishing the containment function (Liquid phase)

To mitigate the dispersion rate of generated α -dust and to minimize the transition to the gas phase, the fuel debris retrieval work would be performed, submerging the fuel debris or by pouring water over the fuel debris. In such cases, a great number of α -particles will be mixed in cooling water (liquid phase). To prevent the cooling water containing α -particles from affecting the environment, it may be of great importance to establish a cooling water circulation/purification system, and a liquid phase containment function.

To ensure a more reliable containment function, water sealing methods by repairing the bottom of the PCV pouring the grout materials have been studied. However, based on the results of previous experimental studies, it is becoming clearer that water sealing by repairing the bottom of the PCV is very difficult. Thus, it may be important to explore a retrieval method, to minimize leakage with the realization of suitable circulation and purification systems of cooling water.

To establish a reasonable containment function at each stage as scale grows, it is rational to monitor the radioactive concentration of the cooling water and verify the validity of the containment function built in the subsequent stage. For example, if the PCVs internal investigations and small-scale retrieval work are performed using the current water circulation system, it may be possible to suppress the increase of the radioactive concentration of cooling water by reducing the retrieved volume and selecting a retrieval method that does not require drilling, together with the containment function (gas phase). From the viewpoint of investigating the methods to detect the effects induced by the retrieval work on the liquid phase, the circulating water system would be monitored, and based on the confirmation of monitoring results of α -nuclides, the fuel debris retrieval method may gradually be changed to a larger retrieval method using drilling equipment. If an abnormal event such as a large volume of cooling water outflow from a PCV to the torus rooms of a nuclear reactor building occurs, measures should be taken such that the water level in the torus room be maintained lower than the groundwater level to prevent the outflow of cooling water to the surrounding ground. For this reason, it is necessary to establish an appropriate PCV water level and a PCV water level control system.

③ Maintaining the cooling function

The decay heat of the fuel debris has been decreased dramatically since the core melt accidents. However, it may be necessary to keep the cooling function to prevent nuclides from shifting from the liquid phase to the gas phase due to thermal energy during the fuel debris retrieval work. At present, the cold shutdown state is maintained with keeping the temperature well below 100°C using cooling water. In addition, during the fuel debris retrieval work, it may be necessary to keep the temperature below the level at which the fuel debris retrieval device can continue to work without any problems for a long period of time.

To maintain the cooling function at each stage of retrieval scale expansion, the consistency with other systems should be checked, such as the concept of water level control within the PCVs for confining the liquid phase and the contaminated water purification system. Based on the data obtained for each stage of retrieval scale expansion, it may be necessary to examine the circulation cooling system to be required in the subsequent stage.

④ Criticality control

At present, the monitoring of the concentration of rare gas (Xe-135) has shown no sign of criticality. Further, it may be pointed out that the possibility of criticality is extremely low based on the expected state of existence of fuel debris. In addition, even if criticality should occur, its impact would be small because it is estimated that the fuel debris is dispersed over wide area. To keep the subcritical condition more reliably, it is important to store the retrieved fuel debris stably, controlling the shape and size of retrieved fuel debris, for instance, by storing the debris in storage cans. To prevent fuel debris from reaching criticality during the fuel debris retrieval work, it is necessary to investigate what kind of conditions during the work would lead to

criticality, including the shape of the fuel debris or the water volume changes, and establish an appropriate management method with combined functions of prevention, detection, and termination of criticality.

In the early stage of retrieval, the fuel debris should be retrieved in a way that does not significantly change the shape of fuel debris. Then, the composition and characteristics of fuel debris and the fluctuation of the neutron signal in the vicinity of fuel debris handled during the work should be checked to evaluate the criticality of the fuel debris. The retrieved volume of fuel debris can be increased based on the measurement of subcritical condition or taking measures such as placing neutron absorbers.

⑤ Securing structural integrity (earthquake resistance) of the PCVs and reactor buildings

The reactor buildings, PCVs, and reactor pressure vessels (herein after referred to as “RPV”s) experienced the hydrogen explosions when the accident occurred. Further, the exposure to the high-temperature environment and the corrosion due to seawater injection may have affected the integrity of the structures. During the period of the fuel debris retrieval work, it is necessary to secure the integrity for the important structures like PCVs and RPVs and to suppress the deterioration of containment functions of PCVs and reactor buildings, considering the effect mentioned above against the possible occurrence of a severe earthquake. In addition, the deterioration of containment function of PCVs and reactor buildings due to corrosion have to be suppressed during the retrieval work. Furthermore, it may be required to prepare for the mitigation measures in advance, evaluating the impact on human beings and the environment induced by the postulated damage to important functions due to a large earthquake.

The previous studies show that the reactor buildings and structural major components of PCV, RPV and pedestal, that supports the RPV of each unit, have relatively large seismic safety margin against a design basis seismic ground motion S_s (600Gal), taking into account the damage caused by the accident, degradation over 40 years by corrosion and increased weight of new facilities required for the fuel debris retrieval work.

It is necessary to evaluate the seismic safety margin of R/Bs, PCVs and RPVs in more detail and to implement the countermeasures, according to the progress of the further PCV internal investigation and the studies of the fuel debris retrieval methods.

⑥ Reducing radiation exposure for occupational workers

The main work areas of the fuel debris retrieval are high dose areas such as inside the reactor buildings. Also, in the new stage of fuel debris retrieval, there comes a need handling of nuclear fuel materials containing α -nuclides with a large internal dose impact. Accordingly, continued strict control of not only for external exposure but also for internal exposure is essential.

Specifically, it is important to prevent excessive exposure to occupational workers through appropriate radiation protection schemes depending on the working environment and working

style. Regarding protection from external radiation exposure, the radiation exposure dose is evaluated considering the radiation sources and the dose rate in the work area. Then, based on the three principles, namely "time, distance, and shielding", it is needed to take measures to keep the radiation exposure dose as low as reasonably achievable. Regarding the protection from internal exposure, measures such as suppressing dispersion of radioactive dust and prevention of contamination expansion are being taken and appropriate protective measures are to be selected depending on the target nuclides, concentration in air and surface contamination density in the work area, to prevent inhalation ingestion and body pollution.

(4) Technical issues and future actions for fuel debris retrieval method

① Securing access route

For transporting, installing and unloading the equipment and devices used for fuel debris retrieval, and transporting fuel debris and waste, an access route should be established by removing obstacles and reducing the dose to the level at which such tasks can be done. When establishing a new opening in the PCV or the like to construct an access route to fuel debris, it should be kept in mind to suppressing the release of radioactive materials from the PCV and RPV and maintaining the integrity of existing structures.

According to the fuel debris retrieval policy based on the partial submersion method that extends the side access to the bottom of the PCV, TEPCO is now conducting the preliminary engineering work. Based on the results of R&D of decommissioning and contaminated water management, an access route from the PCV side opening to the fuel debris is to be constructed. Then, it will be drawn up a plan in which a side wall opening is made on the reactor building and the side wall opening on the PCV is enlarged as required.

According to the fuel debris retrieval policy, the optimum retrieval method should be selected depending on where the fuel debris exists for each reactor unit. At present, it is considered on the premise of accessing from the top to the inside of the RPV.

② Development of devices and equipment

Devices and equipment for accessing fuel debris and retrieving them safely, reliably, and efficiently should be developed. To flexibly respond to the situation on the site, these equipment and devices must meet the specifications of radiation resistance, remote inspection/maintainability, high reliability, and relief mechanisms that do not disturb the subsequent work if a trouble occurs.

Accordingly, the development of a recovery system that can handle various conditions of fuel debris, a fuel debris cutting system, and a dust collecting system, is underway. Furthermore, a technique for installing retrieval equipment is required. The technology used for remote operation, including installing the working cell for establishing a containment function (gas phase) and the device for removing obstacles to provide an access route, are now under development. The developed equipment and devices will be combined and undergo

mock-up tests to verify that the performance mentioned above is demonstrated on the actual site.

③ Establishment of system equipment and working areas

When retrieving fuel debris, it is necessary to install system equipment to establish safety functions and operate them appropriately. Also, it should be prepared that sufficient spaces for installation, operation, and maintenance, and for installing shields for reducing radioactive exposure to operators, so that the required environmental conditions are satisfied.

The system equipment include a negative pressure control system required for establishing a containment function (the air phase), a circulating water cooling/purification system required for maintaining the containment function (the liquid phase) and cooling function, and a criticality control system required for controlling criticality. Because it is essential to monitor the internal situation when retrieving fuel debris, the development of measurement systems (pressure, temperature, radiation, etc.) is an important future issue to be addressed. An investigation on how to implement the system equipment integrating these systems is under way.

The working area required for installing the fuel debris retrieval equipment/related devices and system equipment is now being calculated. Considering the handling of the high-dose area in the reactor buildings and interference with other tasks, study of setting up the systems, including outside of the existing buildings, is underway.

(5) Technical issues and future actions for safe and stable storage of fuel debris

① Handling of fuel debris (collecting, transferring, storing)

The fuel debris retrieval work requires to establish a comprehensive system consisting of a series of steps from collecting, transferring to storing of retrieved fuel debris furnished with safety functions such as maintaining subcritical condition, containment function, countermeasures against hydrogen generation, and cooling. Specifically, the basic specifications of the canister such as the total length and inner diameter has been studied taking the handling property, the storing rate and maintaining of the subcritical condition into account. The allowable transportation period has been investigated in accordance with the estimated volume of hydrogen generation from canister. Based on these results, details of equipment/systems for collecting, transferring, and storing of the retrieved fuel debris need to be discussed. Storing facility adaptable to the safeguards requirement is also required to be studied based on the estimated volume of retrieved fuel debris. It is also important to plan mock-up tests for confirmation of handling of the canister combined with a fuel debris retrieval device.

Proper handling method/devices for retrieved fuel debris in the subsequent stage need to be studied and improved taking the information/data obtained from work experience in previous stage as well as above mentioned technical issues into account.

The Roadmap states that the processing and disposal method of the retrieved fuel debris are investigated and fixed during the third phase after starting the fuel debris retrieval work.

② Treatment of radioactive waste during fuel debris retrieval work

During fuel debris retrieval work, various radioactive waste such as replaced or disassembled components or parts other than retrieved fuel debris are to be generated from fuel retrieval facility inside/outside of the PCV at each stage of its preparation, retrieval and cleaning work. It should be properly classified and stored under safe condition same as fuel debris.

It is important to develop a classification standard in order to judge appropriately such material into fuel debris or radioactive waste during retrieval work, even if only limited information on the retrieved material is available in advance. From above reason, detailed studies on treatment of retrieved materials including classification standard needs to be continued based on the findings and information obtained from the investigation inside of the PCV.

③ Safeguard policy for fuel debris

For the units 1 to 3 of the Fukushima Daiichi Nuclear Power Station, implementation of conventional material accountancy and safeguards is deemed difficult since the fuel assemblies as the basis of the material accountancy would no longer maintain their original shape due to melting, the broken facilities would not allow necessary containment/surveillance schemes, and high radiation would restrict the entry of human beings into the areas and prevent normal inspection activities, and so forth. Additional safeguards operations are currently applied under this situation to the units 1 to 3 as an alternative measure to ensure no undeclared relocation of nuclear materials, etc.

Given, however, the fuel debris retrieval work cause the movement of nuclear materials, corresponding safeguards operations will be required. Japan is providing updated information of the units 1 to 3 of the Fukushima Daiichi Nuclear Power Station to the stakeholders including the International Atomic Energy Agency (IAEA), aiming at the prompt and smooth application of the safeguards in the FDR operations. In addition to these activities, the realistic and transparent enough material accountancy and safeguards must be proposed to reach the global agreement among the stakeholders including IAEA.

Technical issues and further plans described in this article is as shown in Fig. 7.

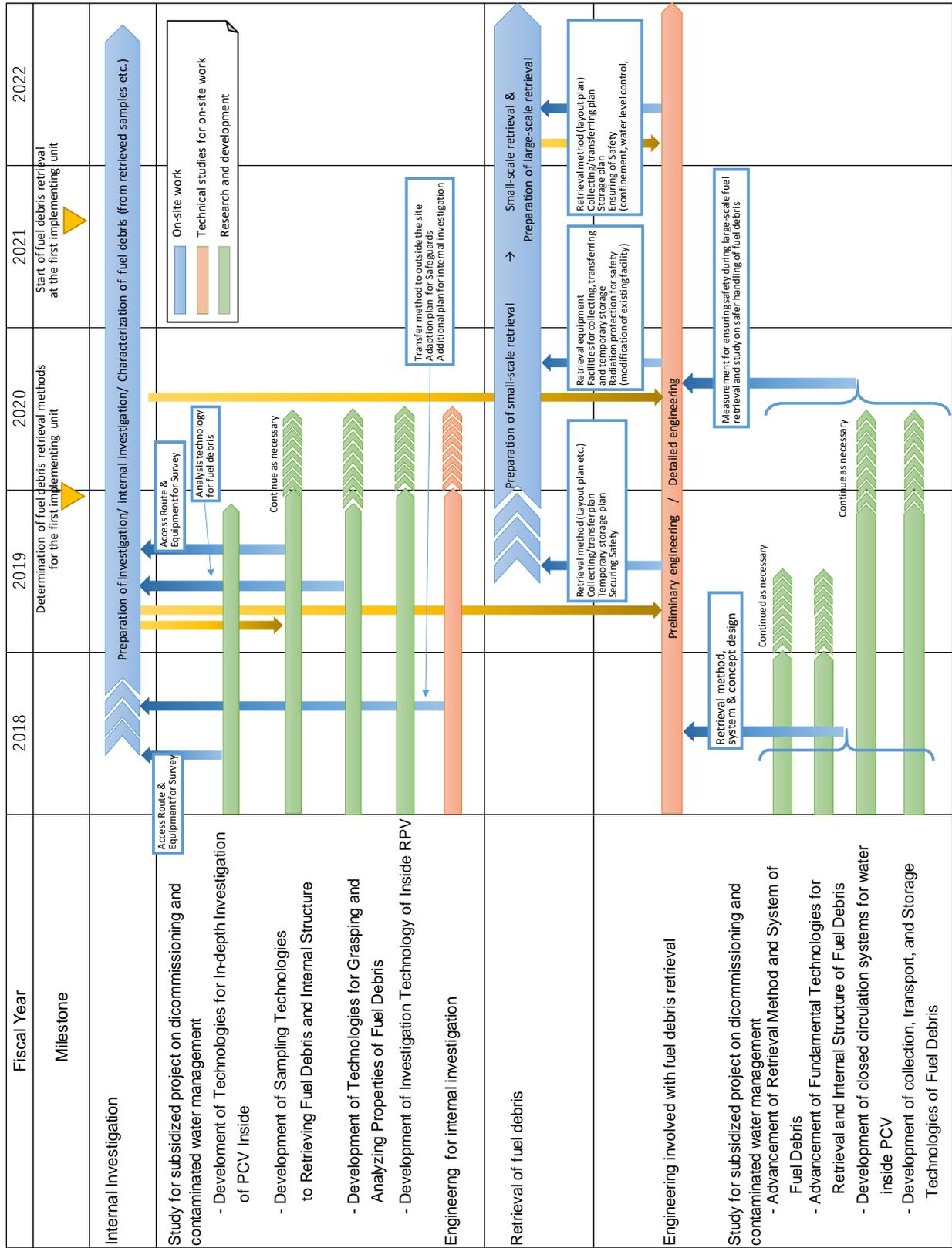


Fig. 7 Technical issues and further plan on fuel debris retrieval

2) Waste management

i. Sectoral target

- (1) As the approaches of solid waste storage, the Solid Waste Storage Management Plan (hereinafter referred to as the “Storage Management Plan”) is appropriately developed, revised and implemented including waste prevention, volume reduction and monitoring, with updating the estimated amount of solid waste to be generated in the next ten years periodically.
- (2) As the approaches for processing/disposal, countermeasures integrated from characterization to processing/disposal of solid waste will be proceeded from the expert point of view, and the prospects of a processing/disposal method and technology related to its safety should be made clear by around FY2021.

<Basic policies on solid waste>

- ① Thorough containment and isolation
Solid waste management should be implemented thoroughly, with containment and isolation of radioactive materials to prevent their dispersion/leakage and human access to them, in order not cause harmful radiation exposure.
- ② Reduction of solid waste volume
The amount of solid waste generated by decommissioning is reduced as much as possible in order to ease the burden of solid waste management.
- ③ Promotion of characterization
To proceed with study on processing and disposal method of solid waste, characterization of solid waste such as nuclide composition and radioactive concentration is needed. In addition to the fact that solid waste of the Fukushima Daiichi NPS is large in volume, and have varied nuclide compositions, it is necessary to address an increase in the number of analysis samples and proceed their characterization properly.
- ④ Thorough storage
To dispose of solid waste, it is essential to understand the volumes and characteristics of the solid waste, and to establish specifications of disposal facilities and technical requirements for waste packages (technical requirements for disposal). However, the volumes and characteristics of solid waste will become clear step by step, with the future clarification of progress and plan of decommissioning. Therefore, the solid waste generated should be stored safely and reasonably according to characteristics of solid waste. Storage capacity should be secured to ensure that the waste can be stored within the site of the Fukushima Daiichi NPS.
- ⑤ Establishment of selection system of preceding processing methods in consideration of disposal
In order to safely store solid waste, the system for selecting the method of processing for stabilization and immobilization (preceding processing) will be established, and selecting the method of the preceding processing, before the technical requirements of disposal are established.
- ⑥ Promotion of effective R&D with a bird's-eye-view of overall solid waste management
To efficiently proceed with R&D concerning solid waste management, close cooperation should be realized between R&D fields such as waste characterization, processing and disposal. Issues and discussions on R&D should be shared between parties, and necessary planning made with a bird's-eye-view of overall solid waste management, should be progressed collectively.
- ⑦ Efficient implementation of R&D projects from the perspective of overall solid waste management
In order to continue safe and steady solid waste management, the continuous operational framework system including development of adequate facilities and human resources, which are concerned with solid waste management, must be undertaken.
- ⑧ Measures to reduce radiation exposure of workers
To steadily proceed with solid waste management, it is important to ensure the safety and health of workers. Therefore, radiation exposure control, safety management and healthcare programs should be implemented thoroughly based on the relevant laws/regulations.

(Note) Numbered and titled by NDF for each item.

ii. Sectoral strategy

(1) The concept of risk reduction in waste management and basic policies on solid waste

The solid waste stored on the sites, such as “rubble, etc.”, is unlikely to increase in risk in the future, but they are still a source of risk which should make its countermeasures properly in the decommissioning process. They are in a state where the risk level is generally lower than other major risk sources, and it is considered that a constant risk level can be continuously maintained by appropriate maintenance and management in the future.

The challenge on solid waste generated by decommissioning of the Fukushima Daiichi NPS is the existence of a large volume of waste with various characteristics. For this reason, in addition to improving the capability of analysis for characterization, it is necessary to develop a flexible and rational waste stream. Specifically, the relevant organizations should proceed their efforts based on each role in line with the basic policies of solid waste management that was compiled in the Roadmap, and the technical study on the integrated countermeasures from the characterization to processing/ disposal of solid waste will be proceeded with following policies at the initiative of NDF.

(2) Storage

The fundamentals of managing solid waste are to contain not to scatter or leak. Also, it should be kept isolated in a properly storage place, and managed appropriately by monitoring and so on. It is important to instill the concept of the waste hierarchy, and raise awareness on reducing the volume of solid waste to be generated.

To store solid waste properly, TEPCO releases its Storage Management Plan, and estimates the volume of solid waste that will be generated in the next ten years, and shows their policy such as on building waste management facilities to be required based on the volume. Since the estimated amount of generation fluctuates depending on the progress of the decommissioning work in the future, it is necessary to revise the volume estimation once a year and update the Storage Management Plan as appropriate.

(3) Further safety improvement in storage

The secondary waste generated by water treatment, which has high fluidity, should be stored in a more stable and reasonable way. In general, it is ideal to conduct waste processing based on the technical requirements of disposal once it is established, if the processing is conducted prior to disposal. However, there may be cases where processing for stabilization and immobilization are required although the technical requirements for disposal are not determined (i.e. preceding processing). Therefore, study will be continued on how to select the preceding processing method with disposal in mind.

(4) Study on the processing/disposal policy

The Roadmap specifies that the prospects of a processing/disposal method and technology related to its safety should be made clear by around FY2021. The overall picture of solid waste

becomes clear step by step according to the progress of the effort. Keeping in mind that it will still remain in a stage of accumulating necessary information on its characteristics around FY2021, the concrete targets for technical perspective are listed as follows:

- Establish safe and rational disposal concept based on characteristics and volume of the solid waste generated in the Fukushima Daiichi NPS with its applicable processing technology, and develop safety assessment method reflecting features of the disposal concept, with considering examples of foreign countries
- Clarify radiological analysis and evaluation method for characterization
- Clarify processing technology that would be expected to introduce actual equipment for stabilization and immobilization considering disposal for several important waste streams such as secondary waste generated by water treatment
- Establish method of rationally selecting processing technology to stabilize and immobilize waste based on the above methodology although the technical requirements for disposal are not determined (i.e. preceding processing)
- Have prospect of setting processing/disposal measure for solid waste of which the processing technology considering disposal is not clarified, using a series of method to be developed by 2021
- Clarify issues and measures concerning storage of solid waste before conditioning

It is described in the Roadmap that in accord with these efforts, specifications and production methods of the waste packages should be determined in the third phase. Then, a processing system should be installed in the Fukushima Daiichi NPS. After establishing the prospects of disposal, production of waste packages should be started, and then carried out

iii. Technical issues and plans for promoting sectoral strategies

(1) Promotion of characterization

Under the circumstance that the Building 1 of JAEA Okuma Analysis and Research Center is scheduled to commence operation at the end of FY2020; it is important to improve the accuracy of models to obtain evaluation data based on the limited number of radiological analysis data. The study will be proceeded on the method of reflecting dispersion of radiological analysis data to inventory evaluation using analytical method, and concept of setting and revising radioactive inventory based on comprehensive evaluation of radiological analysis data and analytical value.

The radiological analysis has been conducted for characterization so far, but target of radiological analysis will be mainly on the predisposal management and review targeted nuclides in near future. The study on radiological analysis to make it simple and rapid is proceeded together to develop efficient radiological analysis method. Through these efforts, a system, facilities and equipment, and technologies for highly accurate characterization of solid waste will be established by the end of FY 2020, and necessary radiological analysis data will be acquired for some solid waste.

(2) Further safety improvement in storage

The secondary waste generated by water treatment is proceeded to be dehydrated for stabilization, and extracted and transferred from temporary storage facilities to storage facilities on a hill as risk reduction measures for the time being.

On the technologies for stabilization, immobilization and conditioning of the secondary waste generated by water treatment, challenges for introducing actual equipment should be dealt, and gathering and evaluation of data on technical requirements should be proceeded. Processing technology expected to be applicable for actual processing should be identified, and specification of waste package should be determined, from the point of view whether it may contributes to establish selection method for preceding processing method.

Regarding the methods of storing high-dose solid waste generated during fuel debris retrieval, study should be proceeded on the items such as the way of sorting fuel debris/waste, the type of waste, the evaluation of waste volume, and the flow of handling waste, and narrow down candidate methods for storage.

For other solid waste, study should be proceeded on generation of hydrogen during storage, together with the timing and content for the case of requiring further measures to secure safety, and reflects to the Storage Management Plan as needed.

(3) Establishing processing/disposal concept and development of safety evaluation method

In order to select candidate technology as a preceding processing method, it is necessary to conduct safety assessment with the specification of the waste packages that is developed by respective candidate technologies, as a target. For that reason, selecting reasonable and feasible candidate technologies and developing safety assessment methods will be proceeded by the end of FY 2021.

(4) Others

As solid waste to be generated with the retrieval of fuel debris in future, structures such as core internals and outside of reactors to be dismantled and removed, and second waste such as filters generated during fuel debris retrieval related works are expected. It is necessary to proceed study on the storage method for the solid waste together with the study on the method of fuel retrieval.

Technical issues and further plans described in this article is as shown in Fig. 8.

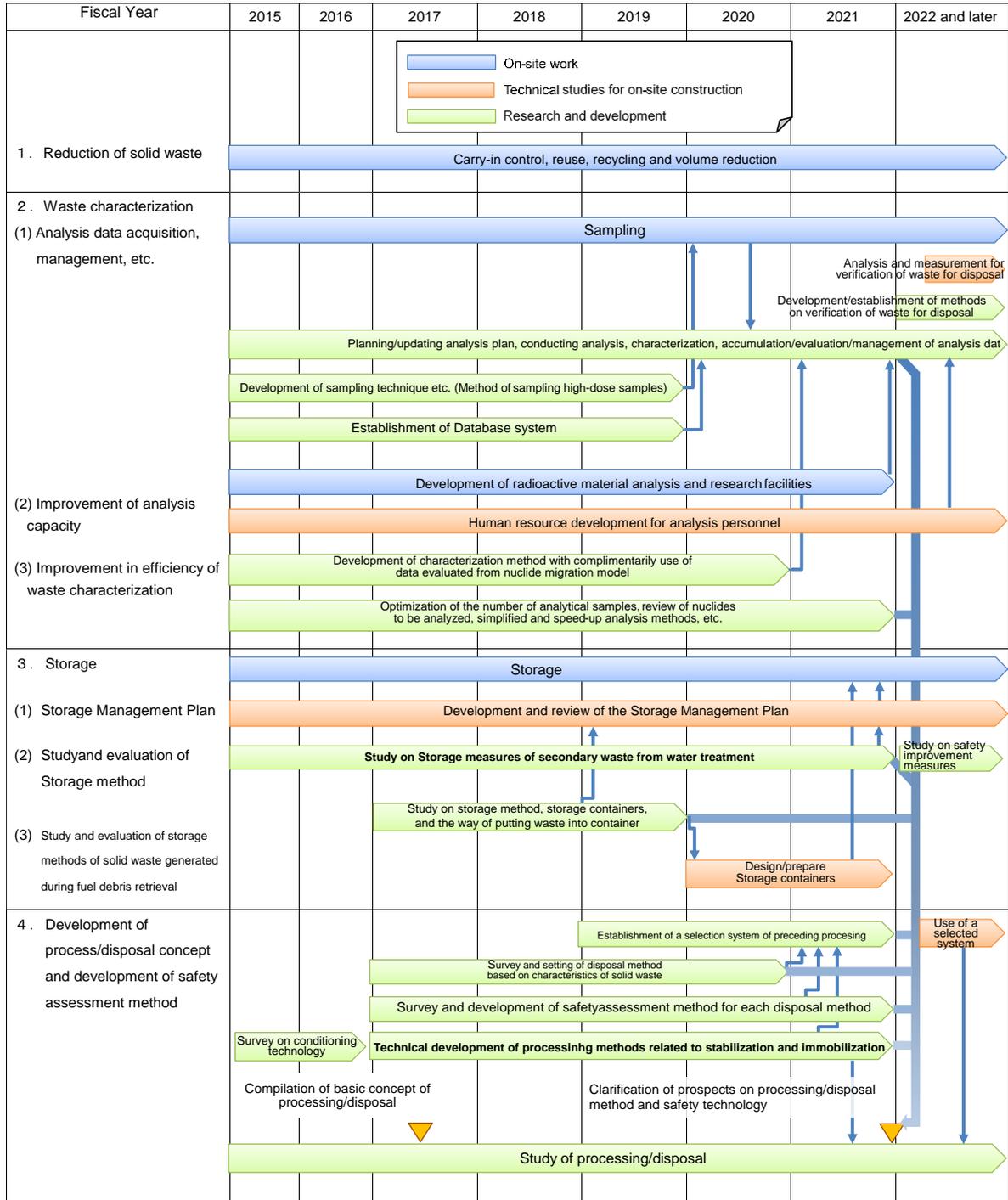


Fig. 8 Technical issues and further plan on waste management

3) Contaminated water management

i. Sectoral target

- (1) Under the three basic principles concerning contaminated water issues (“Removing” contamination sources, “Redirecting” fresh water from contamination sources, and “Retaining” contaminated water from leakage), the reinforcement and optimum operation of the water level control system should be continued. The multilayered measures should be implemented to complete the processing the stagnant water in the buildings by 2020¹.
- (2) Considering the total decommissioning process including the full-scale fuel debris retrieval beginning in near future, the long term strategy should be examined for the measures of the contaminated water.

ii. Sectoral strategy

(1) Concept of risk reduction in contaminated water management

For the contaminated water management, various measures based on the three principles has been implemented both to the contaminated water in the buildings and trench/pits and uncontaminated water such as groundwater/storm sewage. The stagnant water in the buildings is the liquid containing a considerable amount of dissolved radioactive materials and its hazard potential is relatively high. Thus the stagnant water is required to be dealt with as soon as possible.

The stagnant water has been treated with cesium adsorption apparatus and the radioactive materials are transferred to the secondary waste such as adsorption vessel, so that the stagnant water is reducing its risk level.

(2) Steady execution of contaminated water management stated in the Roadmap

From a situation requiring urgent countermeasures immediately after the accident, it is thought that it has shifted to a certain stable state where it is possible to forecast a medium to long-term plan to some extent by preventive and multilayered countermeasures based on the three principles on the issue of contaminated water. The milestones mentioned in the Roadmap are as follows: (1) reduction of the contaminated water generation to about 150 m³/day (by 2020), (2) storing all the water treated by nuclides removal equipment in the welded type tanks (FY 2018) (3) by lowering the level of stagnant water in the buildings, separation of the penetrations between Units 1 and 2 and between Units 3 and 4, respectively (by 2018²), (4) reduction of the radioactive materials in the stagnant water in the buildings up to approximately one tenth of the amount at the end of FY 2014 (FY 2018), and (5) completion of the treatment of stagnant water in the buildings (by 2020), and the tentative actual measures for achieving these milestones

¹ Exposing the floor line for buildings other than the reactor building and lowering the water level of the reactor building to T.P.-1740mm (O.P. - 300 mm or less) (Circulating water injection cooling is carried out in the reactor building, and stagnant water continues to exist).

² Completed in September 2018.

have already been identified. It is expected to achieve the milestones by implementing these countermeasures steadily.

(3) Study on contaminated water management based on the relation with fuel debris retrieval work

Because full-scale decommissioning work including fuel debris retrieval will start after a while, it is necessary to discuss the optimal control of contaminated water and groundwater together at each stage of the decommissioning process.

According to the target process of the Roadmap, it is considered that the processing of stagnant water in the buildings other than the reactor buildings of unit 1 - 3 will be completed by 2020. By that time, a circulation system in which the stagnant water is recovered in the reactor buildings (instead of turbine buildings) and purified to be used as a coolant should be established. Furthermore, the study including feasibility of the PCV circulation cooling system for fuel debris retrieval work is under way, and to secure multiple boundaries, water shielding by repairing the bottom of PCVs has been examined. However, it has been found that complete water shielding through repairing the bottom of PCVs is very difficult, so the circulation system should prepare for the inflow of α -particles from inside of the PCVs to the stagnant water in the reactor building. Even if the water shielding is applicable, it is necessary to consider setting a sufficient difference in water level between stagnant water in the reactor building and groundwater, in case a large amount of cooling water leaks from a PCV into the reactor building.

As the fuel debris retrieval proceeds and water injection for cooling the fuel debris is no longer necessary, the injected cooling water will not stay on the lowest floor of the reactor building. In that case, the groundwater level should be adjusted to a level below the lowest floor of the reactor building, so it can be expected that there is no water inflow into the reactor building. In such a case, it is important to build a system that can stably control the groundwater level for a long period, such as by combining passive equipment with fewer machine troubles than other dynamic equipment.

iii. Technical issues and plans for promoting sectoral strategies

(1) Steady execution of contaminated water management stated in the Roadmap

Stable management of groundwater around the buildings has been made by strengthening the sub-drain function and installing land-side impermeable wall, etc.

(2) Study on contaminated water management based on the relation with fuel debris retrieval work

When retrieving the fuel debris, fuel debris-derived substances including α -particles may be transferred to the PCV circulation cooling system. Therefore, the PCV circulation cooling system must properly remove them. To handle the constant generation of water inflow into the buildings, it is necessary to set the conditions for receiving a part of water treated by the PCV circulation cooling system in the existing stagnant water circulation system.

Technical issues and further plans described in this article is as shown in Fig. 9.

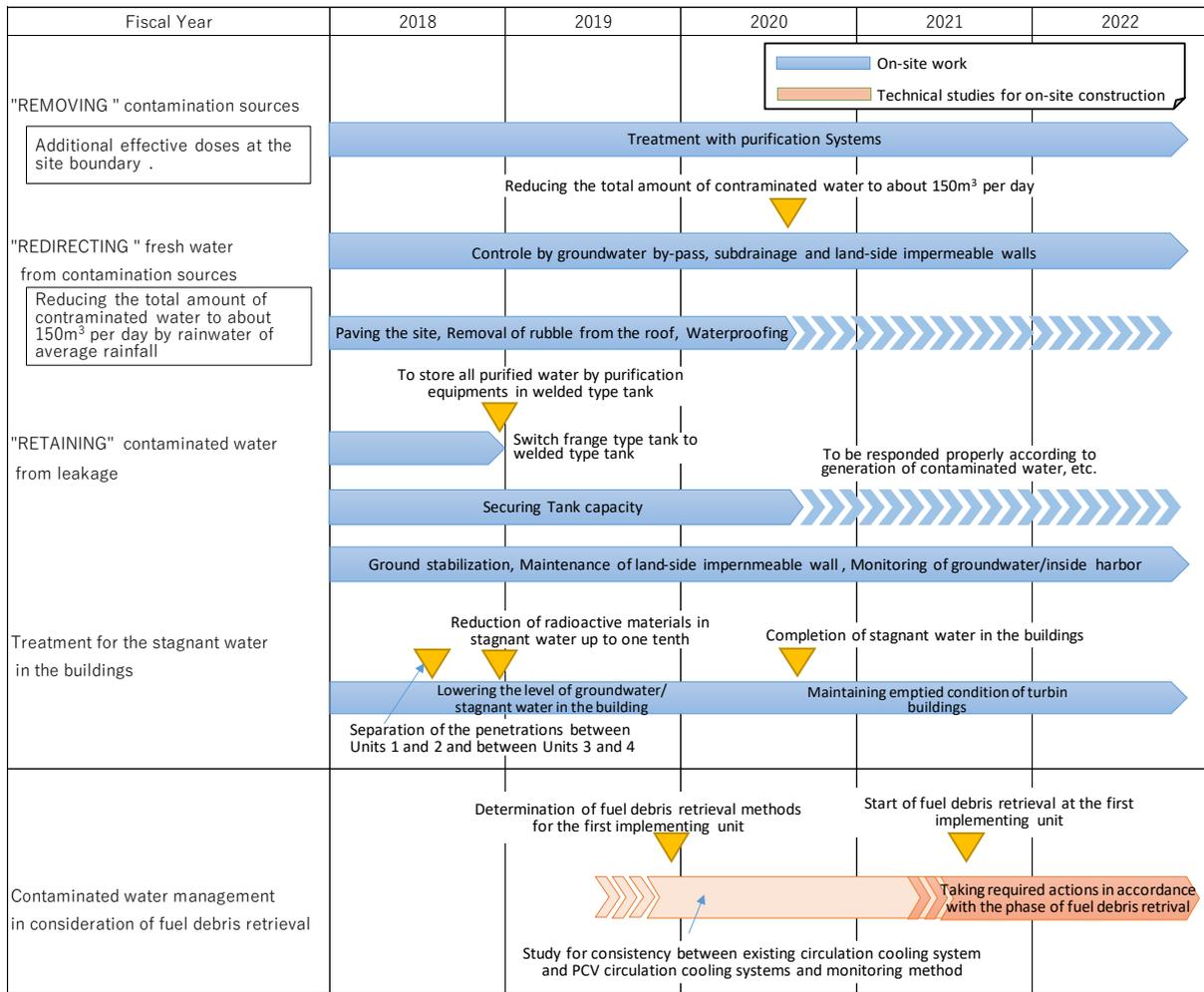


Fig. 9 Technical issues and further plan on contaminated water management

4) Fuel removal from spent fuel pools

i. Sectoral target

(1) To start removing the fuel from the pool by around

- 1) FY 2023 for Unit 1
- 2) FY 2023 for Unit 2
- 3) Mid FY 2018 for Unit 3³

under the rigorous risk assessment and management and taking measures for safety and security including preventing the disperse of radioactive materials.

(2) By transferring the fuel stored in the Common Spent Fuel Storage Pool to the dry cask at the Temporary Cask Custody Area, the fuel in the spent fuel pools of Units 1 to 4 is to be stored in the Common Spent Fuel Storage Pool appropriately.

(3) Based on the assessment of the long-term integrity and investigation for future treatment of the removed fuel, the storage and future treatment methods of them will be fixed around 2020.

ii. Sectoral Strategy

(1) Risk reduction concept and concrete plan for removing the fuel from the pool

The fuel stored in the pool of the reactor buildings of Units 1 to 3⁴, some of which were partially damaged by the hydrogen explosion, is to be transferred to the Common Spent Fuel Storage Pool that needs lower safety management than the pool of the reactor buildings in accordance with an appropriate and concrete work plan developed depending on the situation of each unit, as soon as possible.

Work schedule for Units 1 to 3 was already specified in the Roadmap, and TEPCO has been proceeding with their tasks to meet this schedule. Currently, in Unit 1, the building cover had been removed, wind breaking fence had been installed, and then removal of some fallen rubbles generated by Hydrogen explosion were initiated under taking measures for prevention of radioactive dust dispersion. The time to start removing fuel in the pool is targeted for FY2023. In Unit 2, it is planned to dismantle the upper part of the reactor building in order to install fuel retrieval facilities. Making of opening to have access to the operating floor and installing a front chamber to prevent dispersion of radioactive material have been implemented, surveillance of the operating floor and countermeasures are under way. The time to start fuel removal from the pool is targeted for FY2023. In Unit 3, a cover for fuel removal from the pool was installed in February 2018. Once started the trial operation for fuel handling equipment, several troubles have occurred. TEPCO intends to examine and review the start of fuel removal in the spent fuel

³ In Unit 3, several troubles have occurred after the trial operation of fuel handling equipment is commenced in March 2018. In addition to investigating the cause and taking the measures, trial operation will be restarted after the issue on quality management is improved which is thought as a common factor. By giving the highest priority to safety, TEPCO is examining and reviewing the scheduled target of fuel removal in the pool within November 2018.

⁴ Removal of fuel from the pool of Unit 4 finished in December 2014.

pool which was scheduled in November 2018.

The fuel is also being stored in the pool of Units 5 and 6 reactor building under stable conditions same as a normal nuclear power plant. The Roadmap states that the fuel of units 5 and 6 should be properly stored in each spent fuel pool for the time being and will be removed them from each pool at when such removal work becomes not to affect fuel removal and fuel debris retrieval work of Units 1 to 3.

(2) Storage plan of removed fuel

Appropriate capacity for the fuel in the pools of each unit should be reserved both in Common Spent Fuel Storage pool and in Temporary Cask Custody Area. For this reason, it is necessary to expand storage capacity of the Temporary Cask Custody Area systematically.

(3) Decision on storage and future treatment methods

The spent fuel pools is storing many kind of spent fuel such as flawless spent fuel, damaged one before the accident, and that may be damaged by the fallen rubbles into the spent fuel pool. Corrosion due to seawater sprayed and injected into the spent fuel pool of Units 2, 3, and 4 at the accident is another concern. It is necessary to investigate that additional attention for the handling/storing of such fuels is required compared with that for normal spent fuel.

Storage and future treatment methods for removed fuels from the pools will be decided around 2020 based on the investigation results on long-term integrity assessment and treatment method for them.

iii. Technical issues and future actions for promoting strategies

(1) Removing fuel from the pools

<Unit 1>

During removing rubble on the operating floor, countermeasure for preventing falling the fuel handling machine (FHM) and overhead crane into the fuel pool need to be considered carefully. Removal of rubble on the operating floor and manipulation of the well plugs need to be carried out with countermeasure to prevent dust dispersion as well as dose monitoring system to limit the increase of sky-shine radiation under allowable level.

In addition, appropriate removal method for the damaged fuel before the accident needs to be prepared.

<Unit 2>

Installing a common container/cover for both fuel removal and fuel debris retrieval, or a container/cover exclusively for fuel removal only on the operating floor will be chosen by an appropriate time based on the period of fuel debris retrieval work and fuel removal from the pool.

Also, the scope and method of dismantlement and modification of the above of the operating floor need to be investigated and established to its work plan based on the results of the investigation on the operation floor.

Before removing the fuel from the pool, the exhaust stuck for Units 1/2 will be dismantled.

<Unit 3>

Fuel in a spent fuel pool need to be taken out combined with removal of the fallen rubble on top of the spent fuel. Accordingly, procedure for removing fuel needs to be developed considering how to remove rubble.

(2) Proper storage of removed fuel

For the deliberate transportation and storage of spent fuel and fresh fuel possessed by the entire site, a fuel transport plan need to be developed taking fuel stored in the Units 5/6 into account. As well, the storage capacity need to be increased and additional facilities are also necessary to be installed according to that plan.

(3) Decision on future treatment/storage method

R&D on the long-term integrity of the fuel in the pool which has contacted with seawater or fallen rubble has indicated that removed fuel can be stored safely under the environment of Common Spent Fuel Storage Pool for a long period. Also, it was confirmed that the effect of seawater and scratches by fallen rubble on the fuel is limited for integrity of stored fuel in the dry cask. Furthermore, another R&D showed a perspective that the impact of seawater and scratches by fallen rubble on the fuel is very limited on the treatment of the fuel removed from the pool.

In the future, necessity of further study on its long term storage need to be evaluated based on the inspection/survey results of the fuel taken out from Unit 3, which is experienced the severe explosion caused by the accident and some of fuel may be damaged by the fallen rubble.

Technical issues and further plans described in this article is summarized in Fig. 10.

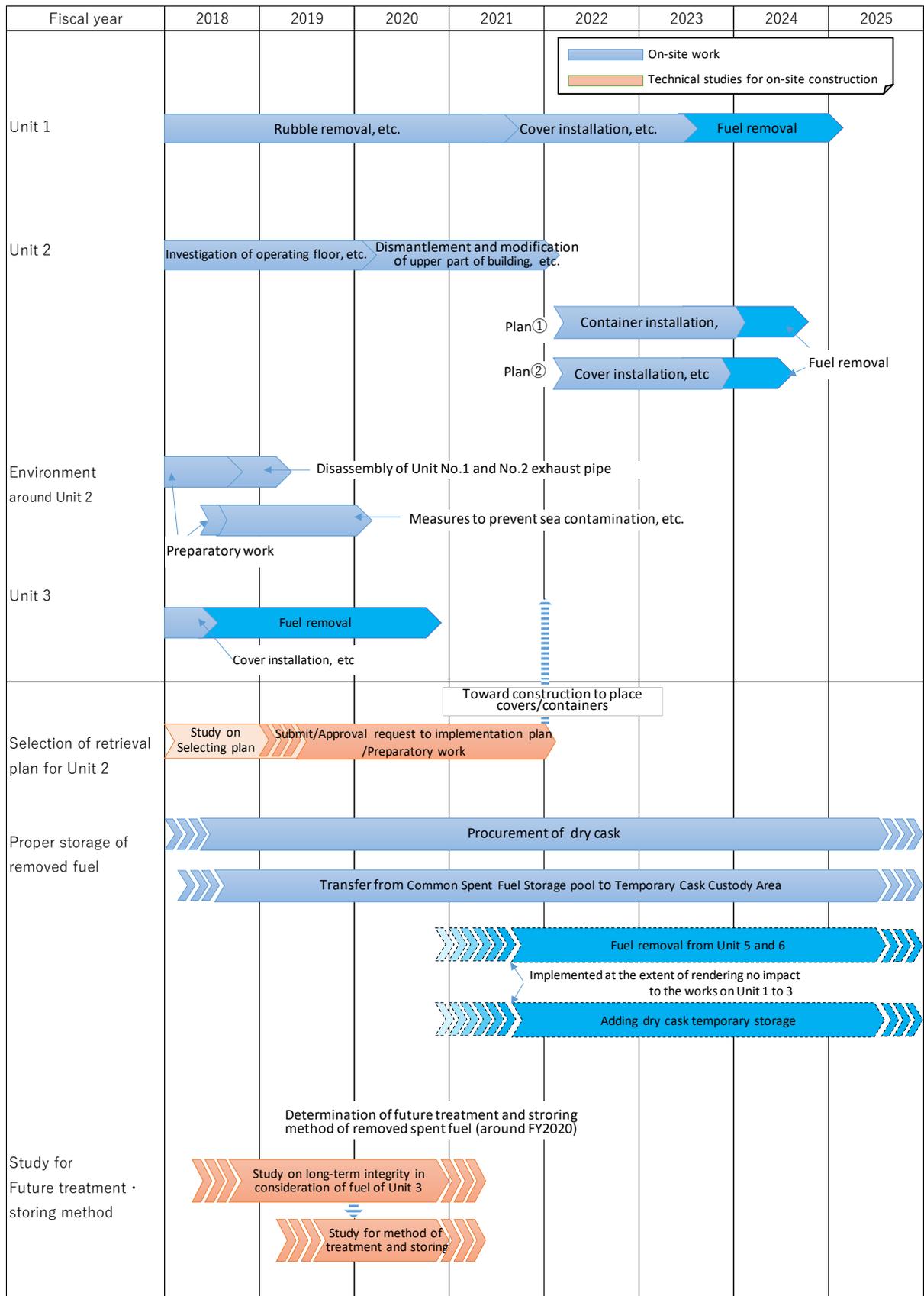


Fig. 10 Technical issues and further plan on removing fuel from the spent fuel pool

5) Other specific measures

i. Sustaining of reactor cold shutdown status

As for the plant conditions of Units 1 to 3, it is judged that a stable state of cold shutdown is maintained based on the internal plant data on PCVs, such as radiation dose, temperature, hydrogen concentration, pressure, radioactive substance concentration, etc. To maintain the stable state in the future, it should be continued to monitor parameters in PCVs and seal nitrogen to reduce a risk of a hydrogen explosion, while maintaining and improving reliability through maintenance and management.

ii. Radiation dose reduction and contamination expansion prevention all over the power station

(1) Prevention of sea contamination expansion

The concentration of radioactive materials in the port is below the concentration limit defined in the notification because of the removal of highly concentrated contaminated water in the trench, installation of the sea-side impermeable wall, covering of the seabed soil, etc. Measures to reduce the concentration of radioactive materials in the drainage channels that flow into the port, including measures to manage rainwater flowing in from the rooftops of buildings and paving around the buildings, should be continued.

Regarding contamination of the soil in the vicinity of the harbor, assessing the impact on the ocean from a long-term perspective and future environmental restoration, R&D should be conducted such as to clarify the near-surface nuclide migration mechanism and refine the analytical models.

(2) Management of gas and liquid waste

Monitoring of gas and liquid waste should be continued and its emission should be closely controlled to ensure that the concentration limits defined in the Notification is strictly observed. With this view, proper countermeasures should be taken as their concentrations are made as low as possible based on a reasonable methods.

(3) Dose reduction through site decontamination

In March 2014, TEPCO formulated "Implementation Policy of Dose Reduction on the Site of the Fukushima Daiichi NPS" and set target dose rates in stages for each area in the sites to reduce the dose. As a result of these efforts, the target dose equivalent rate of 5 $\mu\text{Sv/h}$ was achieved at the end of FY 2015 in the area that lots of workers work other than the zone surrounding Units 1 to 4 and the waste storage area. Currently, the area in which it is permitted to work with general work clothes has increased to 96% of the entire sites. The dose rate should be maintained below 5 $\mu\text{Sv/h}$ and as close as possible to the situation before the accident ultimately by lowering the target dose equivalent rate in stage.

(4) Reduction of environmental impact

Regarding the evaluation of the dose at the site boundary including additional emissions from the entire site, reducing the effective dose is continued to address after the goal to reduce the value to less than 1 mSv/year has been achieved at the end of 2015 in the result of the efforts stated in the previous clauses and purification of highly contaminated water.

(5) Comprehensive risk review

TEPCO conducted a comprehensive inspection of risk sources that may affect the outside of the site and announced it in April 2015. As a result, for the radiation sources requiring additional measures, specific measures were discussed while taking priorities into consideration. They were reviewed as appropriate reflecting environmental changes, and have been explained and announced at places such as the local adjustment meeting for decommissioning and contaminated water management.

Also, the Nuclear Regulation Authority created a target map for reducing the mid-term risk of the Fukushima Daiichi NPS in February 2015. This Mid-term risk reduction target map, which has been updated from time to time, is characterized by a risk reduction work process of about three years emphasizing the presentation of residual risk. In regard to this, TEPCO reported the current approach, issues and responding status according to the further schedule in May 2018.

It is important to continue to reduce and comprehensively grasp the risk sources like this, while taking the positioning and priority in the entire decommissioning project into consideration for implementing each measure.

iii. Plan for decommissioning measures for nuclear reactor facilities

In the Roadmap, TEPCO should formulate a decommissioning plan of the Fukushima Daiichi NPS in phase 3 after commencing fuel debris retrieval work, after starting debris retrieval operations. NDF should provide multifaceted and expert advice and guidance based on the progress and forecast of the decommissioning, the situation of the reactor buildings, and the trends of R&D with wisdom and knowledge from around the world.

As for Units 5 and 6, spent fuel removal should be carried out with reference to progress of works in Units 1 to 4, and then, decommissioning plans should be formulated for Unit 5 and 6.

iv. Concrete efforts toward securing safety

(1) Efforts to ensure work safety

For the work plans that require workers to intervene in a high-dose environment, it is important to evaluate the environment according to input resources from the viewpoint of "justification and optimization", aiming to ensure the safety of the working environment as well as suppressing personal dose. Particularly when the work is "for the first time," "changed," or "for the first time in a long time," it is essential to fully implement work training using a mockup in order to design, implement and verify effective work procedures and test methods.

Moreover, it is necessary to formulate a detailed work plan for each work step, to take preventive measures concerning troubles that may occur, and to consider ways to cope with unexpected situations.

In line with the Roadmap, it is stated that measures for industrial accident prevention will be taken and reviewed continuously, medical preparedness will be planned in anticipation of industrial accidents, and measures will be taken to reduce occupational risk exposure as much as possible. It is important to ensure a perfect system of work safety by continuing these efforts.

(2) Efforts for facilities safety

In the Fukushima Daiichi NPS where there are various kinds of work and safety facilities, special attention to the safety of facilities is also essential. For this reason, measures are implemented to maintain and improve equipment reliability based on the maintenance plan for every piece of equipment. Particularly, for equipment vital to securing safety for cooling fuel debris, it is important to continue thorough measures that will be taken to prevent their important function from stopping, not just from the standpoint of equipment but from management and operation standpoints as well.

(3) Security enhancement

A great quantity of nuclear fuel material is stored in the Fukushima Daiichi NPS. Accordingly, it requires particular attention to be paid for its security same as a normal nuclear plant, measures to confirm the reliability of each individual, enhance nuclear security training, prevent unauthorized intrusion into the sites, etc. are being implemented. Continuing with these efforts, it is necessary to implement appropriate measures for operation to allow accepting the visits of inspectors.

6) Comprehensive efforts for the decommissioning project of the Fukushima Daiichi NPS

As mentioned in Chapter 2, in the decommissioning project of the Fukushima Daiichi NPS in the future, it must be addressed more complex, uncertain challenges over the long term, such as fuel debris retrieval work. Therefore, regarding the efforts of each field listed in 1) to 5), a more proactive, systematic approach will be needed to solve the challenges rather than fulfilling tasks in a reactive manner such as those mentioned above. Particularly, the decommissioning of the Fukushima Daiichi NPS involves great uncertainty, it must be proceeded while always facing project risks like this. If it has a big difference between information or estimation when the plan developed and another obtained by progress of work, it may be difficult to conduct works as scheduled originally. Furthermore, it is important to optimize resource allocation and scheduling while ensuring the consistency and feasibility of the entire efforts to be promoted concurrently while having interrelations. Based on this viewpoint, the overall plan of the decommissioning project should be formulated and discussed while setting reasonable intermediate targets from a facility-wide long-term perspective. Because various efforts are performed in parallel manner, it is a significant challenge how the consistency among works should be ensured.

Furthermore, it is important to optimize resource allocation and scheduling while ensuring the consistency and feasibility of the entire efforts to be promoted concurrently while having interrelations. Namely while this complicated and multilayer project should be controlled based on individual tasks of appropriate scale and control size, the entire decommissioning project should

make progress comprehensively in consideration of the mutual relationship among the smaller projects. The overall plan of the decommissioning project should be formulated and considered while assuming reasonable intermediate targets by overviewing the entire site from a mid-and long-term perspective.

Regard to the project risks to sustain stably for entire decommissioning project as this, it is essential to take appropriate responses from the proper implementation of progress management and fund management of work, while learning from overseas precedent cases.

4 Handling critical enablers for smooth operation of the project

1) Actions toward improvement of working environment and conditions

The working environment of the Fukushima Daiichi NPS has now been dramatically improved. A good working environment is the basis for ensuring safe and steady progress of the decommissioning project of the NPS, which will be carried out over the long term. For example, TEPCO is improving the working environment infrastructure by consolidating and removing existing rest stations and setting up alternative rest stations, etc. Moreover, variety of measures are taken such as management for safety and sanitation, preventing heatstroke, exposure management, dose reduction measures in the site.

2) Concept of securing safety and promotion of cooperation

Because it needs to discuss, in parallel, specific tasks and regulations to be observed in conducting tasks such as fuel debris retrieval work for which no preceding experience exists in the world, principle of securing safety should be established according to the situation of the Fukushima Daiichi NPS. In light of this, NDF, TEPCO, the Agency for Natural Resources and Energy and other organizations will cooperate with each other, communicate actively with the Nuclear Regulation Authority, and take appropriate actions such as presenting policies and observation data related to ensuring safety at an early stage.

3) Enforced management structure for steady mid-and-long-term decommissioning

TEPCO has partly prepared a project structure for various work relating to decommissioning. However, line operation management and project operation coexist in actual management, leading to slow decision-making, there is a challenge that it is not necessarily efficient as a whole. For this reason, it is necessary to shift the organization management to project-oriented management and reinforce the organization and functions to coordinate the projects. At the same time, it is necessary to enable TEPCO to manage its engineering and make it function, in order to make a structure of project management work effectively based on a deep understanding of the technical work of individual tasks.

4) Developing and securing human resources

i. Developing and securing operators and engineers

The decommissioning project of the Fukushima Daiichi NPS requires completely different skills from the technologies related to the construction and operation of NPSs that TEPCO has accumulated to date as well. Accordingly, the Decommissioning R&D Partnership Council has prepared a draft technology map to grasp the overview of necessary technologies and decommissioning personnel, it is expected for related institutions to utilize it for developing and securing human resources.

In handling a complex large-scale project like the decommissioning of the Fukushima Daiichi NPS that involves many related factors, it requires specialized personnel with the ability to manage projects from a comprehensive perspective, including the consideration of the relationship between the projects based on the overview of the entire decommissioning process.

ii. Fostering the next generation to play roles in the Decommissioning of the Fukushima Daiichi NPS in the future

To carry out R&D activities sustainably for a long period, industry, academia, and the government related to nuclear power should steadily continue efforts for human resources such as development and securing of future researchers and engineers.

Specifically, the industry and educational institutions should cooperatively continue the activities to nurture students' understanding of the nuclear power industry and show the attractiveness of the industry. They should also convey students that the decommissioning of the Fukushima Daiichi NPS is an extreme technological challenge unprecedented in the world, as well as building and showing a variety of career paths for researchers and engineers to take part.

Furthermore, in long-term and large-scale projects such as the Fukushima Daiichi NPS decommissioning, it is essential to develop core personnel for research and development who can perform scientific and engineering investigation from an academic perspective and personnel with a panoramic perspective (system integrators) who can integrate individual technology seeds into a system with practical functionality. This activity is being implemented by Essential R&D themes described next in Chapter 5.

5 R&D initiatives

1) Basic policy for R&D

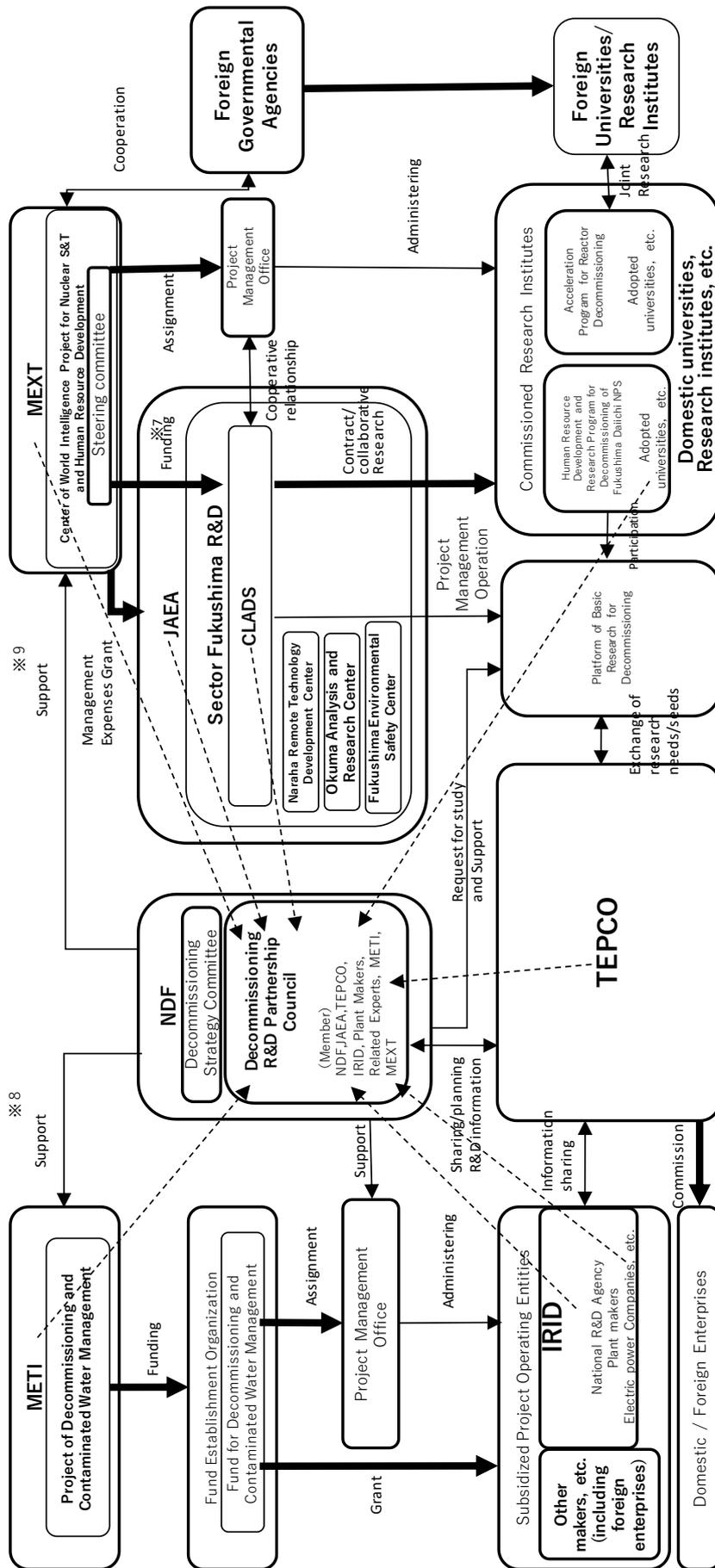
i. Basic policy

NDF has developed an R&D duties implementation policy based on the NDF Act, and has been managing a wide range of R&D to support the steady implementation of initiatives technically according to the Roadmap.

As detailed processes towards the decommissioning will be clarified, the roles of each R&D player should be more clarified. In this case, it is necessary to arrange the division of roles and responsibilities between the government and the operator in an appropriate manner in order to steadily implement R&D results on the decommissioning site. To back up the implementation of the mid-and-long-term decommissioning project, it is considered to be further expected that the government and the relevant research institutes should establish centers of basic research/research infrastructure based on a mid-and-long-term perspective. Research institutes are expected to enhance the technologies required for decommissioning through considerations on the status of the project and the fundamental R&D activities according to scientific and technological issues (needs) regarding the decommissioning.

ii. Entire perspective of R&D

Various problems exist in the decommissioning of the Fukushima Daiichi NPS, and R&D activities for solving these problems are being conducted by variety of industrial-academic-governmental institutions engaged with the Fukushima Daiichi NPS decommissioning R&D projects through the areas of basic/fundamental research, applied research, and development/utilization (Fig. 11). To organically link these activities and efficiently solve the on-site problems through R&D, NDF regularly holds meetings of the Decommissioning R&D Partnership Council according to the decisions of the Team for Countermeasures for decommissioning and contaminated water management.



- ※ 1 Decommissioning R&D Partnership was established in NDF according to a decision of Team for Countermeasures for Decommissioning and Contaminated Water Treatment.
- ※ 2 Bold solid arrow mean supply of R&D and management expenses (except for facilities expense). Light solid arrow means participation in Decommissioning R&D Partnership Council.
- ※ 3 Some institutions including JAEA are at the multiple positions.
- ※ 4 Each institution has their own cooperation with foreign institution based on MOU, etc.
- ※ 5 R&D activities by other institutions including Central Research Institute of Electric Power Industry are abbreviated.
- ※ 6 Among the promotion projects of nuclear energy science technology/human resource development that require collective know-how, the adopted projects up to 2017 were entrusted by MEXT to the trustee, which are not shown in this figure.
- ※ 7 Subsidies for the promotion projects of nuclear energy science technology/human resource development that require collective know-how are delivered to JAEA, but expressed as being delivered to CLADS for the sake of clarity here.
- ※ 8 For Decommissioning and Contaminated water treatment subsidy project, NDF drafts the next R&D plan and METI determines it based on the policies on Roadmap and the Strategic Plan and R&D progresses.
- ※ 9 NDF participates in the steering committee of human resource development project of Nuclear Science Technology that gathers wisdom and intelligence, as a constituent.

Fig. 11. Whole picture of R&D structure of the decommissioning of Fukushima Daiichi NPS (As of FY 2018)

2) R&D of decommissioning required for on-site work/engineering

There are two types of R&D activities towards practical use for successfully implementing the decommissioning of the Fukushima Daiichi NPS: the engineering activities including technological development implemented by TEPCO and the Project of Decommissioning and Contaminated Water Management carried out by selected subsidiary companies. Especially hereafter, R&D tasks engineering studies clarified its importance should be implemented timely and accurately.

Specifically, for the time being, R&D tasks are going to be identified according to the progress of the preliminary engineering work implemented by TEPCO, and then, it is presumable that the timing to implement such R&D tasks will be determined through considerations of the project management. To realize an R&D management system under such project-based schedule, appropriate information sharing should be carried out under the project management system enforced jointly by NDF and TEPCO. To this end, TEPCO and NDF should marshal the details of R&D currently in progress, and R&D tasks required in the future under the project management system in relation to the engineering schedule, that is, clarifying when the problem must be solved and which project needs it.

In this regard, even including implementing the tasks in the Government-led Project of Decommissioning and Contaminated Water Management, implementation of R&D tasks should be considered in line with the basic concept of an appropriate division of roles between the government and TEPCO according to the substances of the tasks. Specifically, more difficult R&Ds are considered to need supports by the government.

As specific processes become apparent, it will be required for TEPCO to make efforts to raise the ratio of technological development to improve the safety and efficiency of the decommissioning work. Under the Reserve Fund system, it is important to steadily figure out and implement the required technological development.

3) Enhancement of basic study and R&D infrastructure for the success of the decommissioning project

i. Essential R&D Themes and its strategic promotion derived from the needs

To facilitate the Fukushima Daiichi NPS decommissioning project in a safely steady and effective manner, it is essential to develop mid-and-long-term R&D strategies including scientific and technological investigation based on understandings of the principles and the theories. For this purpose, NDF has built a task force on research collaboration and specified the 6 Essential R&D Themes that should be preferentially and strategically targeted based on the discussions at the Decommissioning R&D Partnership Council. Thus, the Platform of Basic Research for Decommissioning was investigated and compiled R&D strategies for the Themes.

ii. Building R&D infrastructure based on mid-and-long-term vision

To make the decommissioning work proceed steadily in terms of technology, it is essential to work on developing R&D infrastructure and accumulating technological knowledge, developing generic technologies and collecting basic data, including the Essential R&D Themes, building up research centers, facilities and equipment, and human resource development.

The building for international research collaboration of JAEA/CLADS has opened in April 2017 in Tomioka-machi, Fukushima prefecture. According to a proposition by NDF, the Center of World Intelligence Project for Nuclear S&T and Human Resource Development by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) is implemented under the structure centered on JAEA/CLADS from the newly adopted issues since FY2018.

It is also important to develop research infrastructure of hardware. JAEA put the Naraha Remote Technology Development Center (Naraha-machi, Fukushima Prefecture) in service in April 2016, Fukushima Prefectural Centre for Environmental Creation where Fukushima Prefecture, JAEA, and the National Institute for Environmental Studies have their offices (Miharu-machi, Fukushima Prefecture) opened in July 2016, and JAEA opened the facility management building of the Okuma Analysis and Research Center (radioactive material analysis and research facility) (Okuma-machi, Fukushima Prefecture) in march 2018. R&D infrastructures aiming at the mid-and-long-term vision are being set up mainly in Fukushima Prefecture.

6 Enhancement of international cooperation

1) Significance of international cooperation

In recent years, nuclear reactors and nuclear fuel cycle facilities, constructed in the development age of nuclear power, are coming to the end of operating life and these decommissioning have already been progressing in the world. There are three major nuclear reactors caused severe accidents: Winscale Unit 1 in UK, Three Mile Island Unit 2 in the US, Chernobyl Unit 4 in Ukraine. These facilities have taken stabilization and safety measures for a long time. Furthermore, there is significant uncertainty in the management of various radioactive substances in past nuclear facilities called “legacy sites” where are located in the UK, US and France etc. In these sites, there is implemented decommissioning and environmental remediation for a long-term. For this reason, these countries have been challenging to issues such as technological difficulties called “unknown unknowns” (unknown issues that even uncertainty level is not known), project management over several decades, and securing of large amount of funds.

In order to make steady progress on decommissioning of the Fukushima Daiichi NPS, it is important to learn the lessons of decommission experience from accident reactors and legacy sites in the world as well as actively utilize the world’s best technologies and personnel resources. In addition, to secure and maintain understanding and support from international communities, it is also important to engage in decommissioning with open to international societies.

The decommissioning of the Fukushima Daiichi NPS is expected to offer the opportunity of development for front-line science and technology and to become a source of innovation. For instance, dose distribution measurement in the buildings of Unit 1 and 3 by using the multicopter (RISER), that enables three-dimensional dose evaluation developed in UK, has made some achievements, as a result of testing its applicability in the Fukushima Daiichi NPS. In this way, technologies and knowledge acquired through decommissioning of the Fukushima Daiichi NPS can be beneficial for the countries engaging in decommissioning.

The international institutions such as IAEA, Organization for Economic Co-operation and Development/Nuclear Energy Agency (“OECD/NEA”) have a role of contribution to design the international standard, share the knowledge and experience among nations, and form the international common perceptions for decommissioning. To proceed decommissioning of the Fukushima Daiichi NPS in an open manner, it is important to participate in the activities of these institutions. At the same time, as Japan participates in the discussion for design the international standard, based on the experience of the Fukushima Daiichi decommissioning, it leads to share the experience with memberships of the institutions. It is expected to fulfill the Japan’s responsibility to the international society.

2) Facilitation of international cooperation activities

i. Enhancement of partnership with overseas decommissioning agency

Concerning to long-term process of the Fukushima Daiichi NPS decommissioning, it is necessary for cooperation with overseas decommissioning agencies to engage focusing on creating continuous partnership not as transient. Especially, the decommissioning of legacy sites will serve, as a model for approach preceding to the Fukushima Daiichi NPS decommissioning, in many knowledge in accordance with technology and management.

Decommissioning for legacy sites is promoted by decommissioning institutions that is established officially by each country because it requires the expertise, concept and new technologies, etc. to differ from the operation/maintenance for nuclear reactor or nuclear fuel cycle facility. Therefore, it is important for NDF to reinforce a continuous partnership with these institution such as Nuclear Decommissioning Authority (NDA), Commissariat a l'energie atomique (CEA), United States Department of Energy, Office of Environmental Management (DOE/EM) based on government-level framework. TEPCO should establish a long-term partnership with overseas decommissioning operators, and these should be broad cooperation-based.

ii. Integrating and utilizing wisdom and knowledge from around the world

In regard to decommissioning of the Fukushima Daiichi NPS, wisdom and knowledge from around the world that our country should obtain is implemented with a variety of approaches such as system/policy, providing strategy, project plan/operation, ensuring security, regional communications, and so forth, not only in technical aspect but operational aspect. Up until now, there are signs to support decommissioning of the Fukushima Daiichi NPS by international society, and several kinds of supports have been given by overseas governmental institutions and experts including DAROD project led by IAEA and collaboration projects promoted by OECD/NEA. It is deeply appreciated to these supports.

Decommissioning is implemented by many companies and decommissioning operators under the contract in both domestically and internationally. The decommissioning market is expanding worldwide. In order to use the highest level of technologies and human resources in the world, it should be updated the latest status.

iii. Dissemination to global society

It is essential to promote decommissioning in an open manner to international society for prevention of reputational damages as stated in the Section 7 and it should strengthen to distribute easily understandable information, for helping accurate comprehension from international society.

Consequently, NDF takes dissemination of information about the situation of the Fukushima Daiichi NPS decommissioning globally through holding side events of IAEA General Meeting and giving speeches at key international meeting. Also, International Forum on the Decommissioning of the Fukushima Daiichi NPS is held in order to report information about the situation of the

Fukushima Daiichi NPS decommissioning to the world and to take effort to communicate with local communities.

3) Close cooperation with relevant domestic organizations

As stated in Chapter 2), concerning international cooperation, it is promoted that relevant domestic organizations build and strengthen partnership with foreign organizations in accordance with the role of each organization. It should be shared the knowledge and human connections obtained through these activities to ensure consistency of international cooperative activities in Japan and implement effective international cooperation. Therefore, the relationship of relevant domestic organizations should be further enhanced.

7 Local community engagement and further enhancement of communication

1) Approaches for local community engagement and further enhancement of communication

For implementing decommissioning of the Fukushima Daiichi NPS steadily, Local community engagement is the major premise, and it should be seeking for decommissioning to contribute to the restoration in local communities while trying to establish trustful relationships closely with the region.

Communication is the foundation to establish trust relationship with the region, and it is a starting point to listen to the voice from various standpoints including local communities sincerely. Particularly, it is important to respond to their questions about the project/planning and decommissioning activities as well as anxieties against safety or risk management. While not only providing information on progresses of approach to safety measures and relevant work and on radioactive safety appropriately but also communicating interactively, further decommissioning should be proceeded by establishing common understandings about risk reduction policy. On the foundation of communication like this, it is necessary to co-exist with the regions through decommissioning and its relevant economic activities in contributing to the restoration and revitalization of the region.

2) Actual effort for better communication

As fuel debris retrieval work moves into full swing, it is necessary to consider and put into practice a further well thought-out communication method under proper collaboration of the relevant organizations.

The Japanese government is to engage polite communication by holding “The Fukushima Advisory Board” or by preparing the videos or the brochures “The important story of decommissioning process” that explains current decommissioning status.

NDF hosts International Forum on the Decommissioning of the Fukushima Daiichi NPS annually for providing information and vigorous dialogue about decommissioning with the local citizens as well as prepares a brochure “Hairo-no-iroha” that can express decommissioning in plain words. NDF is to continue vigorously to promote interactive communication activities like these and to take all of the local voice sincerely.

TEPCO is to work on appropriate information dissemination by publishing web contents and “Hairo michi” as a periodic magazine as well as establishing the decommissioning communication center in November, 2017. Moreover, TEPCO promotes to accept observers into the Fukushima Daiichi NPS, and plans to expand observers and enrich the scope of visit further in the future.

3) Further spread of communication and measures to reputational damages

There is a possibility that a reputational damage may be caused by being anxious even if the risk does not become obvious. Moreover, it is pointed out that even seven years have passed after 1F accident, the image, immediately after the accident, is not being wiped off and it has been settled. When delays in responding to reputational damages or troubles on decommissioning work occur, it may produce a vicious cycle such as downgrading evaluation from society for addressing decommissioning then it causes the further delay of activities. In order to prevent from a vicious cycle like this, it is the most important to promptly reduce existing risks while making efforts for proper safety management. Besides, as for measures to be taken to prevent reputational damages, it is necessary to enrich communication with local residents, media, market participants, and distributors as well as consumers including overseas.