Technical Strategic Plan 2020 for Decommissioning of the Fukushima Daiichi Nuclear Power Station of Tokyo Electric Power Company Holdings, Inc.

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Nuclear Damage Compensation and
Decommissioning Facilitation Corporation

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1. Introduction

The overall approach to the decommissioning of the Fukushima Daiichi Nuclear Power Station of Tokyo Electric Power Company Holdings, Inc. (hereinafter referred to as the “Fukushima Daiichi NPS”) started under the Mid-and-Long-term Roadmap towards the Decommissioning of TEPCO’s Fukushima Daiichi NPS Units 1 to 4, released by the Japanese Government in December 2011.

Urgent issues, such as treating contaminated water and removing fuel from the spent fuel pools (hereinafter referred to as “fuel removal from SFP”), have been given top priority in this effort. However, to complete the decommissioning, long-term measures are required such as fuel debris retrieval work, and so it is essential to prepare a mid- and long-term decommissioning strategy. On August 18, 2014, the former Nuclear Damage Compensation Facilitation Corporation was reorganized into the Nuclear Damage Compensation and Decommissioning Facilitation Corporation (hereinafter referred to as “NDF”), a new organization responsible for technical studies needed to proceed with the decommissioning properly and steadily from the mid- to long-term perspective. NDF’s duties include, in addition to those assigned to its forerunner, conducting R&D of decommissioning technologies, and providing advice, guidance and recommendations for ensuring the appropriate and steady implementation of the decommissioning.

Almost 10 years has passed since the accident at the Fukushima Daiichi NPS, and the phase of decommissioning work is shifting from the short-term response to the mid-and-long term response. During this period, concrete progress has been made, such as stabilization of measures at a certain level for contaminated water management that required emergency responses immediately after the accident, completion of fuel removal from Unit 4 SFP, and start of fuel removal from Unit 3 SFP. At the same time, a significant reduction in the radiation dose within the power station has been achieved.

In the future, definite measures to retrieve fuel debris, which is the core of decommissioning work, must be promoted. The government's “Mid-and-Long-Term Roadmap towards the Decommissioning of TEPCO.’s Fukushima Daiichi Nuclear Power Station” (hereinafter referred to as “Mid-and-Long-term Roadmap”), revised in December 2019, clearly states that the retrieval of fuel debris will start from Unit 2 by the end of 2021. To achieve this, Tokyo Electric Power Company Holdings, Inc. (hereinafter referred to as “TEPCO”) announced in March 2020, the “Mid-and-Long-term Decommissioning Action Plan 2020” (hereinafter referred to as the “Mid-and-Long-term Decommissioning Action Plan”) as the main work process for the overall decommissioning project. Through this announcement, TEPCO, as a nuclear power operator, has made clear its stance of taking the initiative in decommissioning in order to materialize complicated and long-term work prospects and to make the decommissioning project transparent to the local community and society.

At present, TEPCO is working on a daily basis to achieve milestones in the Mid-and-Long-term Roadmap, including full-scale engineering to retrieve fuel debris. Based on the new milestones presented in the Mid-and-Long-term Roadmap, "Technical Strategic Plan 2020 for Decommissioning of the Fukushima Daiichi Nuclear Power Station of Tokyo Electric Power Company Holdings, Inc." (hereinafter referred to as "Strategic Plan 2020") presents a technical strategy from a mid-and-long-term perspective that overviews the overall approach taken by the Fukushima Daiichi NPS, aiming for steady implementation of the decommissioning project. Strategic Plan 2020 is characterized by the formulation of a Mid-and-Long-term Decommissioning Action Plan 2020, the identification of requirements necessary for considering fuel debris retrieval methods towards the further expansion of fuel debris retrieval, the clarification of the concept of ensuring safety in decommissioning work, and the strengthening of management systems in response to the growing importance of research and development.

On the impact of coronavirus, TEPCO is taking measures[1] to prevent infection to its staff and workers. As a result of this, as of September 2020, no person has infected with the disease in Fukushima Daiichi NPS. Going forward, based on the circumstances inside and outside of the country, it is necessary to examine strategies for promoting the project in due consideration of measures against coronavirus. In particular, if infected, any effort to secure continuity of the decommissioning project will be needed.

1.1 Structure and system toward the decommissioning of the Fukushima Daiichi Nuclear Power Station

Since April 2020, TEPCO has strengthened its control system over the decommissioning work and converted itself to a project-type organization in order to steadily proceed with decommissioning work by systematically implementing measures to address various issues over the mid-and-long term. From the financial perspective, the Nuclear Damage Compensation and Decommissioning Facilitation Corporation has been carrying out the management of a reserve fund for decommissioning since October 2017 to ensure immediate decommissioning work. The management task aims are, in every fiscal year, (1) TEPCO will deposit the amount at NDF that is specified by NDF to implement decommissioning appropriately and steadily, as well as that approved by the Minister of Economy, Trade and Industry, and (2) based on the "Withdrawal Plan for Reserve Fund for Decommissioning" (hereinafter referred to as "Withdrawal Plan"), that was jointly prepared by NDF and TEPCO and approved by the Minister of METI, TEPCO will withdraw the reserve fund and implement decommissioning (Fig.1).

Under this management task, NDF will (1) appropriately manage the fund for decommissioning, (2) manage the implementation structure for proper decommissioning and (3) manage the decommissioning work based on the Reserve Fund for Decommissioning appropriately, and NDF assumes responsibility as an organization to manage and oversee TEPCO's decommissioning

[1] TEPCO, "Measures against coronavirus infection at Fukushima Daiichi NPS"
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・https://www.tepco.co.jp/decommission/common/images/20200730.pdf
・https://www.tepco.co.jp/decommission/information/newsrelease/reference/pdf/2020/2h/rf_20200807_2.pdf

activities. NDF prepared “the Policy for Preparation of Withdrawal Plan for Reserve Fund for Decommissioning" (hereinafter referred to as “The Policy for Preparation of Withdrawal Plan”), which was drawn up based on the “Technical Strategic Plan for the Decommissioning of the Fukushima Daiichi Nuclear Power Station of Tokyo Electric Power Company Holdings, Inc.” (hereinafter referred to as “Strategic Plan”), and presented to TEPCO the work goals and main activities to be incorporated in the Withdrawal Plan, and evaluated the appropriateness of TEPCO's efforts in the process of jointly preparing the Withdrawal Plan from the perspective of symbiosis and communication with the community, etc. (Fig.2).

In addition to the operation of these systems, the division of roles among the organizations directly involved in the decommissioning of the Fukushima Daiichi NPS, including the Japanese government, NDF and TEPCO, as well as organizations specializing in R&D, such as the International Research Institute for Nuclear Decommissioning [IRID] and the Japan Atomic Energy Agency [JAEA], is shown in Fig.1, which also indicates how the abovementioned systems are implemented. Among these roles, R&D are discussed in Chapter 4, and dialogue with local residents and communities is described in Chapter 5.

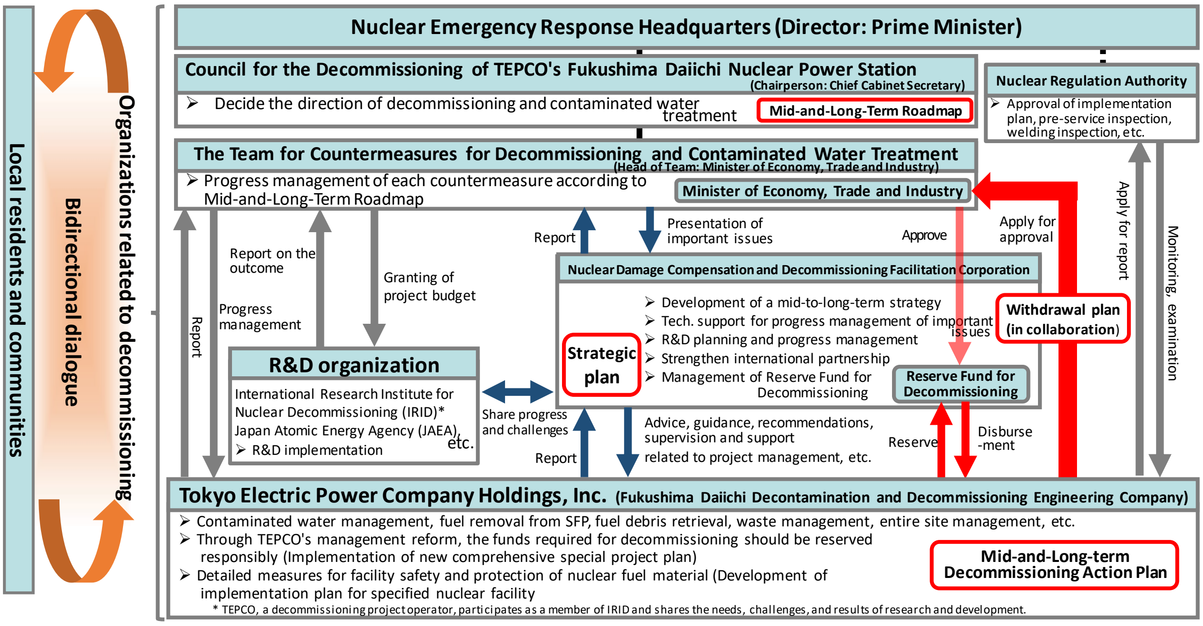


Fig.1 Division of roles of related organizations responsible for decommissioning of the Fukushima Daiichi NPS

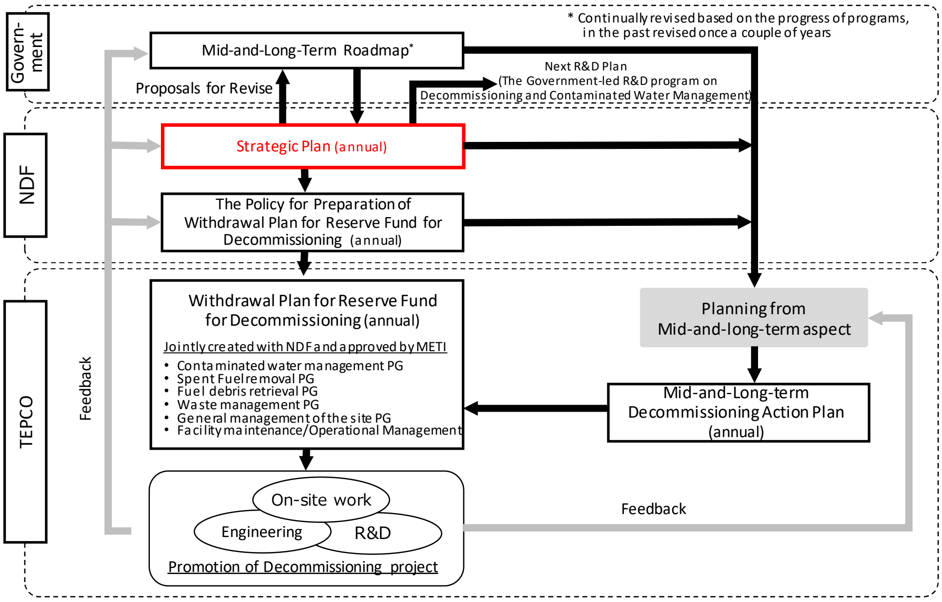


Fig.2 Positioning of the Strategic Plan based on the Reserve Fund

1.2 The Strategic Plan

1.2.1 Positioning of the Strategic Plan

NDF has been compiling a Technical Strategic Plan every year since 2015, with the aim of providing a solid technical basis for the Mid-and-Long-term Roadmap, contributing to a smooth and steady implementation as well as the review of revisions, and accomplishment of the target shown in “Measures for Mid-term Risk Reduction at TEPCO’s Fukushima Daiichi NPS at TEPCO (Risk Map)” provided by the NRA, moreover, providing a reliable basis for The Policy for Preparation of Withdrawal Plan (Attachment 1). The Strategic Plan will also have a technical impact on the annual revision of the Mid-and-Long-term Decommissioning Action Plan.

In response to the revision of the Mid-and-Long-term Roadmap made at the end of last year, the Strategic Plan 2020 presents a technical strategy from the mid-and-long-term perspective that overviews the overall efforts made by the Fukushima Daiichi NPS in order for the operator to steadily carry out decommissioning work in accordance with the new target processes. In particular, the retrieval of fuel debris, which is a highly difficult task, is coming very close, and the roles of the government, NDF, TEPCO, research institutes, etc., have become even greater for the realization of this task. This document also takes these viewpoints into consideration.

1.2.2 Overall Structure of Strategic Plan 2020

Strategic Plan 2020 consists of five chapters.

Chapter 1 (Introduction) stated that in the decommissioning of the Fukushima Daiichi NPS, an attempt has been made to shift from the conventional short-term response to the decommissioning work phase with an eye towards a medium to long-term response, and that TEPCO is now working on engineering towards fuel debris retrieval on a full scale, such as the formulation and publication of a Mid-and-Long-term Decommissioning Action Plan.

Chapter 2 (Concept on Risk Reduction and Safety Assurance for Decommissioning of the Fukushima Daiichi NPS) presents the basic policy for decommissioning the Fukushima Daiichi NPS as an approach to risk reduction and ensuring safety. It also describes the immediate targets, basic approach to risk reduction, and the approach on the order of priority, as well as preliminary implementation and utilization of the obtained information in the latter stages, and the approach on how to deal with temporary increases in risk levels as the policy of ensuring safety.

Chapter 3 (Technical strategies toward decommissioning of the Fukushima Daiichi NPS) sets targets for each of the four areas of fuel debris retrieval, waste management, contaminated water management, and fuel removal from SFPs, and describes the current progress toward these targets, the major challenges in accomplishing them, and the technical strategies to achieve them. In promoting these four areas, significance of analyses and current situation as well as its issues and strategies are specially referred to, since utilization of analyzed result is commonly important.

Chapter 3, Section3.1 (Fuel debris retrieval3.1) describes the points to be noted based on the experience and research and development obtained so far in conducting the trial retrieval of fuel debris and the expansion of the scale of the gradual retrieval at the first implementing unit, Unit 2. Additionally, in further expanding the scale of the retrieval, the flow of examining the retrieval method is shown as a conceptual diagram, as well as its concept of important requirements (Boundary conditions).

Chapter 3, Section3.2 (Waste management) presents, in accordance with the basic policies on processing/disposal of solid waste, specific targets along with a plan for R&D needed to reach these targets to gain a technological vision for waste processing/disposal to be presented in order starting from the Strategic Plan 2021.

Chapter 3, Section3.3 (Contaminated water management) stipulates new targets for contaminated water management and issues such as zeolite sandbags in accordance with progress in the stagnant water in buildings. In addition, it also describes the direction of contaminated water management in the reactor buildings after starting the fuel debris retrieval work.

Chapter 3, Section 3.4 (Fuel removal from spent fuel pools) refers to the new target for removing fuel from SFPs and the appropriate and specific operation plan depending on the conditions of each unit, and proposes the directions of the efforts to secure capacity required for proper storage of removed fuel within the site and of the efforts to determine the future treatment and storing methods for fuel in SFPs including evaluation of the long-term integrity of such fuel.

Chapter 3, Section 3.5 (Utilization of Analysis Results for Smooth Promotion of Decommissioning) describes the implications of analysis results in proceeding with the decommissioning including positioning of importance and analysis of establishment and improvement of analysis system or analysis facilities as a superordinate concept of each project, as well as the need for early initiation of whole strategy for analysis.

Chapter 4 (Efforts for research and development) describes the individual R&D activities described in Chapter 3 in a medium to long-term as a whole, and summarizes the efforts expected of the government, business operators, and related research institutions. It also presents the direction of future efforts toward the acceleration of R&D, including the strengthening of the R&D management system for the Government-led R&D program on Decommissioning and Contaminated Water Management, and the preparation of medium to long-term R&D plans. In addition, from a medium to long-term perspective, the role of each player centered on the JAEA and the importance of fundamental R&D, in matching needs and seeds between decommissioning sites and universities and research institutions, and establishing centers of basic research/research infrastructure are described.

Chapter 5 (Efforts supporting technical strategies) describes the significance, the current situation, the main issues and strategies in each area of further strengthening of project management, improvement of skills required in the decommissioning project operator, enhancement of international cooperation, and local community engagement.

Chapter 5, Section 5.1 (Further strengthening of project management and improvement of skills required in the decommissioning project operator) describes not only the technological investigations described in Chapter 3, but also the implications of the formulation of the Mid-and-Long-term Decommissioning Action Plan, further strengthening of project management, in particular, enhancement of the “safety and operator's perspective” for ensuring safety, improvement of owner's engineering capability, and development and securing of human resources.

Chapter 5, Section 5.2 (Enhancement of international cooperation) describes the need to strengthen international cooperation, such as partnerships with institutions involved in decommissioning projects in countries with legacy nuclear sites, in order to gather wisdom and knowledge from around the world, and proposes efforts that should be made in this regard.

Chapter 5, Section 5.3 (Local community engagement) notes how these institutions, mainly TEPCO should work together toward that end under the fundamental principle of “the coexistence of reconstruction and decommissioning”, to implement continuous decommissioning of the Fukushima Daiichi NPS that spans a long period of time, in consideration that we will seek decommissioning developed with the reconstruction in local communities.

2. Concept on risk reduction and safety assurance for decommissioning of the Fukushima Daiichi NPS

2.1 Basic concept of the decommissioning of the Fukushima Daiichi NPS

<Basic concept of the Decommissioning of the Fukushima Daiichi NPS>

To continuously and quickly reduce the radioactive risks caused by the accident that do not exist in a normal 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” and is maintained in a state with a certain level of stability.

However, the Fukushima Daiichi NPS is at great risk because fuel debris and spent fuels still remain in reactor buildings damaged by the accident, some of the status of the NPS are not sufficiently grasped, and the site has radioactive contaminated water and enormous amounts of extraordinary radioactive wastes. If left unaddressed, these risks may increase due to the aging degradation of the facilities and other factors. Quickly and swiftly reducing these risks is an urgent matter for the NPS.

Accordingly, the basic policy for the decommissioning of the Fukushima Daiichi NPS is “to reduce continually and quickly the risks associated with the radioactive materials that resulted from the accident and do not exist in normal nuclear power plants” by taking measures specifically designed for risk reduction. In general, actions that are effective for reducing the risks at nuclear facilities that have suffered an accident are as follows;

- ✓ Improving the containment function of the damaged facilities
- ✓ Changing the properties and form of the contained radioactive material to more stable ones
- ✓ Strengthening monitoring and control over the equipment to better prevent or mitigate the occurrence or propagation of abnormalities.

To enable these actions comprehensively,

- ✓ Removing radioactive materials from the damaged facilities or insufficient containment status and placing them in sound storage is also effective.

These diverse risk reduction measures have been continued based on careful preparations aimed at preventing accidents and exposure of workers to radioactivity (refer to Attachment 2).

2.2 Concept of reducing risk caused by radioactive materials

2.2.1 Quantitative grasping of risk

The term “risk” may have various meanings depending on the field or scene of use. In general, in the context of appropriate risk management, “risk” can be understood as an expectation value of the negative impact of an event. In other words, the magnitude of a risk (risk level) posed by a subject (risk source) can be expressed as the product of the level of impact and the likelihood of occurrence of the event.

In the Strategic Plan, the method based on the Safety and Environmental Detriment score (hereinafter referred to as “SED”) developed by the Nuclear Decommissioning Authority (hereinafter referred to as “NDA”) is used to express the magnitude of risk (risk level) for radioactive materials. Risk level expressed by SED is given by the calculation formula below.

Risk Level expressed by SED = Hazard Potential × Safety Management

Hazard Potential here is an index of impact of the event, namely, the impact of internal exposure in the event of human intake of the radioactive material contained in the risk source. It can be expressed as the product of Inventory, which is the radioactivity of the risk source (toxicity of the radioactive material), and factors that depend on the form of the risk source and the time allowable until the manifestation of the risk. Safety Management is an index of the likelihood that an event will occur. It is determined by factors that depend on the integrity and other aspects of the facility and on the packaging and monitoring status of the risk source (Attachment 3).

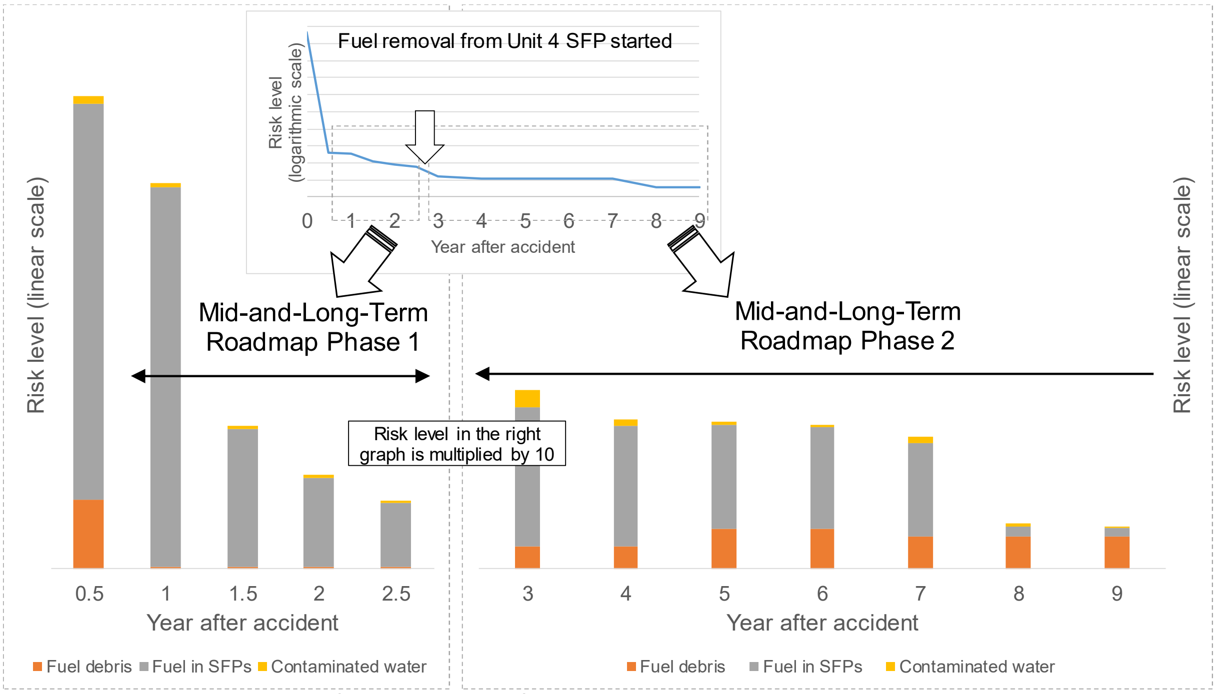
The major risk sources of the Fukushima Daiichi NPS are summarized in Table1, and Fig.3 shows the risks of the Fukushima Daiichi NPS as the sum of these risk sources. The current risk levels assigned to the respective risk sources are expressed in Fig.4 with “Hazard Potential” and “Safety Management” as the axes.

In the Mid-and-Long-term Roadmap, management of these risk sources is broadly classified into three major categories: (1) Relatively high risks given high priority (stagnant water in buildings and fuel in the spent fuel pools), (2) Immediate risk unlikely, but risk may grow when handling with haste (fuel debris), and (3) Increased risk unlikely in the future, but appropriate decommissioning efforts required (solid waste such as sludge generated from the decontamination device). Their priorities are set, and appropriate measures are taken.

Table1 Major risk sources at the Fukushima Daiichi NPS

Fuel debris		Fuel debris in 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 Spent Fuel Storage Pool	Fuel assemblies stored in the Common Spent Fuel Storage Pool
	Fuel in dry casks	Fuel assemblies stored in dry casks
Contaminated water, etc.	Stagnant water in buildings	Contaminated water accumulated in the reactor buildings/the turbine buildings in Units 1 to 4, process main building and high-temperature incinerator building, and sludge containing α-nuclides at the bottom of buildings in Units 1-3
	Zeolite sandbags	Sandbags containing zeolite placed on the basement floors of process main building and high-temperature incinerator building
	Stored water in welded tanks	Strontium-treated water and ALPS-treated water stored in welded tanks
	Residual water in flanged tanks	Concentrated salt water and residual ALPS-treated water left at the bottom of flanged tanks

Secondary waste generated by water treatment	Waste adsorption vessels, etc.	Spent adsorbents used in the cesium adsorption apparatus, a second cesium adsorption apparatus, a third cesium adsorption apparatus, advanced multi-nuclide removal equipment, mobile-type strontium removal equipment, a second mobile-type strontium removal equipment and mobile-type treatment equipment, etc.
	HIC slurry	Slurry produced during treatment by the multi-nuclide removal equipment and added multi-nuclide removal equipment, and stored in high integrity containers (HIC)
	Sludge generated from decontamination device	Flocculated sludge generated during the operation of the decontamination system
	Concentrated liquid waste, etc.	Concentrated liquid waste generated by evaporative concentration of concentrated salt water with further volume reduction by concentration, and carbonate slurry collected from the concentrated liquid waste
Rubble, etc.	Solid waste storage facility	Rubble with high-dose (30 mSv/h and above) stored in the solid waste storage facility
	Soil-covered temporary storage, etc.	Rubble stored in the soil-covered temporary storage facility and containers (1-30 mSv/h), fallen trees stored in the temporary storage pool
	Outdoor storage, etc.	Rubble stored in outdoor sheet-covered storage (0.1-1 mSv/h), rubble stored in outdoor storage (below 0.1 mSv/h), fallen trees stored in outdoor storage
Contaminated structures, etc., in the buildings		Structures, pipes, components, and other items inside the reactor buildings and PCVs/RPVs that are contaminated with radioactive materials dispersed due to the accident; and activated materials generated from operation before the accident



*1: The risk level was high due to fuel debris right after the accident, however, it became largely lower because Hazard Potential has been largely decreased by attenuation of radioactive materials inside fuel debris over one year after the accident.

*2: In the evaluation of eight years after the accident, as a result of incorporating the insight that the rise in water temperature after cooling shutdown was slower than expected, the risk of fuel in SFPs is lower than previously estimated, because the time margin before this risk becomes apparent increases.

Fig.1 Reduction of risks contained in the Fukushima Daiichi NPS

Major risk sources identified at the Fukushima Daiichi NPS are shown in Table1. In addition, the overall decommissioning work over the long term includes waste that existed before the accident and the risk sources that have low hazard potential but are not adequately controlled in a stable manner. Since the introduction of the Strategic Plan 2019, these issues have also been presented. In particular, regarding the facilities containing risk sources that had not been expressly considered in the past, investigations and examinations are being conducted in consideration of external events such as earthquakes, tsunamis, and rainwater (Attachment 4).

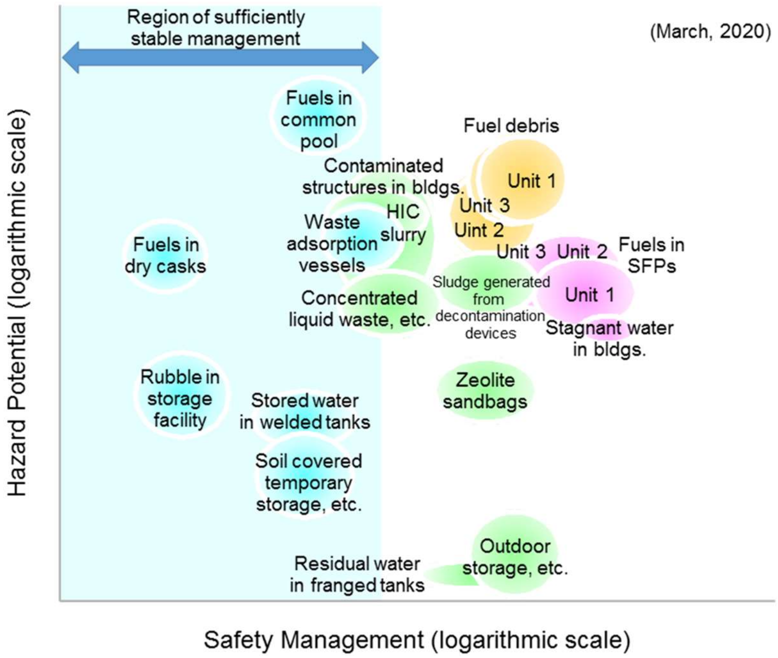


Fig.4 Example of risk levels assigned to the major risk sources at the Fukushima Daiichi NPS

2.2.2 Risk Reduction Strategy

2.2.2.1 Interim targets of the risk reduction strategy

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

The examples of reduction in “Safety Management” include transfer of fuel in SFPs to the Common Spent Fuel Storage Pool, and placement of rubble stored outdoors into storage. Of the various risk reduction measures, the reduction in “Safety Management” is generally considered to be easily realized. Consequently, the decommissioning of the Fukushima Daiichi NPS, which is implemented under the basic concept of “to continuously and quickly reduce the radioactive risks caused by the accident that do not exist in a normal NPS” (refer to Section 2.1), should first focus on steadily managing risk sources by keeping them in higher-integrity facilities to lower their Safety

Management levels. The immediate target of the risk reduction strategy is to bring the risk levels into the “Sufficiently stable management” region (the pale blue area) as shown in Fig. 4.

SED quantitatively shows a current condition of a risk attributable to radioactive materials, and this is an effective method to determine the order of priority for measures against risk sources. When conducting the actual risk reduction, it is required to take measures from engineering aspect in order to inhibit development of risks from radioactive materials associated with its operation. Regarding the Table1, what was changed from last year is that zeolite sandbags were added[2] as part of contaminated water management after the accident. It was revealed in December 2019 that they would be present in a state of high radiation dose in the process of treatment of stagnant water in buildings (For details, see Section 3.2, Contaminated water management). Compared with the stagnant water in buildings shown in the table, “Safety Management” is deemed close to the region in pale blue because its form is difficult to leak through the building walls. Moreover, “Hazard Potential” of residual water in the flanged tanks becomes relatively low because its treatment has progressed.

2.2.2.2 Direction of risk consideration for external events

In the preceding paragraph, based on the concept of SED, Fig.4 is shown as the major risk sources for the Fukushima Daiichi NPS using the indicators of “Hazard Potential” and “Safety Management”. However, how to estimate and evaluate the risks associated with external events such as earthquakes and tsunamis[3] remains to be solved. The definitions of “Hazard Potential” and "Safety Management" (Attachment 3) do not necessarily adequately address the frequency of external events or the consequences. Therefore, it is important to consider the risk management of the whole site promoted by TEPCO, taking into account the seismic resistance and installation height of the facilities against earthquakes and tsunamis to complement the SED concept while adopting a probabilistic approach. In doing so, it is necessary to (1) implement risk reduction by focusing on the high priority external events such as earthquakes, tsunamis, and rainfall that become the source of contaminated water; (2) develop a comprehensive database of seismic resistance, failure rates, and location information for facilities where direct containment is carried out; and (3) enhance scenario analysis and assessment of exposure estimates that may be caused by external events.

2.2.2.3 Basic approach to risk reduction

Decommissioning of the Fukushima Daiichi NPS is a project with considerable uncertainties involved. To date, the internal status of Units 1 to 3 has been estimated to some extent through the simulation of the accident development process, estimation of the places with fuel debris by muon-

[2] In the Strategic Plan 2019, zeolite sandbags were extracted as one of the risk sources that include radioactive materials other than major risk sources. Strategic Plan 2020 added it to the major risk sources.
[3] Earthquakes, tsunamis, rainwater, etc., are listed as external events that need responses in the Measures for Mid-term Risk Reduction at TEPCO’s Fukushima Daiichi NPS at TEPCO (Risk Map), (Nuclear Regulation Authority March 2020).

based fuel debris detection technology, placement of investigation equipment into the Primary Containment Vessel (hereinafter referred to as "PCV"), dose measurement and video photographing in the buildings, and others. There was still significant uncertainty, however, to eliminate uncertainties, many resources and, in particular, a considerably long time are required. In order to realize prompt risk reduction it is necessary to make integrated decisions through a flexible and prompt approach, based on the directions determined with previously obtained experience and knowledge, and with experiment and analysis based simulation, placing safety as the top priority, even though a certain extent of uncertainties remain.

As the viewpoint to make these comprehensive decisions, NDF summarizes the following five guiding principles:

(Five guiding principles)

- Safe: Reduction of the risks posed by radioactive materials and ensuring of work safety
  (Issues such as containment of radioactive materials [environmental impact], workers' radiation exposure, assessment of risk reduction effects)
- Proven: Highly reliable and flexible technologies
  (Issues such as conformity to requirements, effectiveness, flexibility against uncertainty)
- Efficient: Effective use of resources (e.g. people, things, money and space)
  (Issues such as reduction of waste generation, cost, efficiency, securing necessary work area and site)
- Timely: Time consciousness
  (Issues such as early start of fuel debris retrieval, estimation of time required for fuel debris retrieval)
- Field-oriented: Comprehensive three-reality policy by checking actual site, actual goods, and actual situation
  (Issues such as workability including environment-friendliness, accessibility, and operability, and maintainability including ease in maintenance and troubleshooting)

If the five guiding principles are applied to the actual site, it is important to proceed with the decommissioning operation after greatly emphasizing on safety assurance for the purpose of protecting human beings and environment from radioactive materials associated with the operations, thoroughly conducting radiological consequence evaluation, and taking appropriate radioprotective measures. ("Safe" of five guiding principles)

For the decommissioning of the Fukushima Daiichi NPS, because the public risk level is rising with time as the degradation of facilities damaged by the accident progresses, while controlling this risk as low as reasonably achievable ("Efficient") as promptly as possible ("Timely") in light of the situation at the site, and proceeding with the decommissioning in a reliable manner ("Proven") by feasible ways in the harshest condition on-site ("Field-oriented") will lead to ensuring safety in medium-to-long-term.

As for the result judged based on these five guiding principles, it is also important to work to disseminate information carefully so that the results of this judgment will be widely accepted by society.

2.3 Approach to ensuring safety during decommissioning

2.3.1 Basic policy for ensuring safety based on the characteristics of Fukushima Daiichi NPS

Decommissioning of the Fukushima Daiichi NPS containing the reactor involved in the accident is an unprecedented activity that takes place in a special environment different from that of a normal reactor, and therefore, to ensure safety, the following characteristics (peculiarity) in safety should be fully recognized:

- A large amount of radioactive materials (including α-nuclides that have a significant impact on internal exposure) are in an unsealed state, as well as in unusual and various (atypical) forms
- The barriers to contain radioactive materials, such as reactor buildings and PCVs, are incomplete
- Significant uncertainties exist in the conditions of these radioactive materials and containment barriers, etc.
- Difficulty in accessing the site and installing instrumentation devices to obtain on-site information due to constraints such as high radiation levels on site
- Since the current level of radiation is high and there is a concern about further degradation of confinement barriers, etc., it is necessary to take measures considering the time axis without prolonging the decommissioning activities.

Consequently, TEPCO, as the operator of the decommissioning project, needs to pay special attention to the following points in proceeding with the decommissioning work when considering the work based on five guiding principles.

Firstly, with regard to “safety”: There is great uncertainty about the status of radioactive materials and confinement barriers, and on-site access and installation of instrumentation devices to reduce the uncertainty are also restricted. Under these circumstances, a large amount of atypical and unsealed radioactive materials will be handled in an incompletely confined state. Therefore, the starting point for all reviews should be confirmation of the feasibility of ensuring safety with a wide range of possibilities (cases) assumed. At the same time, with regard to “safety”, it is important not to prolong the work period, while paying attention to risk reduction over the entire work period. Therefore, it is necessary to avoid excessive safety measures and to take optimum safety measures (ALARP[4]). Such perspective on “safety” (the safety perspective) should be reflected in the decommissioning work review.

Secondly, with regard to “field-oriented”:

[4] An abbreviation for As Low As Reasonably Practicable. It means that radiological impacts must be as low as reasonably practicable.

・ The on-site environment is under special conditions such as a high level of radiation, and therefore, attention should be paid to the feasibility of construction and implementation of safety measures on site.

・ An approach through design alone has limitation due to significant uncertainties.

From the above-mentioned reasons, it is essential to accurately reflect the actual on-site information into engineering. For this purpose, the views and senses of the individuals and the organizations (operators) that are responsible for the on-site work (including operation, maintenance, radiation control, instrumentation, analysis, etc.) and very familiar with actual site should be highly respected. And their perspectives and judgements directly based on the site (the operator’s perspective) are important.

In the actual design of the decommissioning work in the project, TEPCO, as the project executor, should clearly define the “requirements” for the work in advance, and should design specific safety measures to achieve them. In doing so, it is essential to reflect “the safety perspective” and “the operator’s perspective” to respond to the characteristics (peculiarity) of decommissioning of the Fukushima Daiichi NPS. Specifically, requirements shall be stipulated in consideration of “the safety perspective” and “the operator’s perspective”, and specific safety measures shall be selected for work which satisfies the requirements, considering the two perspectives. When designing the decommissioning work, sufficient attention should be paid to “the safety perspective” and “the operator’s perspective” at each stage of the design.

In this decommissioning work with very significant uncertainties, it is often difficult to clearly define the requirements in advance. Even in such a case, the decommissioning work should be proceeded with flexibly and promptly by fully utilizing the "preliminary implementation and utilization of the obtained information in the latter stages" as described later and “iteration-based [5] engineering”.

2.3.1.1 Optimization of judgment with safety evaluation as its basis and ensuring the timeliness in decommissioning

In proceeding with the decommissioning work with an aim for risk reduction, it is most important to take appropriate safety measures and ensure safety of the work handling a large amount of radioactive materials that is technically difficult and has significant uncertainties, such as fuel debris retrieval. Thus, decommissioning work should be carried out by concentrating on “the safety perspective”.

Specifically, when designing safety measures for each decommissioning activity, it is essential to make decisions based on Five guiding principles after conducting a thorough safety evaluation and confirming that the required safety is ensured. In the decommissioning work of the Fukushima Daiichi NPS, which is unprecedented and has significant uncertainties, by using deliberated safety evaluation as the basis for making decisions regarding safety measures, the decisions will not be

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[5] Approach to obtain a subsequent result based on one result and gradually improve completion rate of engineering by repeating this.

significantly unstable (that is, without devoting too little or excessive resources).Necessary, sufficient and reasonably feasible safety measures can be realized (optimization of judgment based on safety evaluation).

In addition, as "the safety perspective" unique to the decommissioning of the Fukushima Daiichi NPS, the importance of making progress in decommissioning work without delay (importance of time-axis-conscious action) can be mentioned. Considering high radiation effects that have already become materialized, and the possibility of further degradation of containment barriers, etc., making progress in the decommissioning work without delay will significantly contribute to ensuring the safety of the entire decommissioning process from a mid-and-long term perspective. Therefore, unlike ensuring safety for normal reactors, which have a certain margin in terms of human, physical, and financial resources and have low radiological impacts and high stability, it is particularly required to make rational and time-axis-conscious judgement on making progress in the decommissioning work without delay and the resource input. This judgement should be made on the condition that safety is secured, and based on the relationship with the overall balance. (Ensuring timeliness in decommissioning activities)

2.3.1.2 Ensuring safety by incorporating “the operator’s perspective”

To ensure that safety measures are truly effective, it is necessary to satisfy the needs from the standpoint of those who actually perform operations and tasks on site. For this purpose, “the operator’s perspective” (perspectives and judgements from the standpoint of those who are familiar with the site and perform operations and tasks on site) is important. In addition to this standpoint, the Fukushima Daiichi NPS is a facility that has suffered from an accident, and its decommissioning requires an unprecedented approach that could be carried out in the special environments such as high radiation levels, unlike normal reactors. Therefore, when determining the feasibility of safety measures on site, special on-site conditions such as high radiation levels and the environment shall be considered.

“The operator’s perspective” is also important for ensuring safety from the following viewpoints, which are different from those of normal reactors.

- Complementation of design by operations, including operating controls: Due to significant uncertainties, there is a limit in addressing all situations by design alone. For this reason, an effective way is to use the information obtained at the operation stage for the design of subsequent stages, and complement the design with the operators’ actions and on-site operations to improve safety in total with the operation.
- Utilization of information in design obtained through monitoring, analysis, etc.: To cope with significant uncertainties, it is important to utilize the information obtained through on-site operations such as monitoring and analysis, etc., in designing safety measures. When utilizing the information, it should be linked with calculational evaluation, etc., to “make a comprehensive use of it”.

- Responses in case of an abnormality: Although it is essential to take all possible measures to prevent an abnormality from occurring, on-site response as a precaution against the occurrence of an abnormality [6] is effective considering the characteristics that the progresses of abnormalities is moderate and there is sufficient time for response.

2.3.2 Preliminary implementation and utilization of the obtained information in the latter stages

On-site conditions of the Fukushima Daiichi NPS containing the reactors involved in the accident includes considerable uncertainties. If whole operation of large-scale project such as fuel debris retrieval is to be designed under such circumstances, assumptions of extremely large safety margin and wide range of technical options will be needed. Thus, extension of work period or risk of rework will be unavoidable. As a result, feasibility or predictability of the entire project may reduce and that leads to delay in entire decommissioning, rise in decommissioning cost, or increased radiation exposure of workers.

On the other hand, considering current environment with already high radiation level, further deterioration of containment barrier, and the possibility of future major natural events (such as earthquake or tsunami), it is necessary to improve such risk state and reduce uncertainties as quickly as possible. Therefore, a “sequential type approach” is important where the whole operation is divided into several stages, “operation at first stage” is implemented for which practical safety can be ensured, and then the information obtained there is utilized to the next stage. In this approach[7], the operation proceeds with its safety ensured through monitoring the condition inside reactor, restricting operational actions and flexible on-site responses[8] at each stage of the process. The information obtained at each stage of operation is utilized in the design of subsequent stages. This approach allows to reduce uncertainties in the operation of subsequent stage as well as to improve the reliability of safety assurance and rationalize design.

TEPCO is required to quickly introduce approach like this into actual engineering and project management. It is important to accumulate experiences that went well or failed acquired in this approach. It will lead to steady progress in decommissioning and contribute to ensuring safety in decommissioning the Fukushima Daiichi NPS from the perspective of risk reduction in the mid-and-long term.

2.3.3 Approach to address a temporary increase in risk level associated with decommissioning operations

While the decommissioning work is striving for prompt risk reduction from the mid-and-long-term viewpoint, careful deliberation is required over the possibilities that the performance of

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[6] As a long time passed since the accident of Fukushima Daiichi NPS occurred, its immanent energy (decay heat) that becomes the driving force of diffusion of radioactive materials is small. Therefore, it is characterized by abnormity that progresses moderately and sufficient time for response.

[7] The same approach is applied in the UK including the decommissioning site in Sellafield and it is called “Lead & Learn”.

[8] For example, taking measures including installing nuclear instrumentation system, limiting processing volume of debris and restricting operations with the control value of radioactive dust concentration stipulated.

decommissioning work may temporarily change the risk levels and may increase the radiation exposure of workers. This is because carrying out the decommissioning work involves acting on the current situation of the NPS, which is kept in a state with a certain level of stability despite some risks. Such risks may materialize, depending on the way actions are taken. For example, accessing the inside of the reactor to retrieve fuel debris will affect the current containment status, and special operations and maintenance performed for the retrieval will increase the exposure of workers involved in these activities.

The possibility of a temporary increase in the risk level and a rise in workers' exposure arising from such decommissioning work must be addressed by taking measures to prevent and restrict them. In particular, as for the radiation safety of workers, it is imperative to limit the increase in the risk level during decommissioning as much as practicably possible by thorough preparations as achieved through application of the concept of ALARA (to suppress radiation exposure to As Low As Reasonably Achievable).

Note that the basic stance of promptly implementing the decommissioning must be firmly maintained because if the work is delayed excessively, existing large risks will remain over the long term and their risk levels may gradually rise as the buildings and facilities deteriorate over time. For this reason, with regard to the selection of work methods, the design and manufacture of equipment and safety systems, and the development of work plans for the decommissioning work, cautious and comprehensive decision making are required for early implementation of decommissioning in consideration of many constraints such as time, cost, and worker's exposure needed for relevant preparations and work, while giving priority to limiting the risks involved in the decommissioning work (Attachment 5).

The approach to risk reduction and ensuring safety in the decommissioning of the Fukushima Daiichi NPS, as described in this chapter, needs to be promoted with the broad understanding of not only the people directly involved but also the local people. Consequently, it is necessary for local communities, the government (Ministry of Economy, Trade and Industry, Nuclear Regulation Authority), NDF, TEPCO, and others to cooperate with each other to reduce risks based on the approach to ensuring safety based on their respective positions. In doing so, it is important to establish a system for on-going risk monitoring which enables a wide range of people to easily understand how the overall risks at the site have been continuously reduced through the decommissioning work. NDF and TEPCO are considering such a system, and TEPCO needs to introduce such a system in the future.

3. Technological strategies toward decommissioning of the Fukushima Daiichi NPS

3.1 Fuel debris retrieval

3.1.1 Targets and progress

(Targets)

(1) Retrieve fuel debris safely after thorough and careful preparations including safety measures, and bring it to the state of stable storage that is fully managed.

(2) Beginning trial retrieval of fuel debris from Unit 2, the first implementing unit within 2021, then start the gradual expansion of fuel debris retrieval and a series of operations timely. Through this process, acquire knowledge and experience necessary for the further expansion of fuel debris retrieval in the future. (For the target of fuel debris retrieval, see Attachment 6)

(3) To further expand fuel debris retrieval, thoroughly examine the result and progress of the fuel debris retrieval from the first implementing unit, through internal investigation, R&D (the government-led program on decommissioning and contaminated water management and TEPCO's voluntary project), on-site environmental conditions. Through this process, study the best methods of contain, transfer, and store.

(Progress)

According to the Mid-and-Long-term Roadmap, Unit 2 is designated as the first implementing unit for fuel debris retrieval, and trial retrieval will be started by the end of 2021. After that, the operation to gradual expansion of fuel debris retrieval will be promoted. For a trial retrieval, the retrieval device is inserted through an existing opening part that leads to the inside of the PCV. TEPCO has presented the work schedule up to 2031 in the Mid-and-Long-term Decommissioning Action Plan, and is working according to this schedule.

(1) Unit 1

Since the second half of FY 2020, further detailed information inside PCV is planned to be gained by inserting a boat-type access investigation device with diving capabilities (an underwater ROV) into PCV and investigating the internal status such as distribution of deposits widely scattered at the bottom of outside the pedestal, presence or absence of fuel debris involved in deposits, and structures inside the pedestal. In preparation for the start of this investigations, removal of obstacles within the PCV is being promoted while taking measures to control dust dispersion and monitoring dust concentration by considering the change in dust concentration when opening the inner door at the penetration X-2.

(2) Unit 2

An arm-type access investigation device (a robot arm) is being manufactured (Fig.5), and measures to control dust dispersion are under consideration in preparation for the trial retrieval and the start of internal investigations of PCV by the end of 2021.

A plan to gradual expansion of fuel debris retrieval is also underway, and the retrieval device will be improved by increasing the weight capacity and enhancing accessibility while complying with specifications for the devices for trial retrieval and internal investigations of PCV. The retrieved fuel debris is transferred to the receiving/delivery cells on site and stored in temporary storage installations. In addition, some of the fuel debris will be collected in the receiving/delivery cells for analysis and transported to the facility for analysis. At present, the retrieval device, receiving/delivery cells, and temporary storage installations are being designed. (Fig.6)

In response to the unprecedented approach to retrieving fuel debris from the first implementing unit, NDF is considering confirming the actual site applicability of the device and the results of the review on modifications to the safety system from the viewpoints of safety, reliability, reasonability, timely, and the field-oriented stance, in accordance with the progress of engineering at TEPCO.

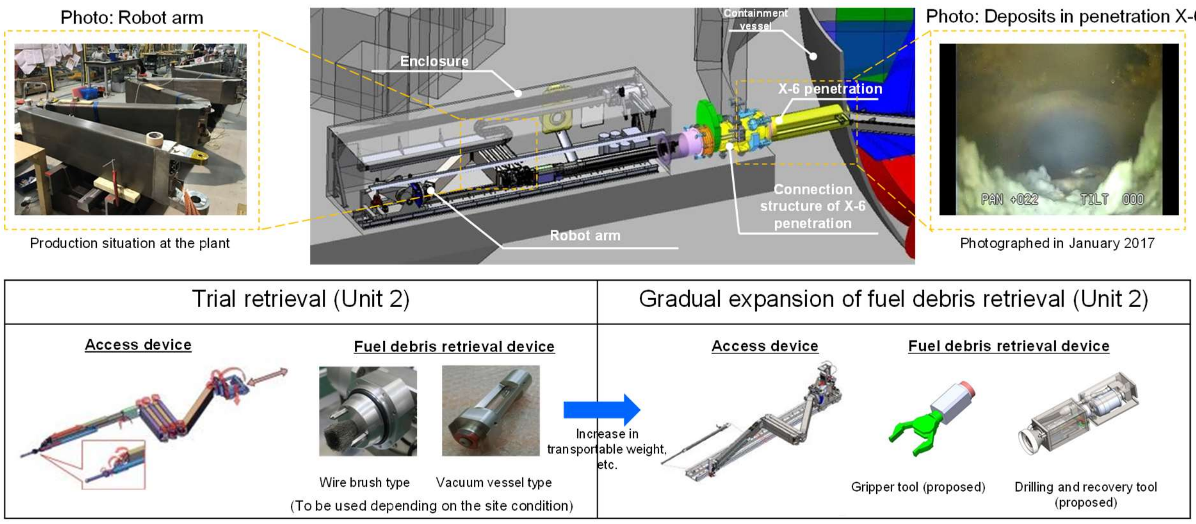

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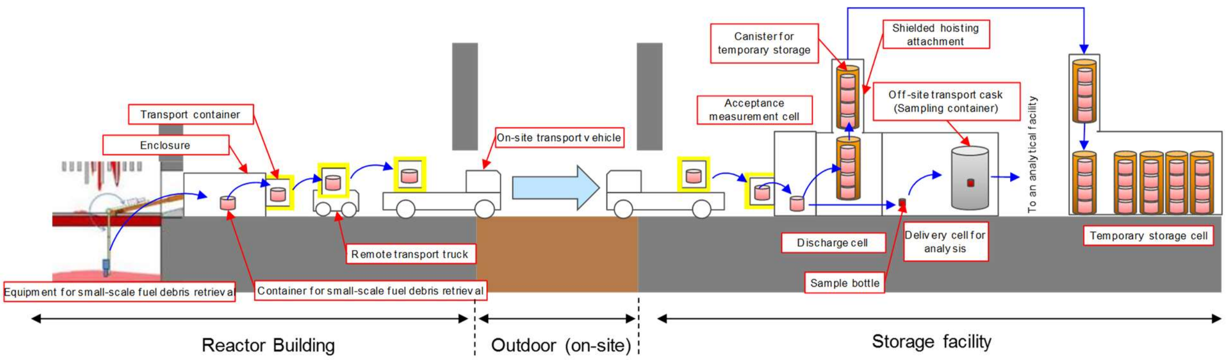
Fig.5 Image of fuel debris retrieval system (Trial retrieval and subsequent gradual expansion of fuel debris retrieval)



(TEPCO material edited by NDF)

Fig.6 Image from retrieval to temporary storage of fuel debris (Gradual expansion of retrieval scale)

(3) Unit 3

As for Unit 3, due to high water levels in the PCVs, it is planned to gradually lower the PCV water levels, taking into account the improvement of earthquake resistance of the suppression chamber (hereinafter referred to as “S/C”) and conducting internal investigations of PCV. The concentration of radioactivity may be high in the S/C-encapsulated water, and measures depending on the water quality in S/C should be taken. Therefore, in the design and construction of a PCV water intake installation and in the planning of water treatment, activities are under way to determine water quality by sampling the S/C-encapsulated water.

3.1.2 Key issues and technical strategies to realize them

Since the research and development necessary for understanding the situation inside the PCVs and for fuel debris retrieval is still limited, the current design and the plan for on-site operations related to fuel debris retrieval should be continuously reviewed based on the knowledge that will be obtained in the future. In addition, considerations are given and the research and development for fuel debris retrieval is being promoted, which should lead to an accurate reflection of the outcome thereof.

3.1.2.1 Trial retrieval, internal investigation of PCV, and gradual expansion of fuel debris retrieval

With regard to the trial retrieval, there are uncertainties and difficulties in the development of robot arms and the removal of deposits and obstacles due to a limited understanding of the conditions inside the PCV. Therefore, it is important to conduct a mock-up test simulating the site from the operator's perspective, while adequately confirming safety and the actual site applicability to steadily proceed. Especially for a mock-up test, it is important to simulate its severe environment at the site. Moreover, it is needed to make a sufficient preparation for countermeasures at the actual site application, while clarifying operations that cannot be simulated.

In addition, it is also important for TEPCO to take the initiative in promoting engineering based on the considerations in (1) to (3) that have been gained from past experience under the strengthened project management system.

Based on the engineering schedule led by TEPCO, NDF will set in advance the points to be confirmed, such as the actual site applicability of access devices, results of examinations on modifications to the safety system, and the safety assessment of dry storage, and will confirm the outcome of research and development, engineering results, and the progress in on-site operations from the viewpoints of safety, reliability, reasonability, timely, and the field-oriented stance.

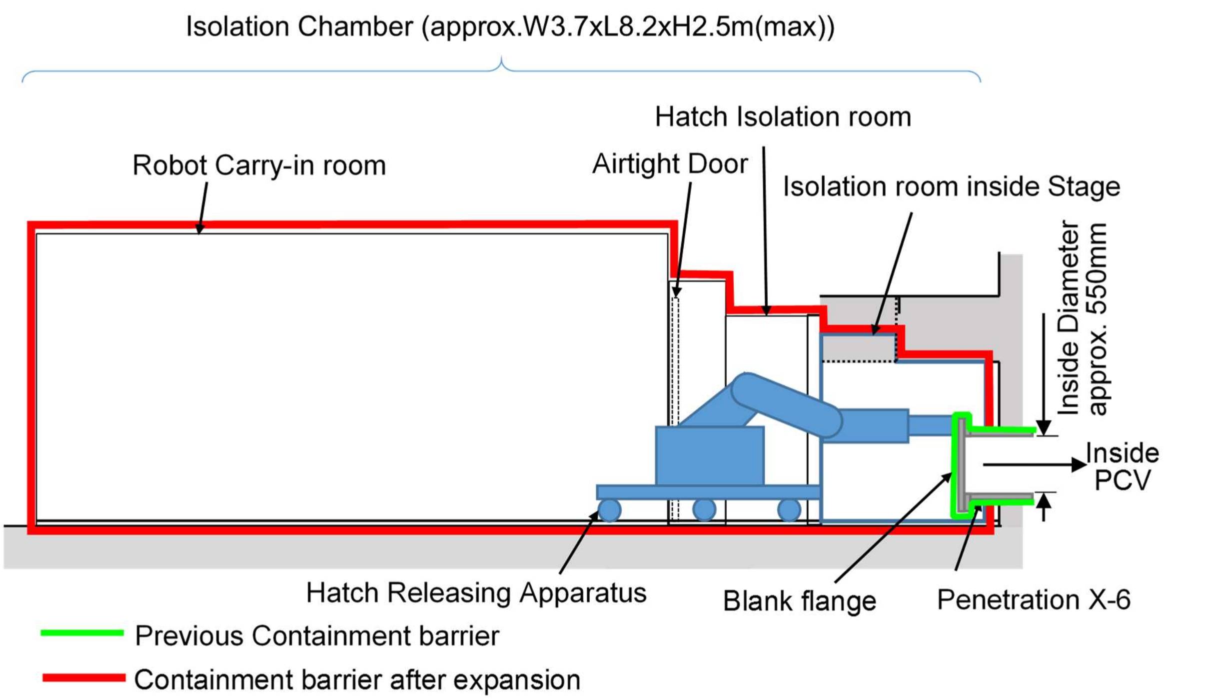
At Unit 2, while reviews have proceeded toward the start of a trial retrieval and internal investigations of PCV using the same robotic arm by the end of 2021, the review process should be proceeded with after ensuring safety by reaffirming that safety is most important. Furthermore, due to the restricted attendance of engineers and technicians because of the recent worldwide spread of the coronavirus, it is assumed that the planned work would be more difficult than before, and therefore, more deliberate and careful attention should be paid to ensuring safety.

In the conventional internal investigations of PCV, an opening of 115 mm in diameter was made in the blank flange part of the penetration X-6 to maintain airtightness using an isolation valve or the like. In the future trial retrievals and internal investigations of PCV, pressure will be reduced to a level close to the atmospheric pressure in order to suppress dust dispersion. The work will be performed by opening the flange of the penetration X-6 to make a larger opening than before (approx. 550 mm in the inner diameter of the penetration X-6) through which the arm-type access investigation equipment is moved in and out to retrieve fuel debris inside the PCV. In this work, an expansion will be made to provide an isolation chamber (composed of a robot carrying-in room, etc.) to be built during the penetration X-6 opening work (Fig. 7) and an enclosure to be newly provided (which will enclose an arm-type access investigation equipment, etc.) (Fig. 8), since the conventional containment barrier was located in the blank flange part of the penetration X-6. Although small in scale, this is a fundamental form of site construction for future retrieval work, in which an opening will be newly provided in the PCV to extend the containment barrier outside the PCV. This presents an approach that enters a new stage. The information obtained through this approach will be reflected in future work.

When extending the containment barrier of the penetration X-6, the penetration X-6 shall be opened while maintaining the function by installing an alternative device, etc., in order to maintain the containment barrier function that is currently retained. In doing so, there will be very difficult considerations, including building an isolation mechanism to continuously maintain the opening device and the containment barrier function that is currently retained, installing these devices through remote operation, etc. In the opening work of the penetration X-6, it is planned to cover the circumference of the penetration X-6 with an isolation chamber when devices and equipment are installed. As described above, since the opening work of the penetration X-6 is associated with maintaining the containment barrier function, a review shall be carried out with considerable attention to safety in particular, and preparations, verifications and training shall be performed in a more deliberate and careful manner.

The removal of obstacles, a trial retrieval, and internal investigations of PCV that are performed after opening the penetration X-6 shall be conducted based on the information on the inside of the penetration X-6 obtained on site and the varying site conditions, etc. According to the state of obstacles in the PCV and the internal conditions actually obtained, the sequence and method of removing obstacles, a trial retrieval, and internal investigations of PCV may vary depending on the observation results obtained at that time. Therefore, these activities shall be deemed as integrated work.

In the future, based on the knowledge to be obtained through trial retrieval, we will proceed with the design and review of the retrieval installations and safety systems toward gradual expansion of fuel debris retrieval.



(TEPCO material edited by NDF)

Fig.7 Schematic drawing of Isolation Chamber to be installed at Penetration X-6
(during the opening work of the penetration X-6)

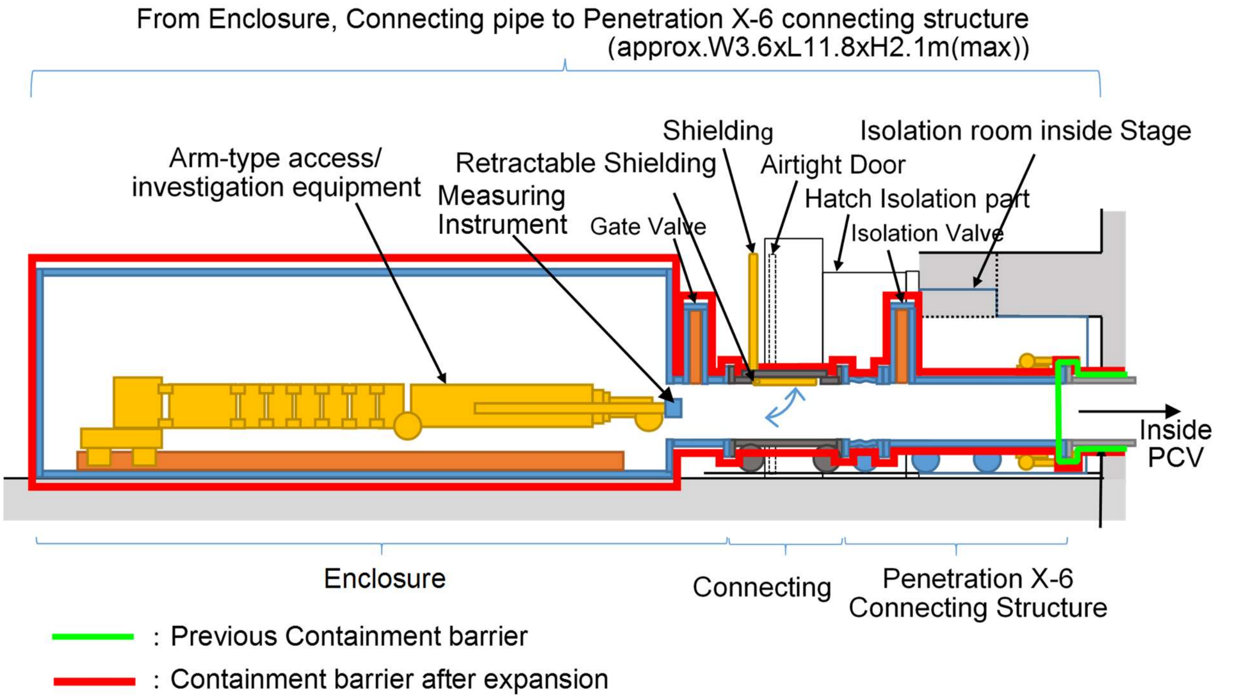


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Fig.8 Schematic drawing of Enclosure to Penetration X-6
(during a trial retrieval and internal investigations of PCV)

(1) Promoting the project with a strong awareness of safety from the initial stage

When opening the inner door of the penetration X-2 to conduct Internal investigations of PCV of

Unit 1, the dust monitor for monitoring the work reached the control value, and the measures to control dust dispersion and dust concentration monitoring were carried out by taking sufficient time. Specifically, the work was carried out with the cutting amount limited, and a number of measures were taken, such as cutting with a reduced peak density based on the data obtained on dust dispersion characteristics and the addition of a new dust monitor for monitoring the work. Despite the unknown conditions inside the PCV, these measures were taken by carefully working while newly obtaining knowledge on dust diffusivity. Giving more consideration to dust dispersion control from the viewpoint of safety at the initial stage of the project will enable the work to be implemented systematically. To smoothly proceed with the project by utilizing this experience, safety assessments should be conducted more often than ever from the initial stage of the examination and the requirements should be defined clearly by considering the actual site applicability.

(2) Clarification of quality requirements considering actual site applicability

Based on the experience obtained in the research and development and the TEPCO-led engineering, development of devices will be carried out for gradual expansion of fuel debris retrieval and further expansion of fuel debris retrieval. Depending on the amount of fuel debris to be retrieved, the scale of the device becomes large and stable reliability should be ensured over the long term. Consequently, it is important to proceed with the development of the devices after clarifying the specifications such as the functional requirements, in consideration of the actual site applicability in advance. Quality control of the fuel debris retrieval device is especially important. TEPCO is required to proceed with the development of the devices on the premise that TEPCO will ensure the quality by sorting out the quality level and the basic requirements concerning quality in advance according to the situation at the Fukushima Daiichi NPS.

In addition, it is expected that more and more efforts will be made in the future in considering the fuel debris retrieval and in the construction work by combining with knowledge and experiences from overseas. In the research and development carried out with overseas companies, etc., we have experienced several challenges in the process control other than quality control, as well as in understanding the design and production capabilities of the suppliers. To exploit overseas knowledge and experience, more detailed process control must be carried out also by contractors and their subcontractors.

(3) Acquisition and utilization of information during fuel debris retrieval

TEPCO has begun to consider the selection of data to be acquired and the installations for acquiring such data, aiming for gradual expansion of fuel debris retrieval and further subsequent expansion. This study involves difficulties in overcoming various limitations such as the weight capacity of the handling equipment, the cumulative dose of the equipment, remote operability, etc.

Although the on-site situation is uncertain, it is important to acquire data through condition monitoring, such as instrumentation monitoring and visual observation during the fuel debris retrieval operation to make simulation-based assessments, and to acquire the parameters to be used as design conditions for safety systems and various devices. Thus, an approach is required to link the data to the results of analyses that will be separately conducted, and to utilize them in considering the retrieval method and the safety assessment.

In addition, it is necessary to study the methods for storage and control of solid waste generated during fuel debris retrieval. It is important to collect various samples, improve data, and repeat analyses and assessments from the viewpoint of contributing to the examination of processing and disposal methods, in addition to the acquisition of data indispensable for immediate storage and management during the stage of trial retrieval and gradual expansion of fuel debris retrieval, examinations, and work. For this purpose, the analysis and assessment should be proceeded with in a systematic and flexible manner as required.

The most important thing in the debris retrieval work and in the handling of the waste generated during retrieval is to proceed with the work under strict work safety management.

3.1.2.2 Further expansion of fuel debris retrieval

To further expand fuel debris retrieval, more consideration should be given to study the retrieval method from the perspective of the entire Fukushima Daiichi NPS, in association with the scale-up of operations, devices, and facilities. Since TEPCO is at the stage of making a very important decision for decommissioning as the project executor, TEPCO is required to set up a basic policy with the perspectives on cost, duration, and total exposure dose, while giving top priority to ensuring safety, and taking responsibility for carrying out the project. The outcome and information newly obtained from R&D and internal investigations should be reflected in the study of the retrieval method, and an approach has to be taken in a flexible manner considering the retrieval method. In addition, it is important to ensure safety through design and on-site operations, such as reflecting the information obtained from on-site operations in the design of subsequent stages, based on the concept of preliminary implementation and utilization of the obtained information in the latter stages, while paying attention to social aspects such as the impact attributable to the long-term decommissioning project.

With regard to further expansion of fuel debris retrieval, we will continue to improve the environment inside and outside the buildings of Units 1 and 3, and continue to study the concept of fuel debris retrieval installations and safety systems, as well as promote the installation design, based on the research and development results and knowledge obtained through the retrieval at Unit 2. In particular, it is important to ascertain the feasibility of safety systems designed to secure the safety functions necessary for proper operation of equipment and devices for the safe retrieval and storage of fuel debris, and to steadily proceed with studies on the fuel debris retrieval method through a reliable approach.

(1) Study flow of the retrieval method

With regard to further expansion of fuel debris retrieval, consideration will be given to the methods including those for collection, transfer, and storage of fuel debris, by ascertaining the progress in the fuel debris retrieval at the first implementing unit, Internal investigations of PCV, research and development, and the on-site environmental improvement, etc. In doing so, operations, devices and equipment, and facilities will be larger in scale and the scope of construction will be wider than in the case of retrieving fuel debris from the first implementing unit (Unit 2). Therefore, much more attention should be paid in overviewing the entire Fukushima Daiichi NPS, including other work. In addition, due to a wider range of operations to be done and studies in technical fields to be conducted, consideration should be given to the retrieval method by continuously gathering international insights. In addition, because of the high dose on site and the limited understanding of the situation inside the PCVs, the scope of operations will be enlarged. Therefore, it is important to specify the requirements required for operations and devices more clearly and to proceed with the study of the systematic retrieval method. NDF will evaluate the actual site applicability and feasibility of the retrieval method based on the results of TEPCO's conceptual study. The study flow (conceptual diagram) is shown in Fig 9.

TEPCO's Mid-and-Long-term Action Plan for Decommissioning assumes that the study for Unit 3 will be conducted in advance to apply to Unit 1. While a trial retrieval and gradual expanded scale of the retrieval will be implemented at Unit 2, it is Unit 1 or Unit 3 that enables easy access to a large amount of fuel debris, because fuel debris remains in bulk at the bottom of the pedestal of these Units.

As for Unit 1, the outside of the pedestal will be investigated through the penetration X-2 first for internal investigations of the PCV, and. Based on the result of these investigations, the retrieval method should be examined. As for Unit 3, the structures inside the PCV and the bottom of the PCV were investigated from the penetration X-53 using cameras and dosimeters in October 2015, and the inside of the pedestal was investigated to obtain information by inserting an underwater ROV from the penetration X-53 in July 2017.

In addition, from the viewpoint of securing the work area for accessing to the penetration X-6 and others, it is estimated to take time in reducing the radiation dose in high dose areas at Unit 1. As for Unit 3, although the PCV water level must be lowered below the first floor of the reactor building to insert the survey equipment and the retrieval device, the work can be considered to proceed faster than that of Unit 1.

In view of the sufficiency of information mentioned above and the site conditions, Unit 3 will be able to commence debris retrieval and obtain information earlier.

By setting a certain unit as a representative one, it will enable advancement of engineering including study of retrieval method, and earlier obtainment of technical points and items to be further studied. Utilizing the results in other units will lead to reducing the overall risk of fuel debris in Units 1 to 3. From the above, it is deemed appropriate to consider Unit 3 as a pioneer unit.

In this way, while taking a pioneering approach at Unit 3, the status of other units and the review results should be reconfirmed, and the unit under review as a pioneer unit may need to be reconsidered, depending on the outcome. Even if the first implementing unit (Unit 2) is in the process of retrieving fuel debris, the method of proceeding with the fuel debris retrieval shall be flexibly considered in light of optimizing the overall decommissioning work, for example, by starting the retrieval from another unit that is in preparation for retrieval based on the operation experience from Unit 2.

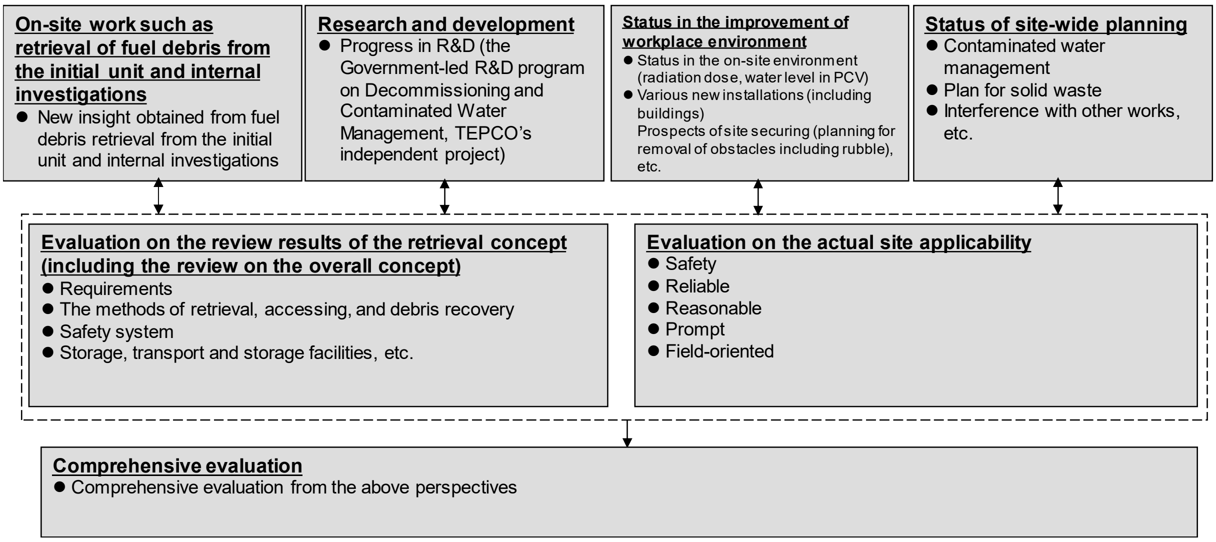


Fig.9 Study flow of the retrieval method (Conceptual diagram)

(2) Concept of important requirements for the retrieval method (Boundary conditions)

At present, TEPCO is studying the retrieval method by tentatively setting preconditions for requirements based on the research and development. Although the gradual expansion of fuel debris retrieval has entered the stage of engineering, the phases of design improvement, performance verification, operation training, and preparatory work have not yet been started. The further expansion of fuel debris retrieval is still in the research and development stage, and the extraction and examination of the technologies and installations that are supposed to supplement R&D have just started toward commercialization, but narrowing down a method based on realistic feasibility has yet to be performed. In narrowing down the method, the uncertainty of the conditions inside the reactor are an obstruction to full-scale engineering.

To proceed with the examination of a systematic retrieval method in the future, it is required to reexamine the important requirements related to the determination of a retrieval method (the boundary conditions) among the preconditions established at the initial stage of research and development based on the information and the results of the analyses that have been obtained to that point to clearly define the requirements, and to revise them as required. In addition, the appropriateness of the concept of the construction method devised at the research and development stage should be considered and, with regard to a realistic methods, it is also required to carry out engineering processes such as a trial manufacture in design, performance verification by mock-up, design improvement, addition of functions in view of the approach to safety, ancillary preparatory work, and design of the surrounding installations on a considerable scale.

Based on the basic policy, including the perspective described at the beginning of this section, when stipulating the requirements and proceeding with the study on retrieval methods, TEPCO is required to clearly define the important requirements (the boundary conditions) as the project executor. The important requirements (the boundary conditions) shall be stipulated based on the safety perspective and the operator's perspective, regarding which requirements to be defined as important and which level of performance is required. For example, the important requirements (the boundary conditions) may include the total exposure dose of workers, criticality, dust (containment), reduction of waste generation, and the recovery rate of fuel debris. Requirements shall be defined in specifics to evaluate the actuality: For example, for the total exposure dose, requirements from the viewpoint of how to control the total exposure dose of workers and the exposure dose of individual workers; for criticality, requirements for subcriticality monitoring and prevention of criticality with the retrieval method; for dust (containment), requirements for suppression of dispersion of radioactive dust and gas-phase containment; for suppression of waste generation, requirements from the viewpoint of characteristics of generated waste and suppression of generated amount by the retrieval method; for the recovery rate of fuel debris, arrangement of realistic targets in terms of achievable recovery speed and recovery rate from the operation side. In addition to these, TEPCO is required to take the initiative in making decisions on various important requirements (the boundary conditions) to steadily proceed with the examination of retrieval methods.

(3) A flexible approach in studying the retrieval method

TEPCO is examining retrieval methods according to research and development. Going forward, after the aforementioned important requirements (the boundary conditions) are stipulated, it is required to take a flexible approach depending on the situation, including partial improvement of the retrieval method, according to the assessment of the actual site applicability to be implemented based on the cases of dust dispersion during the opening work of the inner door of the penetration X-2 for the Internal investigation of PCV at Unit 1, the results to be obtained from future research and development, and the information to be acquired from a trial retrieval, Internal investigations of PCV, and gradual expansion of fuel debris retrieval at Unit 2.

When studying the dust dispersion control in "containment" as an example, although the limits for the amount of release during normal operations and the limits for public exposure during an accident must be satisfied, we are studying the retrieval method by establishing preconditions including assumptions, because the amount and properties of particles generated vary depending on the processing method and the object. In addition to the outcome obtained through these studies, a repetitive and iteration-based approach will be required by incorporating newly obtained information to verify the appropriateness of the preconditions to be established based on the safety perspective and the operator's perspective, and to review the retrieval method based on the results.

(4) Ensuring safety through design and on-site operation

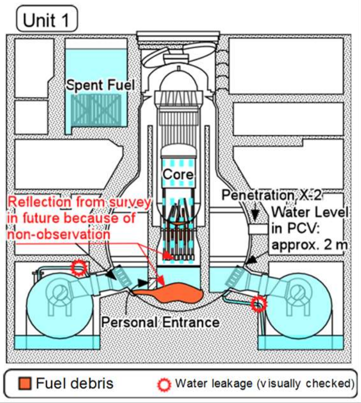
Since the decommissioning of the Fukushima Daiichi NPS is an unprecedented approach, the perspective and awareness of those responsible for on-site operations (operation, maintenance, radiation control, instrumentation, analysis, construction, etc.) are more important than those for conventional reactors. Chapter 2 describes the concept of safety assurance in the decommissioning work. For example, the operability of the retrieval device for safe handling of fuel debris, condition monitoring to understand the state of dust dispersion during the retrieval work, and exposure assessment during the retrieval work are important information for on-site operations. In addition to this information, it is necessary to acquire information through on-site operations such as analysis while conducting trial retrieval, gradual expansion of fuel debris retrieval, as well as investigations and work, and reflect the information in the next design to ensure safety.

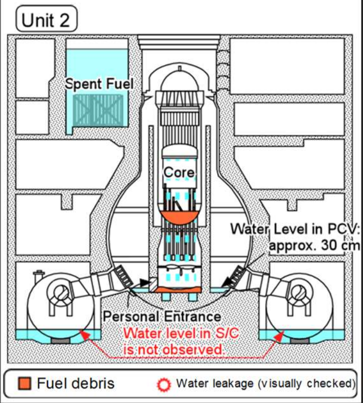
In addition, the perspective and awareness of those responsible for on-site operations should be considered in establishing the requirements stated in [2], and should be treated as the requirements in studying the retrieval method in order to determine specific conditions thereof.

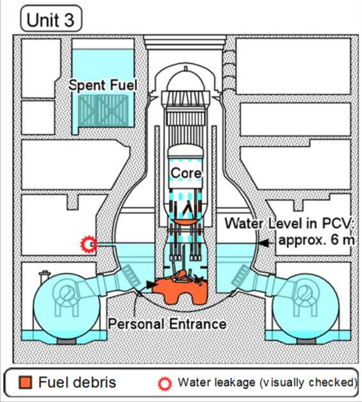
3.1.2.3 Continuation of internal investigations, etc., and steady implementation of the Mid-and-Long-term Decommissioning Action Plan

Fig.10 shows the comprehensive analysis and the evaluation results of the distribution of fuel debris, access routes to fuel debris and condition of the structures around fuel debris of Unit 1 to 3. These results were derived from actual measured values of plant parameters obtained during the accident, results of the severe accident progression analysis, information obtained by internal investigations of PCV, and the knowledge obtained through various examinations. Although the state of distribution may vary, the analysis indicates that fuel debris exists both inside the Reactor Pressure Vessel (hereinafter referred to as “RPV”) and at the bottom of the PCV. In order to retrieve fuel debris from each unit, better understanding of the conditions inside the RPV and PCV through continuous implementation of internal investigations as well as research and development. In addition to these efforts, since it is important to understand the current condition of each unit and what happened in the accident in order to proceed with decommissioning safely and reliably, activities should be taken to clarify the causes of the accident at the Fukushima Daiichi NPS to the reasonable extent, in cooperation with domestic and international organizations. (Attachment 7)

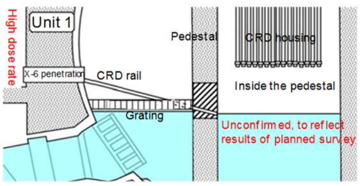
The Mid-and-Long-term Decommissioning Action Plan presents the work schedule for trial retrieval, gradual expanded scale of the retrieval, and further expanded scale of the retrieval, and will be reviewed and revised on an ongoing basis, based on the knowledge to be obtained through future Internal investigations of PCV, etc. The work schedule should be broken down into more specific items to realize steady implementation of preparatory work toward fuel debris.

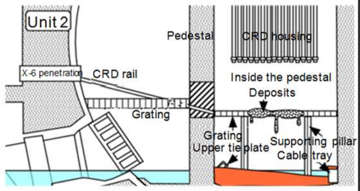


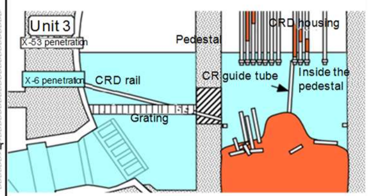




	Unit 1	Unit 2	Unit 3
Core region	· Little fuel debris remains.	· Little fuel debris remains. (Partially intact fuel might exist in the peripheral region)	· Little fuel debris remains.
At RPV lower head	· A small amount of fuel debris is present · A small amount of fuel debris is present inside and on the outer surface of the CRD housing.	· Large amount of fuel debris is present · A small amount of fuel debris is present inside and on the outer surface of the CRD housing.	· Part of fuel debris is present · A small amount of fuel debris is present inside and on the outer surface of the CRD housing.
At the PCV bottom (Inside the pedestal)	· Most of the fuel debris is present.	· A certain amount of fuel debris is present.	· Amount of fuel debris in Unit 3 is more than that in Unit 2.
At the PCV bottom (Outside the pedestal)	· Fuel debris may have spread outside the pedestal through the personal entrance.	· The possibility of fuel debris spreading outside the pedestal through the personal entrance is low.	· Fuel debris may have spread outside the pedestal through the personal entrance.
Radiation dose in operation site[*1]	· Radiation dose around the penetration X-6 on the first floor of R/B is high (630 mSv/h).	· Radiation dose on the first floor of R/B had reduced to approx. 5 mSv/h as a whole.	· Radiation dose on the first floor of R/B is higher than tens of mSv/h.







	Unit 1	Unit 2	Unit 3
Information on the access route to fuel debris[*2]	• The D/W bottom outside the pedestal is accessible from the upper side of the steel grating. • Condition around the CRD rail connecting into the pedestal from the penetration X-6 has not been observed.	• No large obstacles have been observed on the CRD rail and around the pedestal entrance. • The bottom inside the pedestal is accessible through the pedestal entrance.	• The bottom inside the pedestal is accessible through the pedestal entrance.
Information on the condition of structures around the access route	• No significant damage has been observed on the wall surface outside the pedestal on the steel grating upper side.	• While a part of fuel assemblies have fallen, no damage has been observed on the CRD housing support in the examined range . • No damage has been observed on the wall surface and the structures (CRD exchanger, etc.) inside the pedestal.	• Some damaged structures and fallen objects (which may include internal structures), and the fall and deformation of a part of the CRD housing support have been observed inside the pedestal. • No damage has been observed on the wall surface inside the pedestal.

*1 Data provided by TEPCO

*2 Results obtained through PCV internal investigation performed up to date were presented for judging whether any obstacles such as fallen objects may exist on the route to the inside of the pedestal from X-6 penetration, which is considered as a dominant access route for fuel debris retrieval by the side access method.
Other access routes through the equipment hatch and others have been investigated under the Governmental-led R&D program on Decommissioning and Contaminated Water Management.
Due to high dose rate around X-6 penetration of Unit 1, an access route through the equipment hatch may be used in case that it is difficult to improve the environmental condition around X-6 penetration.
PCV internal investigation of Unit 1 will be performed through X-2 penetration (equipment hatch) considering accessibility of devices for PCV internal investigation.

(Created based on "Reference 1 : Water sampling included inside the suppression chamber (S/C)" in Unit 3, The 81st Study on Specified Nuclear Facility Monitoring and Assessment, etc.)

Fig.10 Estimated fuel debris distribution, access route and surrounding structures of Units 1 to 3

3.1.2.4 Technical issues for technical requirements and future plans

3.1.2.4.1 Technical issues for ensuring safety of fuel debris retrieval work

In general, when considering ensuring safety at a nuclear facility, a series of evaluations are conducted by assuming accident scenarios in which the potential hazards of the facility become materialized, evaluating that these scenarios fall within the safety standards, and confirming that the safety measures are appropriate. In an ordinary nuclear power plant, such a series of safety assessment procedures are established and standardized by national regulations and guides. On the other hand, since there are no established and standardized regulations and guides for the decommissioning work at the Fukushima Daiichi NPS, it is necessary to organize an approach to ensuring safety based on the safety-related features of the Fukushima Daiichi NPS and to share it with the parties concerned.

Decommissioning of the Fukushima Daiichi NPS containing the reactor involved in the accident is an unprecedented activity that takes place in a special environment different from that of a normal reactor, and therefore, to ensure safety, it should be fully recognized that following characteristics (peculiarity) in safety.

- A large amount of radioactive materials (including α-nuclides that have a significant impact on internal exposure) are in an unsealed state, as well as in unusual (atypical) and various forms
- The barriers to contain radioactive materials, such as reactor buildings and PCV, are incomplete
- Significant uncertainties exist in the condition of these radioactive materials and containment barriers, etc.
- Difficulty in accessing the site and installing instrumentation devices to obtain on-site information due to constraints such as high radiation levels on site
- Since the current level of radiation is high and further degradation of containment barriers, etc., is a concern, it is necessary to take measures in consideration of the time axis without prolonging the decommissioning activities

Based on these characteristics, NDF is organizing an approach to ensuring safety with the following as the basis:

- Optimization of judgement with safety assessment as its basis:
  When making decisions by comprehensively considering technical reliability, reasonableness, promptness, etc., safety assessments should be fully used to avoid a great variance in decisions for safety measures (to avoid too excessive or too insufficient resource input).
- Ensuring timeliness in decommissioning activities:
  While paying attention to the prevention of accidents and the mitigation of their impacts, measures should be taken with concentration on the time axis so as not to prolong the decommissioning period, in consideration of high radiation effects that have already become apparent, as well as further deterioration of containment barriers, etc.
- Complementing design by operating controls, monitoring, analysis, and on-site operation in the event of an abnormality:

Due to significant uncertainties, there is a limit in addressing all situations by design alone. For this reason, the information obtained at the operation stage, including that obtained through monitoring and analysis, should be utilized in design, and the design should be complemented by operators' efforts and on-site operation to enhance safety in total with the operation. In the preparation for abnormalities, consideration should be given to on-site response considering the characteristics that the progresses of abnormalities is moderate and there is sufficient time for response.

In addition, along with organizing the concept for ensuring safety, technical requirements have been established for ensuring safety of fuel debris retrieval and intensive studies are being conducted as shown in the following Sub-sections 3.1.2.4.2 to 3.1.2.4.7.

3.1.2.4.1.1 Establishing the containment functions (gas-phase)

Dispersion of radioactive material in ordinary operating nuclear power plant is prevented by keeping interior of a reactor building under negative pressure against the ambient air (active containment function by maintaining under negative pressure) and pressure in a PCV is maintained to be equal to that inside of a reactor building (passive containment function). On the other hand, the reactor buildings, PCVs, etc. of the Fukushima Daiichi NPS are partially damaged by the hydrogen explosion and their containment function has been deteriorated. Due to this, establishment of an active containment function by controlling pressure in negative is being considered during fuel debris retrieval work. Moreover, from the viewpoint of prevention of hydrogen explosions due to steadily generated hydrogen by the process of radiolysis of water and of corrosion (inactivation) of structural materials due to the presence of oxygen, nitrogen is injected into the PCV to maintain it in a nitrogen atmosphere. As for the exhaust from inside the reactor buildings, the release of radioactive materials has been prevented by the PCV gas control system, which is furnished with filters to remove radioactive materials and measure radioactivity[9].

We expect that existing safety systems will be able to cope with the retrieval of fuel debris, such as gripping and suction, in the case of a trial retrieval or gradual expansion of fuel debris retrieval. In the subsequent work such as fuel debris cutting, it is necessary to construct the containment function of the gas phase system in consideration of re-scattering of Cs, etc., that adhere to the equipment and structures in the PCV, aerosolization of water containing radioactive materials, and generation of short-lived iodine and noble gases if criticality should occur.

In addition to re-scattering of Cs, etc., it is concerned that dispersed fine particles (α-dust) containing α-nuclides may be generated and the radioactivity concentration in the PCV gas-phase part may increase. Therefore, dispersion of α-dust from inside the PCV must be suppressed as

[9] TEPCO, The assessment result of the additional volume of release from Units 1 to 4 reactor buildings (June 2020). presented as Handout 3-6 at the 80th Meeting of the Secretariat of the Team for Countermeasures for Decommissioning and Contaminated Water Treatment, May 28, 2020
https://www.tepco.co.jp/decommission/information/committee/roadmap_progress/pdf/2020/d200528_11-j.pdf

much as possible, and a function for containing the gas-phases should be provided to make the dose impact on workers and the public fall within the allowable value.

Accordingly, it is reasonable to expand the retrieval scale while understanding the tendency of dust dispersion at each stage of expanding the fuel debris retrieval scale, and verifying the appropriateness of the containment function built in the subsequent stage. In the engineering conducted by TEPCO, the improvement of dust monitoring installations inside and outside the reactor buildings and the study of equalizing or reducing pressure in the PCV using existing equipment are being carried out based on the outcome of the Government-led R&D program on Decommissioning and Contaminated Water Management. In the future, the effect on the surroundings will be assessed based on the monitoring results of the changes in condition such as the dispersion of α-dust associated with the work, and the retrieval scale of fuel debris will be gradually expanded.

In doing so, we are considering establishment of a secondary containment function and study its necessity, while assuming the possibility of an increasing impact on the surroundings.

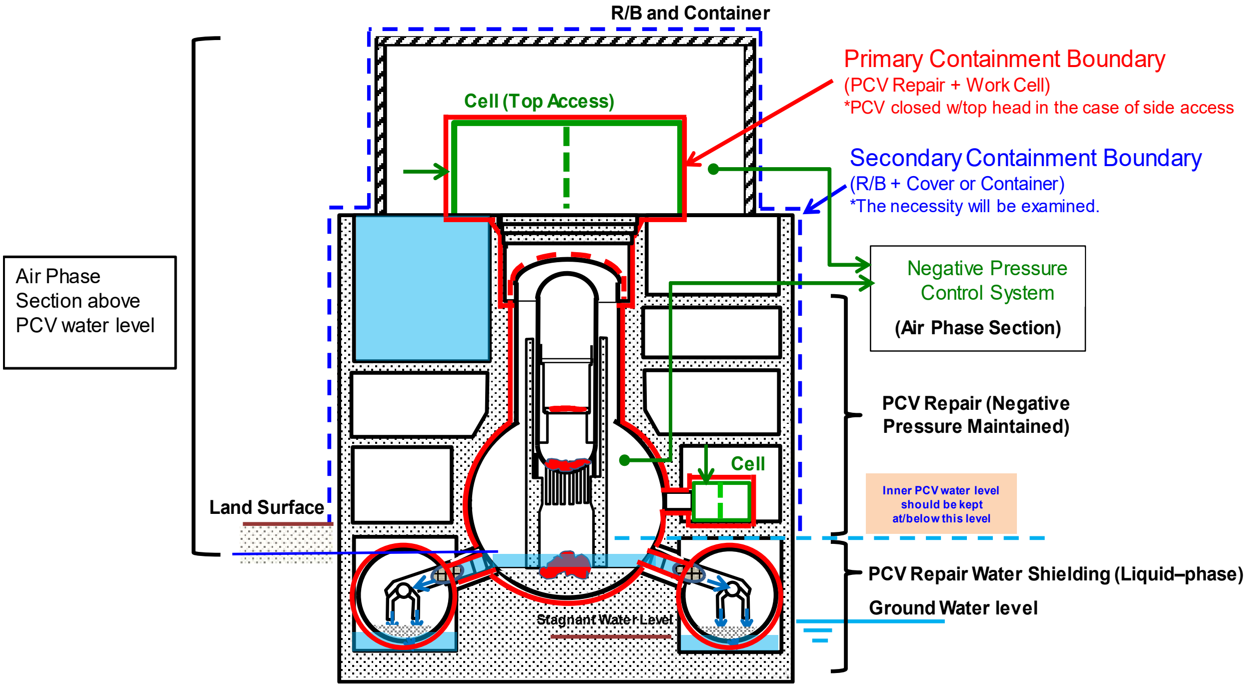


Fig.11 Example of containment function (gas-phase) by negative pressure control

In establishing the containment function (gas-phases), technical issues to be addressed immediately for further expansion of fuel debris retrieval are as follows:

(1) Understanding of the dispersion rate of α-dust

As described above, for the purpose of fuel debris retrieval work, it is necessary to collect data such as α dust dispersion rate and to establish measures to suppress the transition of α-dust gas phase as much as possible based on the collected data.

To collect data such as the dispersion rate of α-dust, it is necessary to plan demonstration and confirmation of the dispersion rate measurement during a trial retrieval and the gradual expansion of fuel debris retrieval that are expected in the future. Moreover, in order to proceed with the review of technologies and R&D activities for the fuel debris retrieval method/system under conditions where such demonstration data have not been obtained, the general behavior related to α-dust dispersion should be roughly understood. For this purpose, verifications are currently underway by using the mock-up debris for developing analysis and estimation techniques to characterize the fuel debris.

In order to suppress the transition of α-dust to the gas phase, it is desirable to submerge the fuel debris and to perform retrieving of it as much as possible under water. However, the water level in the PCV is to be adjusted with other technical requirements such as the building of the containment function of the liquid phase described in the next section. Therefore, not all fuel debris can be retrieved under water, and transition of α-dust to gas phase is considered to be mitigated by splashing water on the fuel debris that is not submerged.

(2) Ascertaining the feasibility of negative pressure control in the PCV

A. Technical feasibility of negative pressure control based on the site conditions

In order to maintain pressure in the PCV in negative, enough capacity of gas exhaust system is required considering PCV damage condition. Although damaged part have not been identified yet, and the exhaust capacity is currently evaluated based on the relationship between actual nitrogen supply volume and actual PCV internal pressure. At this time, it is necessary to maintain sufficient pressure difference to respond to the internal pressure rise of the PCV due to abnormal events such as an internal temperature rise or stoppage of the gas exhaust system. In order to achieve these, repair of the damaged parts of at the upper part of the PCV will be considered as necessary, but there are some difficulties such as remote work or exposure of workers due to work under high dose conditions.

In this way, it is necessary to ascertain the technical feasibility of maintaining the negative pressure in the PCV based on the site conditions and the information obtained during trial retrieval or the gradual expansion of fuel debris retrieval.

B. Effect of air flow into the PCV during negative pressure control

Air flows into the PCV when maintaining pressure in the PCV in negative. Therefore, it is necessary to examine measures of maintaining inactivated condition in the PCV by increasing nitrogen gas supply into the PCV as necessary based on evaluation on occurrence of accidents such as fire and Hydrogen explosion using accumulated information regarding to volume of hydrogen generated by radiolysis of water in the PCV and inflow volume of air (oxygen) into the PCV.

C. Study on the necessity of a secondary containment function

As illustrated in Fig.11, for fuel debris retrieval, it is assumed that a working cell is newly installed as connected to the PCV under negative pressure control, and the work from retrieving the fuel debris to collecting the container into a transfer cask is performed in this cell. The PCV and this working cell have a primary containment function to prevent α-dust to the exterior.

In addition to this, in order to respond to an event in which radioactive materials are dispersed from the containment boundary caused by loss of primary containment function through negative pressure control, the necessity of the secondary containment function has been investigated by installing building covers and containers in the existing reactor buildings and maintaining slightly negative pressure inside of the reactor buildings to recover and treat radioactive materials. However, large capacity of gas exhaust system is considered to be required to maintain negative pressure in the secondary containment boundary since the reactor building has a large volume and the its leak tightness may have been deteriorated due to the accident. Therefore, based on the accumulated results of the tendency of dust dispersion obtained hereafter, it will be necessary to ascertain the required functions to establish a secondary containment function and to proceed with research and development accordingly.

D. Deterioration control of the containment function of the PCV

In order to maintain pressure in the PCV in negative during the fuel debris retrieval work, it is necessary to consider how to respond deterioration of the primary containment function consisted of the PCV and the attached cell due to earthquakes and aging. This is outlined in Section 3.1.2.4.1.5.

(3) Study on exhaust gas management

In control of exhaust gas associated with negative pressure control, it should be confirmed that radioactive materials in gases that may contain nuclear fuel materials derived from fuel debris are maintained below the radiation dose standard for the public in the vicinity of the facility by measuring and controlling the release concentration and the release amount. In addition, α-nuclides derived from fuel debris should be included in the assessment and constantly monitored/measured during fuel debris handling so as to evaluate their normal fluctuation range in advance. By using such data, a system for early detection of abnormal events such as leakage and implementing appropriate impact mitigation measures should be established for preventing an impact on environment and workers.

Reliability or accuracy of mechanical property and chemical composition of the fuel debris needs to be improved because these are essential information for designing the decontamination equipment for efficient collection of radioactive dust.

3.1.2.4.1.2 Establishing the containment functions (Liquid-phase)

To mitigate the dispersion rate of generated α-dust and to minimize the transition to the gas phase, fuel debris cutting, etc., would be performed by pouring water over the fuel debris for fuel debris retrieval. Existing safety systems are expected to be capable of fuel debris retrieval by gripping and suction. For the subsequent work such as fuel debris fabrication and removal of obstacles, a large amount of α-particles will flow into 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. (Fig.12)

For this reason, it is necessary to examine technologies for removing soluble nuclides that may be leached from fuel debris to the circulating cooling water as well as treatment technologies for solid matter trapped by the filter equipped in the circulating cooling water system. Accordingly, the Government-led R&D Program on Decommissioning and Contaminated Water Management has been promoting research and development. In parallel with this, the establishment of a PCV circulating cooling system that takes water from the PCV and injects it into the reactor for cooling, which is beneficial in terms of preventing the spread of cooling water containing α particles, was considered in research and development by the Government-led R&D Program on Decommissioning and Contaminated Water Management.[10]

To establish a reasonable containment function in each phase of the scale expansion of fuel debris retrieval, it is rational to monitor the radioactive concentration of cooling water per phase and verify the validity of the containment function to be built in the subsequent phase. As with the containment function (gas phase), from the viewpoint of verifying/investigating the impact of the retrieval work on the liquid phase, TEPCO, through the engineering work, has been discussing monitoring of the circulating water system as well as system addition/installation, etc., for the purpose of reducing the concentration of radioactive materials at the inlet in the existing water treatment systems according to the results of the Government-led R&D Program on Decommissioning and Contaminated Water Management.[11] With regard to the effects on the liquid phase during debris retrieval operations, the scale of fuel debris retrieval will be expanded gradually, based on the results of monitoring changes in the condition of waste fluid containing α-nuclides. The water level in the reactor building is required to be maintained lower than the groundwater level to prevent the outflow of cooling water to groundwater and to appropriately control the water level in the PCV. Safety systems are to be established taking this into consideration.

In establishing this containment function (liquid phase), technical issues to be addressed immediately for further expansion of fuel debris retrieval are as follows.

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[10] IRID, FY 2017 Supplemental subsidies for the Government-led R&D Program on Decommissioning and Contaminated Water Management, "Technical Development for Water Circulation System Establishment in the Primary Containment Vessel (Full-scale Test)", Final Implementation Report for FY 2019, August 2020.
http://irid.or.jp/wp-content/uploads/2020/09/2019006mizujyunkan.pdf
IRID, FY 2017 Supplemental subsidies for the Government-led R&D Program on Decommissioning and Contaminated Water Management, Technical Development for Water Circulation System Establishment in the Primary Containment Vessel (Full-scale Test), Final Implementation Report for FY 2019, August 2020
http://irid.or.jp/wp-content/uploads/2020/09/2019007mizujyunkanjitukibo.pdf

[11] IRID, FY 2016 Supplementary Budget, Subsidies for the Government-led R&D Program on Decommissioning and Contaminated Water Management, Advancement of Retrieval Method and System of Fuel Debris and Internal Structures, FY 2018 Final Report, July 2020.
http://irid.or.jp/_pdf/20180000_13.pdf

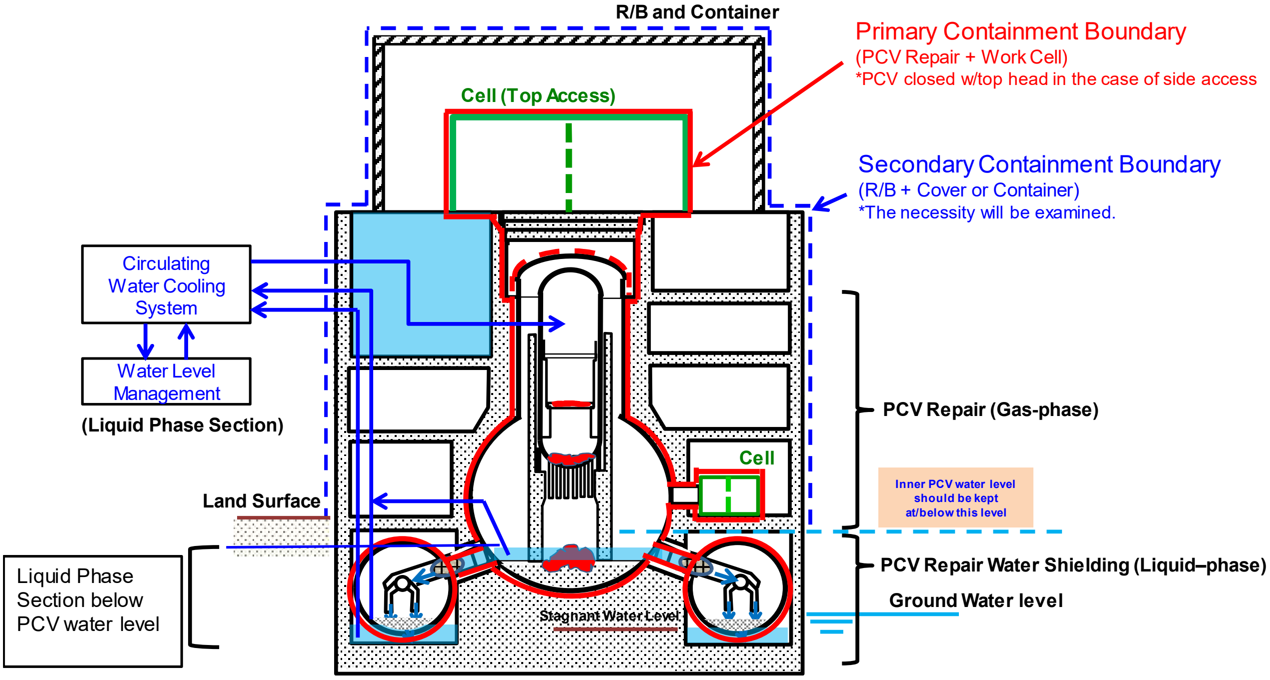

Fig.12 Build example of containment function (liquid phase)

(1) Suppression of radioactive concentration increase in cooling water due to fuel debris retrieval work

As an approach to assess the radioactive concentration in the cooling water, it is necessary to plan to investigate the impact on waste liquid when gradually expanding the scale of retrieval.

To suppress an increase of radioactive concentration in cooling water in the PCV, dust generated by fuel debris cutting is planned to be collected through the PCV circulating cooling system to mitigate dispersion of dust. It is recommended to incorporate the results of monitoring by the existing water circulation system into examinations on the PCV circulating cooling system as necessary in the phase of gradually expanding the scale of retrieval.

(2) Setting of water level in the PCV

Due to a low seismic margin of SC support columns, it is recommended to lower the water level in the S/C. In this instance, it is required to appropriately set and manage the water level in the PCV with consideration for the damage situation of the PCV in each Unit and prevention of the outflow of cooling water to groundwater (maintaining the water level in the reactor building below the groundwater level), etc., and to confirm that safety is ensured in terms of fuel debris cooling and control of dust dispersion.

3.1.2.4.1.3 Maintaining the cooling functions

Fuel debris generates heat due to the decay of radioactive materials. At Unit 2 after a lapse of 10 years since the accident, for example, the amount of heat generation has reduced to 1/1000 of the level at the time of the accident. However, the maximum heat generation is still estimated to be 69 kW[12]. Therefore, unless cooling is continued, the surrounding materials gradually absorb heat generated and there is concern that the following events may occur.

- The oxidation proceeds caused by increasing the temperature of uranium oxide in fuel debris (increased O/U ratio) resulting in volume expansion, crack generation, and thereby progression of pulverization.
- Moisture in concrete structures is also dissipated and dried by heat, and then cracks occur to decreased concrete strength.
- The inside of the PCV becomes dry, causing radioactive dust to be easily scattered and sent airborne.
- When water is injected after the PCV becomes dry, the water that contacts fuel debris turns into steam and raises the PCV internal pressure, which leaks from damaged areas with radioactive dust.

In order to prevent above four events and excessive temperature rise of fuel debris, the temperature is being maintained below 100°C (cold shutdown condition) currently by conducting circulating cooling with water injection into the reactor.

Until FY 2019, water injection into the reactor has been temporarily suspended with the aim of optimizing operation/maintenance management of cooling systems and emergency response procedures, etc. In addition, during the fuel debris retrieval work, it is 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.

However, it should be considered that the injection of cooling water may become redundant in the future due to further decrease in the amount of decay heat along with reduction in the remaining amount of fuel debris, as the fuel debris retrieval progresses.

In maintaining this cooling function, the technical issues to be addressed for the time being include setting of the target temperature inside the PCV to make each task feasible, as well as the countermeasures to be taken under the assumption of cooling function abnormalities when each task is performed. While essential countermeasures would be to continue cooling by early recovery of the cooling water circulation system or by flexible countermeasures, etc., it is necessary to evaluate changes in the PCV internal condition based on the time margin in an emergency and to consider emergency response measures and procedures, etc., including collection of devices.

As temperature monitoring in the PCV is also evaluated by the temperature of devices and water around the fuel debris, the fuel debris temperature is not directly measured. In preparation for reducing the amount of cooling water, a temperature measurement of fuel debris must be made or, if direct measurement is difficult, examining techniques to estimate it from the temperature of the devices and water used for the current assessment.

In addition, during the fuel debris retrieval operation, the processing of cutting fuel debris while

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[12] Nishihara Kenji, *et al.*, JAEA, "Evaluation of fuel composition in Fukushima Daiichi NPS", JAEA-DATA/Code 2012-018(2012).

spraying water is conceivable from the viewpoint of dust dispersion control, and attention should also be paid to water level control inside the PCV, as well as controlling of the contaminated water generated.

From the above, monitoring parameters and their criterion need to be studied and prepared through engineering work in order to carefully promote fuel debris retrieval work while observing how this work will affect the existing circulating water cooling and purification system, as well as its cooling function.

3.1.2.4.1.4 Criticality Control

At present, monitoring of the concentration of Xe-135, which are short-half-life fission products, has shown no sign of criticality as the concentration remains lower than the criticality criterion of 1 Bq/cm3. In addition, the possibility of re-criticality of the fuel debris at the Fukushima Daiichi NPS is presumed to be low based on the expected condition of the existing fuel debris from the engineering viewpoint, because the alternation of molten fuel assemblies is not likely to reach criticality due to the abundance ratio with water, and the mixture of impurities, such as internal structures, can be expected in the course of core meltdown. Furthermore, the fuel debris is presumed to scatter in a wide area beyond the core as a result of the accident progression. Even assuming the possibility that control rods may have melted down before the fuel elements in the course of core meltdown and that the optimum mixing of incidentally crushed fuel debris with water occurs, the scale of criticality is considered to be small.

Though the possibility of criticality is low, fuel debris retrieval alters the shape, etc., of fuel debris. Therefore, it is essential to prevent reaching criticality during retrieval without fail by investigating what conditions would lead to criticality if shapes, etc., of fuel debris change, and to establish an appropriate control method for ensuring prompt detection and shutdown in case of an unexpected criticality.

In the initial phase of fuel debris retrieval work, fuel debris should be retrieved by limiting the treatment amount based on methods that will not significantly change the fuel debris shape, such as by gripping and sucking, as well as the estimated fluctuation of reactivity. Also in the process of expanding the retrieval scale and cutting, the retrieved volume of fuel debris will likely be increased, while taking measures such as measurement of pre-work subcriticality and preparation for insertion of neutron absorbers. In addition, through the overall retrieval operations, unless the criticality is unlikely to occur in consideration of the retrieval conditions, it is necessary reliable criticality prevention measures that combine design and evaluation with operator monitoring and judgment, specifically fuel debris retrieval while evaluating it’s criticality by checking the amount of neutron signal fluctuation in the vicinity of the fuel debris.

To maintain the subcritical condition more reliably for fuel debris storage after retrieval, it is important to store it stably while controlling the shape and size, for instance, by storing the debris in canisters.

For this criticality control, technical issues to be addressed for the time being are as follows.

(1) Establishment of criticality evaluation method

It is necessary to refine the information on the conditions for reaching re-criticality in fuel debris based on information to be obtained from each phase of fuel debris retrieval, including internal investigations. In this regard, an evaluation method has been developed to estimate the conditions for subcriticality and the degree of influence of criticality if it should happen. In conducting these evaluations, a plan should be made so that the information on the critical parameters with high impact on the criticality evaluation can be obtained in the course of internal investigation and retrieval, and to revise the plan through information updates as needed.

(2) Local neutron measurement around retrieval point

There are various kinds of existing neutron detectors according to application such as fission chamber, B-10 proportional counter tube, semiconductor detector, etc. Taking advantage of each feature, selection of neutron detectors to each phase is under consideration. The key specifications for the neutron detectors required for criticality monitoring are; (1) ability to survive accumulated radiation dose (Gy) according to the operation period and (2) installability in assumed equipment (size/weight, cable diameter) or installability at a work site (size/weight, cable routing); and (3) required detection efficiency (time, accuracy). Accordingly, it is important to select an optimal detector based on the information on PCV dose rate obtained by internal investigation and the progress of equipment development for each unit. In addition to subcriticality measurement, a small detector is highly likely to be used for continuous monitoring of local neutron measurement as a single detector, and therefore it is necessary to continue discussions toward practical applications of local and continuous monitoring. More specifically, the feasibility of continuous monitoring needs to be examined, including not only the specifications of neutron detectors and their location and quantity, but also what kind of evaluation can be performed based on the obtained data. As specific operation methods, moreover, it is required to set up determination criteria on operation suspension/resuming due to fluctuation of the neutron flux and on boron injection as a neutron absorber.

The possibility of criticality needs to be examined in places other than retrieval locations. For example, criticality may occur in places where fuel debris cutting particles are accumulated, which cannot be collected in the circulating water cooling system (i.e. outside the PCV bottom pedestal, in piping, water filters, waste water receiving tanks, etc.). Though criticality can be detected by the PCV gas monitor system, countermeasures will be considered in accordance with criticality risk scenarios and evaluations, including the feasibility of approach-to-criticality monitoring.

In the engineering work, the concept design is in progress for circulating water system configurations and system specifications for further expansion of fuel debris retrieval. In order to avoid redoing work in a later phase, criticality assessment for each device needs to be performed early, and activities are in progress to extract criticality prevention measures that greatly affect the device specifications in advance.

(3) Feasibility study of measuring the degree of sub-criticality

When measuring the degree of sub-criticality, in addition to the required specification of (2), it is necessary to select a detecting device with high fidelity and response speed in order to measure a weak neutron signal, capturing a neutron fluctuation in a very short time under a gamma ray environment. From the examination to date, considering the equipment mountability (size/weight/electromagnetic noise) and operation methods (measurement time and duration, installation location, etc.) by sensitivity are key issues due to the necessity of lead shielding in a high γ-ray environment (assuming 1000 Gy/h). In the future, it will be necessary to consider selection and optimization of the neutron detector, reflecting the constraints (weight, size, cable handling, interference with arms, balance between measurement and processing time, etc.) introduced by the fuel debris retrieval methods and systems. Meanwhile, practical applicability of the detectors on site is under review in light of an approach to assess the γ-ray radiation dose rate and neutron count rate in the vicinity of the fuel debris as well as constant monitoring, and by downsizing with the combined use of several detectors, etc.

In addition, in order to verify the applicability to fuel debris, where various mixes of compositions and properties of the fuel debris are expected, it is required to assess the technical feasibility and limit the applicability by planning and demonstration for technical verification.

(4) Feasibility study of neutron absorber

Based on the information obtained in each phase of scale expansion, in preparation for cases where the level of fuel debris criticality is high or technical feasibility of measuring the degree of subcriticality has limitations, assessments on the required boron concentration and feasibility studies on installations are in progress for the cases of filling with sodium pentaborate during normal fuel debris retrieval. As a result, environmental impact in the event of leakage and compatibility with concrete as structural materials has been evaluated[13]. While examining operation details to maintain the boron concentration in consideration of the impact on the PCV circulation cooling system as well as the impact on systems and waste during segregation, collection, re-use and treatment of boric acid, their needs to be consideration of the necessity and adverse effect of constant injection of sodium pentaborate, and verification of the applicability on site together with critical approach monitoring methods described in (2) Local neutron measurement around retrieval point.

In addition, if criticality should occur, emergency sodium pentaborate injection would be used to achieve a subcritical state, however, the methods for maintaining subcriticality after transition (lowering the water level, maintaining the boric acid concentration, etc.) as well as recovery methods need to be determined.

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[13] IRID, FY 2017 Supplementary Budget, Subsidies for the Government-led R&D Program on Decommissioning and Contaminated Water Management, Advancement of Retrieval Method and System of Fuel Debris and Internal Structures (Development of Technology for Criticality Control in Fuel Debris Retrieval), Final Report, July 2019, http://irid.or.jp/_pdf/20180000_04.pdf

Moreover, to ensure subcriticality maintenance when the margin for criticality of fuel debris is small, development is also underway for a non-soluble neutron absorber that can locally limit the impact on the PCV circulating cooling system. Until now, fundamental property testing and radiation resistance testing have been conducted to list B_4C metal sintered materials, glass containing B/Gd and Gd_2O_3 particles, sodium silicate and Gd_2O_3 granulated powder as candidates for non-soluble neutron absorbers. For these candidates, the impact of long-term irradiation on the integrity of canisters during storage of fuel debris, the method of spraying on fuel debris for debris crushing, and the effect after spraying have been verified.

To introduce non-soluble neutron absorbers, it is required to study the impact on PCV corrosion and environmental impact in the event of an environmental release.

(5) Detection of criticality by PCV gas management installations

Immediate criticality monitoring and sophistication of detectors in the PCV gas monitor is required to detect when approaching criticality and criticality in the vicinity of fuel debris retrieval, and to detect criticality due to the fall of fuel debris and/or accumulation of powder debris in locations other than fuel debris retrieval.

By measuring Kr-87/88 with high trackability for reactivity changes, in addition to Xe-135 that has already been measured, it has been found that criticality detection can be accelerated and that the level of subcriticality of the entire PCV can be presumed. However, the method of application to the actual plants is to be examined in the future.[13]

3.1.2.4.1.5 Ensuring the structural integrity of PCVs and buildings

As for the main devices in the PCV/PRV pedestal, etc., and reactor buildings, their structural integrity has been evaluated in post-accident studies by TEPCO and the Government-led R&D Program on Decommissioning and Contaminated Water Management. As a result, it has been confirmed that the main devices and reactor buildings have a certain level of seismic margin.

Hereafter, the existing main devices and reactor buildings, as well as devices/systems (hereinafter referred to as "systems") and buildings (including modified areas of the existing systems and building) to be newly installed for fuel debris retrieval over a relatively long period, should satisfy the functional requirements and (1) be capable of performing operations safely and (2) ensure the required level of safety against external events such as earthquakes and tsunamis. Assuming (3) long-term maintenance management, in addition, it is important to (4) feedback new knowledge to be gained from planned Internal investigations of PCV and debris analysis results, etc., to the design of fuel debris retrieval systems and the study of retrieval methods. The following shows the key functional requirements as examples.

- ○ Existing systems and buildings (including modified areas. The impact of aging is also considered as necessary)
  - Control deterioration of containment functions of PCV, RPV and reactor buildings,

etc., and control/prevent large release of radioactive materials (maintaining containment functions).

- Reactor buildings, etc., safely support systems to be newly installed in the reactor buildings for fuel debris retrieval in addition to the existing main devices (maintaining support functions).

○ Systems and buildings to be newly installed for fuel debris retrieval (including connections to the existing systems)

- Have functions according to design requirements and control/prevent large release of radioactive materials (ensuring containment functions).
- Safely support systems to be installed for fuel debris retrieval (ensuring support functions).
- New buildings, etc., provide a safe work environment as required (ensuring shielding performance, etc.).

With further progress in designing, the loading conditions (layout, size, weight of the new systems, new openings on PCV/biological shielding walls, etc.) during fuel debris retrieval will be specified. In order to ensure the structural integrity of systems and buildings, while reflecting the site conditions, examinations will be promoted steadily based on the latest design information.

In the specific design of new systems and buildings, it is important to define seismic classes and perform seismic evaluation accordingly. On the other hand, it is still challenging to repair and reinforce buildings and major devices damaged by the accident in a high radiation dose environment. Because of that, earthquake motions and criteria used in the design will be appropriately defined, taking into account the viewpoint of risk assessments.

3.1.2.4.1.6 Reduction of radiation exposure during work

In accordance with the Mid-and-Long-term Roadmap and TEPCO's Mid-and-Long-term Decommissioning Action Plan, removal of obstacles and radiation dose reduction in the reactor buildings are in progress as improvement of the work environment in work areas and access routes. As a related operation to fuel debris retrieval, removal of equipment with high radiation doses is planned, in which reduction of exposure during operation is an issue.

The main work areas related to fuel debris retrieval are high radiation dose areas such as inside the reactor buildings. Also, there comes the need to handle nuclear fuel materials containing α-nuclides from fuel debris with a large dose contribution in the case of internal exposure. Accordingly, enhanced control of not only for external exposure but also for internal exposure is essential for reduction of exposure.

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 radiation dose rate in the work area. Then, based on the three principles, namely “time, distance, and shielding”, taking measurements to reduce radiation exposure to as low as reasonably achievable will be needed.

Therefore, an appropriate combination of exposure reduction measures such as decontamination, shielding, remote technology etc. is to be selected, with the following ideas in mind.

- Consider first of all the reduction of exposure to radiation by a combination of remote technologies and decontamination. Then, plan on-site radiation exposure management for site workers by the “time, distance and shielding” approach.
- In the extremely contaminated areas such as inside the PCV and torus rooms, work should be pursued by remotely controlled machines, etc. to avoid engaging personnel inside.
- With regard to the inside of the reactor buildings, except for the areas mentioned above, consideration should be given to the optimal combination of decontamination, shielding, removal of unnecessary objects, remote technology, and reduction of working time in order to keep the accumulative dose for the entire project at a low level.
- Where remote technologies are employed, additional work will be required, such as the installation of systems, maintenance and technical troubleshooting, which must be taken into consideration in the above evaluation and planning.
- As for the decontamination tasks, the judgment between remote technologies and personnel employment must be made based on factors such as the dose rate in the target areas, type of contamination, space for work, frequency of use, applicability and development situations of remote technologies, schedule and cost, etc.
- A priority must be placed upon areas where work requirements are clearly identified. Considerations must not be pursued if task requirements are unclear, or in a non-specific “betterment-oriented” manner such as to aim for an overall reduction of radiation dose.

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, airborne concentration and surface contamination density in the work area, to prevent inhalation ingestion and body contamination. In the abnormal event of intake, in order to assess the committed effective radiation dose by external counting (lung monitor) or bioassay, it is important to select α-nuclide important for exposure assessment in advance and incorporate it into the control of airborne concentration, standards of wearing protective equipment, and device calibration management. Controlling the surface contamination density in the work environment and the body of workers entering/leaving contaminated areas is also important to early detect the spread of contamination beyond the area division and to prevent an intake of re-suspended dust from loose contamination.

With the objective of dose reduction in long-term decommissioning, it is important to accumulate knowledge such as on-site operation experiences and lessons learned and to hand down knowhow. For further expanding fuel debris retrieval, it is necessary to develop a database that enables sharing of information and prompt feedback for the next work plan.

In particular, concerning the reduction of radiation exposure of workers in the reactor building, it is important to conduct sufficient investigations on the dose distribution and contamination conditions, including the contribution of surroundings of the subject areas, to identify the source locations and intensity as much as possible and to develop a plan for radiation dose reduction for securing the essential work environment for work areas and access routes. Upon adequate verification on the operation feasibility, the target dose rate in the work areas and access routes shall be set in consideration of the margin for the radiation exposure dose limit (50 mSv/year and 100 mSv/5 years) for workers specified by laws and regulations. In the radiation dose reduction plan for high radiation dose areas, it is important to take management measures to reduce the total radiation exposure dose to as low as reasonably achievable and accomplish operations with respect to work hours in accordance with dose limits and required work hours to accomplish operations.

Once fuel debris retrieval is started in the future, the generation of α-nuclide increases in the series of operation processes. In addition to normal operations, management methods and systems are required, which are capable of containment and leakage detection in preparation for diffusion in the air and to the water treatment system due to problems, etc. Since α-nuclides have been detected in the stagnant water and on contaminated floors, it is necessary to take measures to prevent body contamination of workers and the spread of contamination outside the R zone, and it is important to have changing places and improve contamination detectors for α-rays.

In addition, adequate radiation exposure control should be conducted after formulated a long-term work plan that includes not to concentrate workers' radiation exposure on individual workers and to help reduce whole workers' radiation exposure.

3.1.2.4.2 Technical issues related to fuel debris retrieval methods

3.1.2.4.2.1 Securing access route

For transporting, installing, and unloading the devices and equipment used for fuel debris retrieval work, and transporting fuel debris and waste, access routes should be established by removing obstacles on the access routes and reducing the radiation dose in the R/B to the level at which such tasks can be performed. When establishing new openings in the PCV or the like to construct the access routes to fuel debris, it should be kept in mind suppressing of the release of radioactive materials from the PCV and RPV and integrity maintaining the existing structures in terms of the gas phase containment function described in Sub-section 3.1.2.4.1.1.

The Mid-and-Long-term Roadmap indicates that the first implementing unit would be Unit 2 and trial retrieval begins within 2021 toward gradual expansion of fuel debris retrieval. Accordingly, TEPCO is currently proceeding with specific engineering studies to conduct an access route from penetration X-6 at Unit 2.

On the other hand, toward a further expansion of fuel debris retrieval, studies are underway on the construction of access routes from the side opening of the PCV to fuel debris (the side access method), based on the results of research and development conducted to date by the Government-led R&D Program on Decommissioning and Contaminated Water Management. In the side-access method, suspension bridge and access tunnel systems is being examined. However, the issue is to address containment, shielding for connecting structures between newly installed heavy structures and side-opening of the PCV, and seismic displacement.

As for the construction of access routes including top access, in addition to the side access, the technology to remove obstacles as well as transportation methods that shorten the preparation processes for retrieval are under review for enhancing throughput. The Government-led R&D Program on Decommissioning and Contaminated Water Management is currently examining the feasibility of the method to retrieve and transport interfering structures as a single or a large unit while ensuring containment and shielding.

In the future, based on the above-mentioned tasks, it is necessary to define the access route clearly to be built at the next stage from the data obtained at each phase of scale expansion. In particular, at the time of cutting the inner door of the penetration X-2 at Unit 1, the dust concentration in the PCV increased more than expected before the start of the work. Therefore, not only countermeasures against dust dispersion, but also the time required for responding to such a situation shall be considered and planned.

Since the fuel debris retrieval policy stipulates that an optimum combination of retrieval methods should be selected depending on the location where fuel debris exists for each reactor unit, it is important to proceed with research and development toward a future scale expansion.

3.1.2.4.2.2 Development of devices and equipment

In each phase of trial retrieval, gradual and further expansion of fuel debris retrieval, devices and equipment for fuel debris retrieval need to be developed with emphasis on safety, reliability, and efficiency. To flexibly respond to the situations inside the RPV and the bottom of the PCV where fuel debris is predominantly present, the specifications of devices/equipment to be developed in these phases should be established in consideration of radiation resistance, dust resistance, waterproofness, range of temperature, remote inspection/maintainability, remote operability, securing visual field, seismic resistance, protection mechanism for collision avoidance or automatic shutdown in case of abnormality, high reliability, appropriate redundancy, a rescue mechanism that does not disturb the subsequent work when trouble occurs, and efficiency of fuel debris retrieval.

Equipment development for trial retrieval and gradual expansion of fuel debris retrieval has been in progress as part of research and development of the Government-led R&D Program on Decommissioning and Contaminated Water Management. After the gradual expansion of fuel debris retrieval, TEPCO needs to take over and substantiate the development results. TEPCO is proceeding with the engineering of robot arms, etc., to be applied to Unit 2, while preparing education/training for the operation of fuel debris retrieval using these remote devices. Prior to installing remote equipment such as robot arms on site, adequate performance verification and operation training are essential by using mockups simulating the expected PCV internal environment. For this purpose, development of mockup systems is required.

As for devices and equipment for further expansion of fuel debris retrieval, development is underway for construction methods for improving efficiency, retrieval/handling systems according to diverse conditions of fuel debris, and dust collection systems for dust generated during fuel debris crushing. Specific examples of ongoing development activities include: Research and development for removal of large-scale structures by the top access and removal of obstacles by top and side access methods; development of fuel debris cutting/crushing systems (mechanical, thermal) and dust collection/dispersion control systems; development of retrieval/collection systems according to diverse conditions of fuel debris (fragments, sludge, fine powders, etc.); remote operation support for robot arms, etc.; on-site transportation of unit cans including fuel debris; removal of soluble nuclides in circulating cooling water; treatment of deposits collected from the PCV; and prediction of dust behavior in the PCV. Furthermore, techniques to install devices and equipment used for fuel debris retrieval are required. With the assumption of remote operation, research and development is under way for installing work cells to establish radiation shielding and gas phase containment functions and for connection methods with the existing structures.

As for how to proceed with development, it is required to flexibly promote operations in the subsequent phase based on the information gradually obtained from preceding investigations and retrieval work, and to continue development for emerging important issues. The developed devices and equipment need to be combined as a system and undergo a series of mockup tests to demonstrate that they can demonstrate their performance safely and reliably at the actual site. This mockup test needs to be implemented in a facility simulating the on-site environment in order to verify the applicability of remote equipment and operability/maintainability of the entire remote system under severe environmental conditions containing significant uncertainties. Therefore, in cooperation with organizations concerned, NDF and TEPCO are engaged in examining how to proceed with the remote mockup test plan, the test plan review, the scope of the mockup facility to be maintained, the necessary time, operation management, etc.

3.1.2.4.2.3 Establishment of system equipment and working areas

Assuming to ensure safety functions, and considering avoiding excessive system specifications, it is required to examine the establishment of system installations, etc., take necessary measures such as system additions based on the results of such examinations, and then to operate them properly. In examinations, sufficient areas should be secured to satisfy the required environmental conditions while considering installing shields for reducing radiation exposure for workers in addition to system installation, operation/maintenance management.

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. Moreover, realization of measurement systems (for pressure, temperature, water level, radiation, etc.) to monitor the PCV internal conditions is a significant issue, which is essential for fuel debris retrieval. In order to build safety systems incorporating the above, TEPCO, through engineering work, has tentatively set assumptions (design conditions for installations) based on research and development by the Government-led R&D Program on Decommissioning and Contaminated Water Management, and has been examining system design and layout. In particular, it is important to ascertain the feasibility of safety systems designed to secure the safety functions necessary for proper operation of equipment and devices for the safe retrieval and storage of fuel debris, and to steadily proceed with studies on the fuel debris retrieval method through a reliable approach.

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

3.1.2.4.3 Technical issues related to safe and stable storage of fuel debris

3.1.2.4.3.1 Handling of fuel debris (collecting, transferring and storing)

Before initiating fuel debris retrieval work, a comprehensive system should be established that consists of a series of steps from containing and transferring to storing of retrieved fuel debris furnished with safety functions such as maintaining subcritical condition, containment function, countermeasures against hydrogen generation, and cooling. The following examinations are in progress accordingly[14].

- Drawing up of basic specifications of the container, that is, overall length considering its handling, internal diameter in light of work efficiency and maintaining subcriticality, etc., and demonstration of the structural integrity of the container by performing structural verification test.
- Examination of a practical and rational prediction method of hydrogen generation from fuel debris stored in container; determination of vent mechanism for hydrogen gas exhaust on the container lid by using the said prediction method and establishment of safe transferring conditions with consideration for accumulation of hydrogen gas in transferring casks.
- Development of efficient drying technology applicable to fuel debris in the container or the unit can, and consideration on a drying system using this technology

In the future, based on the results of these studies, specific systems and devices/facilities from containing to storing fuel debris should be developed in coordination with other associated projects. In addition, further studies should be made on the specific transfer method, the specific type and size of the storage facility, and others by taking into account the amount of fuel debris to be retrieved

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[14] IRID, FY 2018 Supplementary Budget, Subsidies for the Government-led R&D Program on Decommissioning and Contaminated Water Management “Development of Technology for Collection, Transfer and Storage of Fuel Debris), FY 2019 Implementation Report, August 2020, https://irid.or.jp/wp-content/uploads/2020/09/2019010syuunouisouhokan.pdf

per day and the fill rate of containers. In developing the specific facilities and systems for handling and storing retrieved fuel debris, it is also necessary to give consideration to the system/devices responding to safeguards requirements.

It is important to reflect various measurement data such as the amount of hydrogen generated from fuel debris, as well as knowledge and experiences on handling fuel debris during the operations from receiving the fuel debris by containers for on-site transportation to temporary storage collected and accumulated during gradually expanded scale of fuel debris retrieval work, into the design of systems and facilities for containing, transporting, and storing fuel debris safely, reliably, and reasonably at further expanded scale of fuel debris retrieval work as much as possible. In addition, it is necessary to specify transfer routes and storage facility locations for further expanded scale of fuel debris retrieval work in light of the usage plan for the entire site.

The Mid-and-Long-term Roadmap stipulates that the processing/disposal method of the retrieved fuel debris shall be investigated and fixed during the third phase after starting the fuel debris retrieval work.

3.1.2.4.3.2 Classifying of fuel debris and radioactive waste during fuel debris retrieval

In each operation phase of fuel debris retrieval, preparations and cleanup work for that, etc., a variety of radioactive waste such as removed or disassembled structures or parts, with nuclear fuel materials attached or fused will be retrieved from the PCV in addition to fuel debris. Of these, if substances containing (or are adhered to) a small amount of nuclear fuel materials are all deemed as fuel debris, the amount would be enormous. It is not rational because scales of equipment and facilities become larger and securing of site will be needed. For this reason, it is important to develop classification criteria between fuel debris and radioactive waste and their necessary measuring technologies.

At present, progress has been made to collect and analyze the information on the distribution and properties of fuel debris and structures in the PCV necessary to examine methods for classifying retrieved material from PCV into fuel debris or radioactive waste including various obstacles and structures, and storing properly. However, it is practically difficult to accumulate, organize, and analyze sufficient information necessary for research and development of classification prior to actual fuel debris retrieval work. Under these circumstances, it is recommended to aim for classifying retrieved material into fuel debris or waste based on the measurement results of the amount and concentration of nuclear fuel materials. The following studies were conducted as a first step in response to this.[15]

- Considering in which steps in a series of operation processes, from retrieval in the PCV to storage, classifying is feasible to sort retrieved materials from the PCV (fuel debris,

[15] IRID, FY 2018 Supplementary Budget, Subsidies for the Government-led R&D Program on Decommissioning and Contaminated Water Management (Development of Technology for the Further expansion of Fuel Debris and Internal Structure Retrievals), FY 2019 Implementation Result, April 2020 https://irid.or.jp/wp-content/uploads/2020/09/2019008kibonosaranarukakudai.pdf

structures, etc.) into fuel debris and radioactive waste (consideration of categorizing scenarios)

- Investigation of techniques/equipment that may be capable of measuring the content of nuclear fuel materials contained in the materials retrieved from the PCV for classifying (investigation of possible measurement techniques)

From these studies, it is currently considered as highly difficult challenge to measure or estimate the amount and concentration of nuclear fuel materials in the retrieved material from the PCV.

However, it is determined that development of classifying criteria and necessary measuring techniques/equipment to appropriately judge whether the materials retrieved from the PCV should be treated as fuel debris or radioactive waste at the time of further expanded scale of fuel debris retrieval work will contribute to achieving efficient and safe decommissioning, such as by reducing the physical amount of materials to be stored as fuel debris. For this reason, it is recommended to continue development of criteria for classifying into fuel debris and radioactive waste, and measurement techniques/equipment. It is also important to continue activities to enhance the effectiveness and practical applicability of classification methods (classifying criteria, scenarios) and techniques (measuring techniques/equipment) by leveraging knowledge and information obtained by survey of internal PCV and analysis results of samples batched off from fuel debris retrieved during trial scale, gradually expanded scale or further expanded scale of fuel debris retrieval work.

3.1.2.4.3.3 Examining safeguards methods

At the Fukushima Daiichi NPS, the safeguards implemented before the accident are not applicable due to the damage on fuel assemblies and destruction of reactors/buildings. However, the appropriate safeguards have been applied along with the progress of the decommissioning process through cooperation and information sharing between Japan Safeguards Office (hereinafter referred to as “JSGO”) of the NRA, International Atomic Energy Agency (hereinafter referred to as “IAEA”) and TEPCO. As a result, the IAEA and JSGO confirmed that there had been no diversion of nuclear materials and undeclared nuclear materials or nuclear activities. (For the concept of the safeguards, refer to Attachment 8)

New material accountancy and safeguards are expected to be applied to the retrieved fuel debris depending on its properties and conditions. As it is unprecedented, TEPCO may face technical issues in examining and applying them to the site.

In response to that, NDF will support the examinations aimed at solving such technical issues from an engineering viewpoint, and will share information on the progress of the project with TEPCO in order to ensure that system arrangements related to the application of safeguards do not affect the decommissioning process.

3.1.2.5 Summary of key Technical issues

The main technical subjects and plans described in this section are summarized as shown in Fig.13.

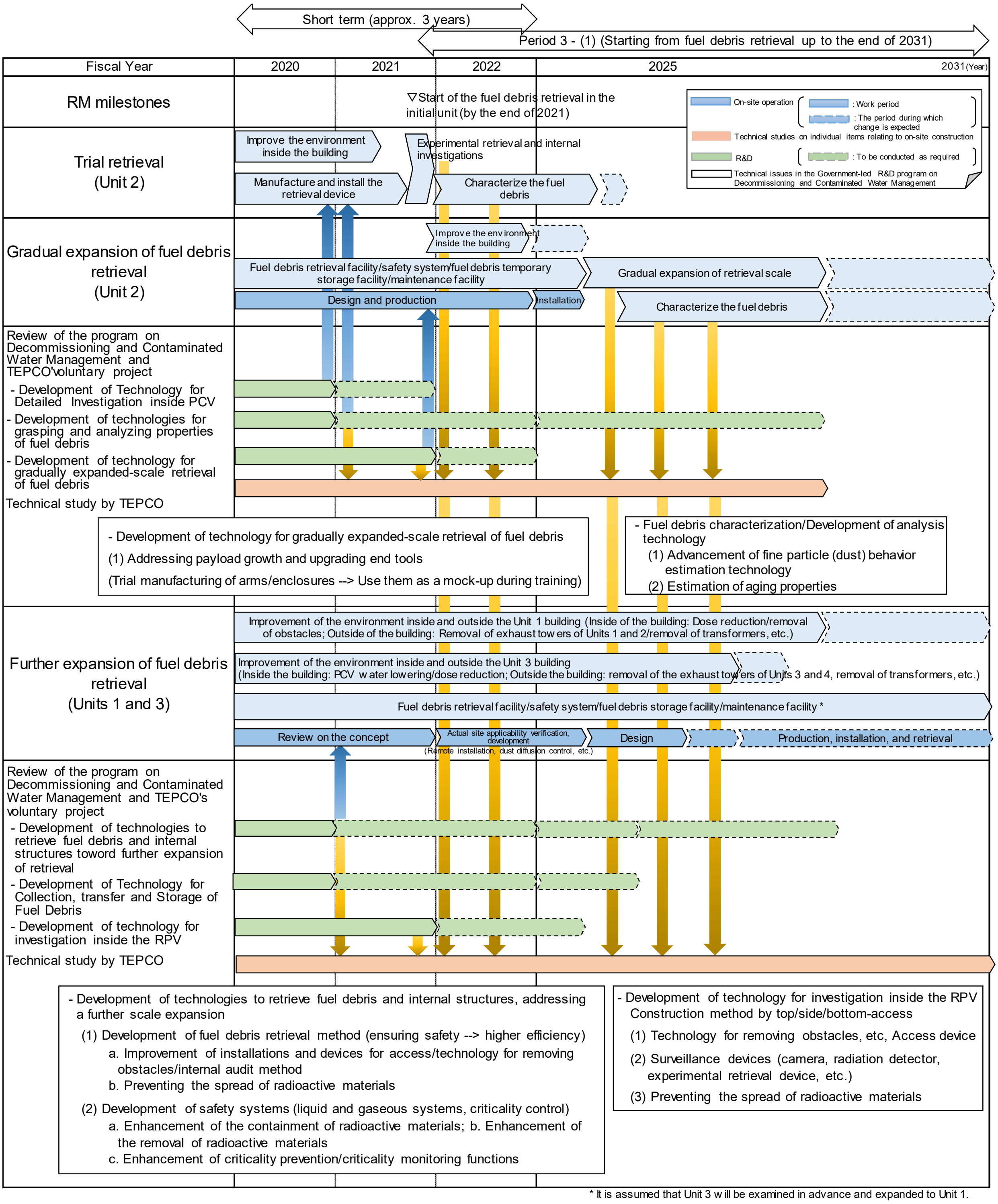


Fig.13 Technical issues and future plans on fuel debris retrieval (progress schedule)

3.2 Waste management

3.2.1 Targets and progress

(Targets)

(1) The Solid Waste Storage Management Plan (“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) Countermeasures integrated from characterization to processing/disposal of solid waste are studied from the expert point of view, and the prospects of a processing/disposal method and technology related to their safety should be made clear by around FY2021.

<Key Points of "Basic Policies on Solid Waste">

(1) Thorough containment and isolation
Thorough 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.

(3) Promotion of characterization
Proper characterization addressing an increase in the number of analysis samples to proceed with study on processing/disposal method of solid waste.

(4) Thorough storage
Generated solid waste 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
To establish selecting methods of processing for stabilization and immobilization (preceding processing) and select a method of the preceding processing before technical requirements of disposal are established.

(6) Promotion of effective R&D with a bird’s-eye-view of overall solid waste management
To confirm required R&D tasks after cooperating with each field of R&D for characterization and processing/disposal and overviewing the overall management of solid waste.

(7) Development of continuous operational framework
In order to continue safe and steady solid waste management, the continuous operational framework including development of relevant facilities and human resources must be undertaken.

(8) Measures to reduce radiation exposure of workers
Radiation exposure control, safety management and healthcare programs should be implemented thoroughly based on the relevant laws/regulations.

(Progress)

Waste management is a long-term effort that needs to attain the prospect of implementing final disposal, while reducing risks in every stages. The definitions of the terms regard to radioactive waste management, provided by the IAEA is shown in Attachment 9, and the classification and disposal of radioactive waste inside and outside the country are shown in Attachment 10.

Since a large amount of solid waste with various characteristics is generated in association with decommissioning of the Fukushima Daiichi NPS, a flexible and reasonable waste stream (the flow of the measures united from characterization to processing/disposal) is being developed in addition to improvements in characterization analysis ability. Specifically, the related organizations are promoting efforts based on each role in accordance with the fundamental view for solid waste arranged in the Mid-and-Long-term Roadmap, and NDF is taking the initiative to advance the technical examination for measures united from characterization to processing/disposal of solid waste.

3.2.1.1 Storage

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 (refer to Table2 for the status of solid waste storage).

Based on this plan, TEPCO decided that any outdoor storage of solid waste, excluding secondary waste generated by water treatment and re-use/recycle objects, would be eliminated by the end of FY 2028, and TEPCO is promoting the arrangement of the required system (Attachment 11). The concrete rubble which dose level is corresponding to it of the background of the site is being recycled as roadbed material from the standpoint of reducing the waste generation amount. The recycle and re-use of the metal, concrete, and dismantled pieces of flange tanks with a very low surface dose is being studied while they are temporarily stored outside solid waste storage facilities for the time being.

Secondary waste generated by water treatment is planned to be transferred to store in a building, and large waste storage building is being constructed as a storage facility for adsorption vessels. Also, the slurry generated in the Multi-nuclide Retrieval Equipment, etc., and the waste sludge have a comparatively high risk in storage and management due to high mobility. Stabilization (dehydration) treatment will be carried out for the slurry (operation will start in FY 2022), and transfer will be carried out from the underground storage tank in a building, the present storage area to high ground for the waste sludge (to be completed in FY 2023).

For waste generated in association with fuel debris retrieval, the type and amount of materials are evaluated, and, studies are being carried out for the storage method, the storing method, and the specifications for containers including measures against hydrogen gas generation, are being carried out in the Government-led R&D program on Decommissioning and Contaminated Water Management.

3.2.1.2 Study on the processing/disposal measures

With regard to the processing/disposal approach to solid waste, the Mid-and-Long-term 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 it 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 could be expected to introduce the 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 methods to be developed by around FY2021.
- Clarify issues and measures concerning storage of solid waste until it is conditioned

To achieve these matters, the applicability of various processing methods (thermal/non-thermal processing) using engineering-scale testing equipment, etc., is being confirmed, the disposal concept based on the characteristics of the waste and applicable processing technologies is being established, and a safety assessment method is being developed, through the Government-led Project of Decommissioning and Contaminated Water Management.

Also, to effectively understand the characteristics of solid waste required for the study, simplified and speed-up analysis methods, analysis ability improvement focusing on the arrangement of Radioactive Material Analysis and Research Facility Building 1 in which waste samples with a low dose will be analyzed, and accuracy improvement of the analytical inventory estimation method are being advanced. Sampling and analysis are being carried out for rubble, contaminated water, secondary waste generated by water treatment, and so on, and the correlation of the nuclide composition for each analyzed waste is becoming clear gradually.

3.2.2 Key issues and technical strategies to realize them

3.2.2.1 Promotion of characterization and enhancement of analysis systems and technical capabilities

Human resources development for radiological analysis, and transfer/strengthening, technical capabilities on analysis, are important issues in addition to the arrangement of facilities to promote characterization steadily. For the time being, it is important to proceed with human resource development for analysis in the organized manner as well as to arrange the Radioactive Material Analysis and Research Facility and to reflect achievement of simplified and speed-up analysis methods.

3.2.2.2 Storage

Since the measures against hydrogen generation become an issue in the safe storage of high dose waste, the concepts for a container with a vent and drying technologies are being studied. Also, since integrity evaluations of storage containers becomes an issue when storage is prolonged, the study, including the evaluation method and the measures against the generation of corrosion, is being advanced.

3.2.2.3 Development of processing/disposal concept and safety assessment method

In order to select candidate technologies for preceding processing methods, it is necessary to identify reasonable and feasible processing technology and develop safety assessment technique for disposal corresponding to such technology.

For the selection of processing technology, it is necessary to confirm the technical feasibility as the whole processing system, including a supply system and an exhaust system, in addition to the confirmation of the feasibility of solidification. Also, the required items and information are collected and arranged to develop safety assessment method for disposal.

Furthermore, concerning the disposal approach, various possibilities will be studied using overseas examples as reference, due to the fact that the waste from the Fukushima Daiichi NPS is large in quantity, having various properties, and showing characteristics of having large uncertainties.

3.2.2.4 Examining further approaches based on the view of the waste hierarchy

Many measures are being implemented based on the concept of the waste hierarchy (desirable approaches in the order of (i) waste prevention, (ii) waste minimization, (iii) re-use, (iv) recycling, and (v) disposal) in the UK and the USA (Fig. 14). In UK, the NDA developed low-level solid radioactive waste management strategy in 2010 based on the application of this concept, and so on, and the initiatives shown in Table 3 has been implemented. As a result, 95% of the low-level radioactive waste generated in the UK in 2009 was transferred by waste producers to the existing low-level radioactive waste disposal facilities as they were, but now, the amount of low-level radioactive waste to be disposed of directly to the facility was reduced to 5% in 2019. It is achieved by establishing routes such as disposal of very low-level radioactive waste in the specific landfills based on appropriate segregation with characterization, treatment through volume reduction by metal recycling via melting, incineration, and compression. The measures based on this concept are being practiced at the Fukushima Daiichi NPS as well. Further possibilities will be studied based on preceding examples in other countries in advancing reasonable waste management.

With regard to the prospects of a processing/disposal method and technology related to its safety based on the results of these efforts, should be made clear by around FY 2021 as the target based on the results of R&D and TEPCO’s engineering achievements, etc.

Table 2 Solid waste storage status

(a) Storage of rubble, felled trees, used protective clothing, etc. (as of June 30, 2020)

Storage method	Stored volume (m^3) / Storage capacity (m^3) (Percentage)
Outdoor storage (surface radiation dose rate ≤ 0.1 mSv/h)	212,900 / 266,500 (80%)
Outdoor sheet covered storage (surface radiation dose rate 0.1 - 1 mSv/h)	42,800 / 71,000 (60%)
Soil-covered temporary storage facilities, Outdoor container storage (surface radiation dose rate 1 - 30 mSv/h)	17,900 / 24,600 (73%)
Containers* (in solid waste storage building)	22,500/ 48,000 (47%)
Total ----	296,000 / 410,100 (72%)

Cut down trees

Classification	Storage method	Stored volume (m^3) / Storage capacity (m^3) (Percentage)
Trunks, roots, branches, leaves	Outdoor storage	97,000 / 134,000 (72%)
Branches, leaves	Temporary storage pool	37,300 / 41,600 (90%)
Total	----	134,300 / 175,600 (77%)

Used protective clothing

Storage method	Stored volume (m^3) / Storage capacity (m^3) (Percentage)
Container	37,800 / 68,300 (55%)

*Including secondary waste generated by water treatment (small filters, etc.)

(b) Management status of secondary waste generated by water treatment (as of July 2, 2020)

Adsorption vessels, etc.

Storage Place			Storage Number		Stored volume/Capacity (Percentage)
Outdoor Temporary Storage area of used Vessels	Cesium adsorption apparatus		779	Number of vessels and filters	4,332 / 6,372 (68%)
	2nd Cesium adsorption apparatus		232	Number of vessels and filters	
	HICs from multiple nuclides removal system	Existing	1,788	Number of containers	
		Expansion	1,741	Number of containers	
	Used vessel from high-performance multi-nuclides removal equipment	High performance	74	Number of vessels	
	Used column from multiple nuclides removal system	Existing	17	Number of columns	
	Used vessels and filters from mobile-type strontium system		213	Number of vessels and filters	

Waste sludge

Storage Place	Stored volume (m^3) / Storage capacity (m^3) (Percentage)
Sludge storage facility (Indoor)	419 / 700 (60%)

Concentrated waste liquid

Storage method	Stored volume (m^3) / Storage capacity (m^3) (Percentage)
Concentrated waste liquid storage tanks (Outdoor)	9,380 / 10,300 (91%)

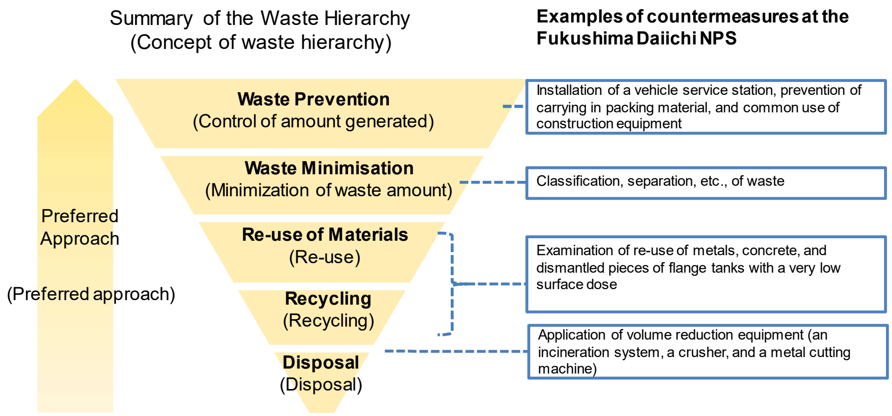


Fig. 14 Summary of waste hierarchy[16] at the NDA, UK, and countermeasures at the Fukushima Daiichi NPS

Table 3 Measures based on the concept of the waste hierarchy in the UK

	Countermeasures
Minimization of waste amount	Diversification of classification/segregation by extensive characterization Volume reduction (cutting, compression, incineration) Decontamination
Re-use	Transfer of assets that have accomplished their original purpose of use Use as backfilling materials of soil and rubble
Recycling	Metal recycling by melting
Disposal	Setting of new classification for very low-level radioactive waste and its disposal at landfills

[16] The figure is based on NDA, Nuclear Decommissioning Authority Strategy Effective from April 2016 (2016), p.60, Figure 7. Summary of the Waste Hierarchy.

3.2.2.5 Summary of the main technical issues

The main technical issues and plans described in this section are summarized as shown in Fig. 15.

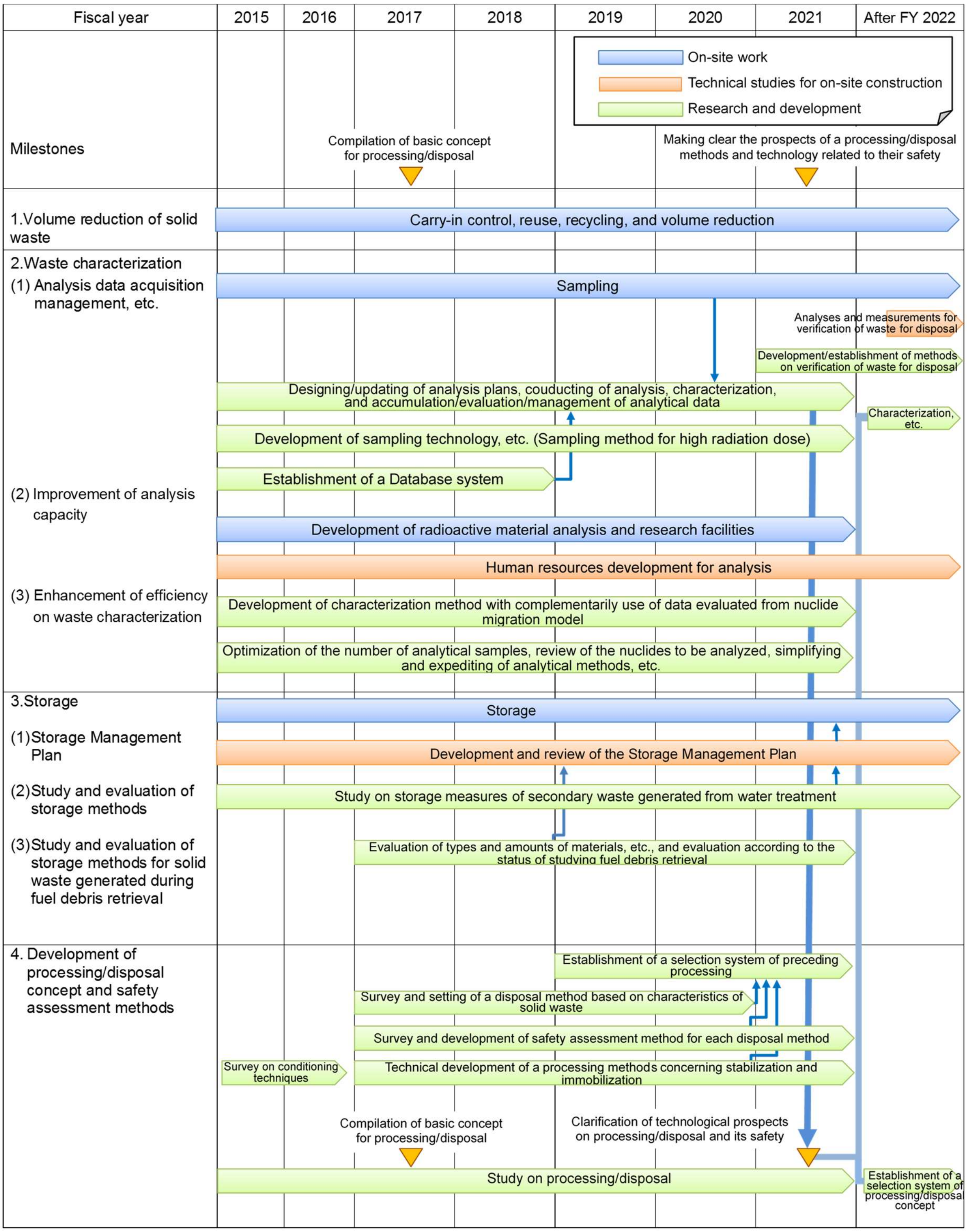


Fig.2 Main technical issues and future plans on waste management (progress schedule)

3.3 Contaminated water management

3.3.1 Targets and progress

(Targets)

(1) Under the three principles concerning the contaminated water issues ("Removing" contamination sources, "Redirecting" fresh water from contamination sources, and "Retaining" contaminated water from leakage), to reduce the stagnant water in the reactor buildings in FY 2022 to FY 2024 to about the half of the amount of the end of 2020 while continuing the operation of the constructed water-level management system and controlling the generation amount of the contaminated water to 100 m^3/day or less in 2025.

(2) To arrange the relationship with a decommissioning process including full-scale fuel debris retrieval beginning in the near future, and to promote examinations of the measures of the contaminated water management for mid-and-long-term prospects.

(Progress)

Fig. shows three principles and measures for the issue of contaminated water. From the viewpoint of measures to reduce the risk from radioactive materials, stagnant water in buildings, that is, the contaminated water with a mixture of cooling water contacted with the fuel debris and groundwater/rainwater flowed into the buildings is liquid containing a considerable amount of the dissolved radioactive materials (inventory). Therefore, its hazard potential is relatively high and so is the Safety Management level, as the storage condition of such stagnant water deviates from what is originally intended and has high uncertainties (refer to Section 2.2).

Out of such stagnant water in buildings, efforts are being promoted for more stable operation based on three principles in order to complete the treatment of stagnant water in buildings in 2020, excluding the Units 1 to 3 reactor buildings, where circulating water injection is ongoing, and the process building/high-temperature incinerator storing contaminated water temporarily for purification treatment.

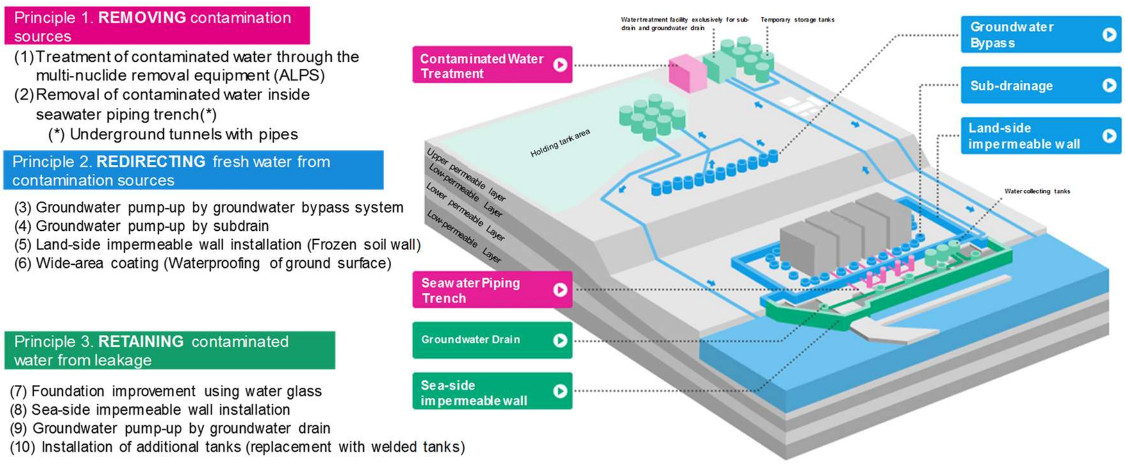


Fig.16 Tree principles and measures for the issue of contaminated water

With regard to "removing" contamination sources, the third cesium adsorption apparatus (SARRY2) purifying high-concentration contaminated water has started full-scale operation since July 2019, and a system using three units together with two established units (KURION and SARRY) has made possible stable purification treatment.

With regard to "redirecting" fresh water from contamination sources, the groundwater level around the reactor building is stably managed at a low level by multistory contaminated water management, such as land-side impermeable walls and sub-drains, and the increase of the generation amount of contaminated water during rainfall also tends to be controlled by the site's surrounding pavement and the repair of broken parts of roofs. Through these measures, the generation amount of contaminated water has been reduced to about 180 m^3/day (FY 2019) from about 540 m^3/day (May 2014) before taking measures. The aim is to control the generation amount of contaminated water at about 150 m^3/day in 2020 and below 100 m^3/day in 2025.

With regard to "retaining" contaminated water from leakage, since all water purified by the multi-nuclide removal equipment and the like, has been stored in welded type tanks since FY 2019, leakage risk from tanks is reduced. Treatment of the remaining water in the multi-nuclide removal equipment in the bottom of a flange type tank has been completed (July 2020), and only approx. 500 m^3 of the concentrated salt water remains in storage (as of the end of August, 2020). Also, efforts and monitoring for the prevention of the spread of contamination are being carried out by the maintenance of a sea-side impermeable wall, and monitoring of groundwater and the harbor.

As a result of the above efforts, treatment of the stagnant water in buildings excluding the Units 1 to 3 reactor buildings, the process building, and the high-temperature incinerator, is planned to be completed in 2020. It is considered that contaminated water management has shifted to a certain level of stability compared with the situation requiring emergency measures immediately after the accident.

In addition, for handling the water treated with the multi-nuclide removal equipment, so-called ALPS, etc., a comprehensive examination, including technical aspects and the social impact such as rumors was conducted by the governmental subcommittee, and a report was published in February 2020. Based on the report, the government has been arranging opportunities since April 2020 to hear the opinions of citizens at large and a wide range of relevant parties, including local governments and agricultural, forestry, and fishery businesses, in order to determine the policy for handling ALPS-treated water as the government.

3.3.2 Key issues and technical strategies to realize them

3.3.2.1 Issues in the future treatment of stagnant water in buildings

According to the investigation since March 2019, a relatively high total α is detected at the bottom of the torus chamber of the reactor buildings of Units 2 and 3. In reducing the stagnant water in the reactor buildings to about half of the level at the end of 2020 in FY 2022 to FY 2024, it will be an important issue to prevent the spread of α-nuclides (Fig.17). As measures, it is required to strengthen the monitoring of α-nuclides concentration in each building and the water treatment system as well as property analysis. Research and development are also required to establish a measure to remove sludge-like sedimentation containing α-nuclides.

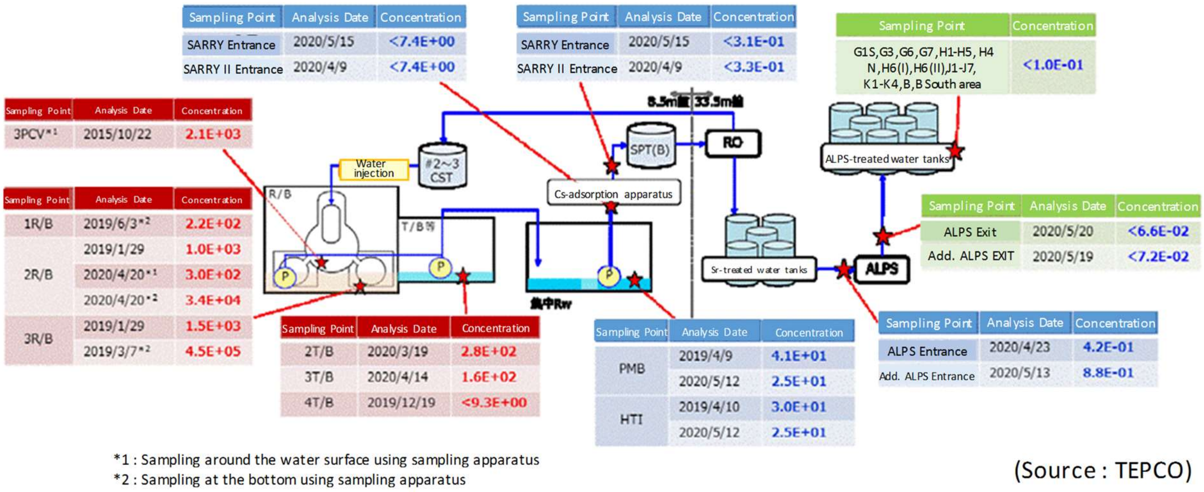


Fig.17 Measurement result of total α in the stagnant water in buildings [Bq/L]

Also, in the process building and the high-temperature incinerator, it became clear in December 2019 that there were zeolite sandbags (approx. 20 tons) with a high dose installed at the underground floor after the earthquake disaster. The maximum radiation dose rate on the surface of sandbags is as high as approximately 3000 mSv/h in the process building and approximately 4000 mSv/h in the high-temperature incinerator. Therefore, in order to complete the treatment of the stagnant water in these buildings in the future, dose mitigation measures will be an important issue. A method to remotely collect zeolite and store it in containers and the like, and a method to remotely accumulate zeolite on the underground floor and temporarily store it in containers and the like, are being examined. It is required to select an appropriate method by comprehensively evaluating radiation exposure dose received during work, long-term safety, and the construction period, etc. (Fig. 18).

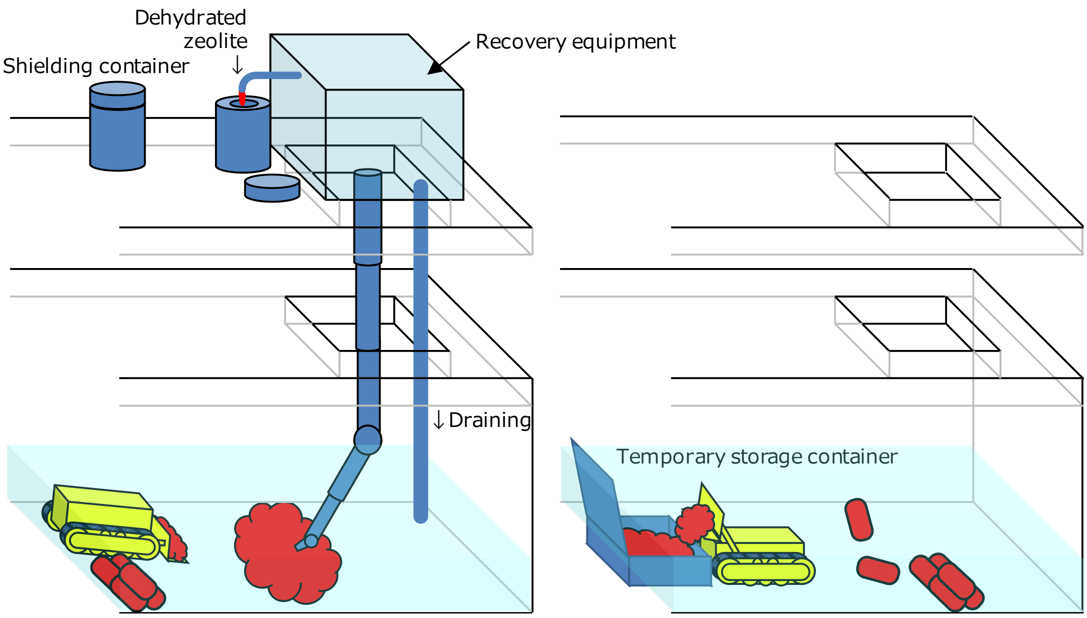


Fig.18 Study on stabilization of zeolite, etc.

3.3.2.2 Issues of contaminated water management considering the decommissioning process such as fuel debris retrieval

In the fuel debris retrieval, it will be an important issue to examine the whole system of contaminated-water management based on various information, experience, and results obtained in trial retrieval, gradual expansion of retrieval scale, and further expansion of retrieval scale. The possibility that the material derived from fuel debris containing α-particles is mixed into the water treatment system in association with cutting, fabrication, etc., of fuel debris cannot be denied. It is required to take measures, such as the strengthening of monitoring of water treatment systems, installation of α-particle collection systems, and criticality monitoring.

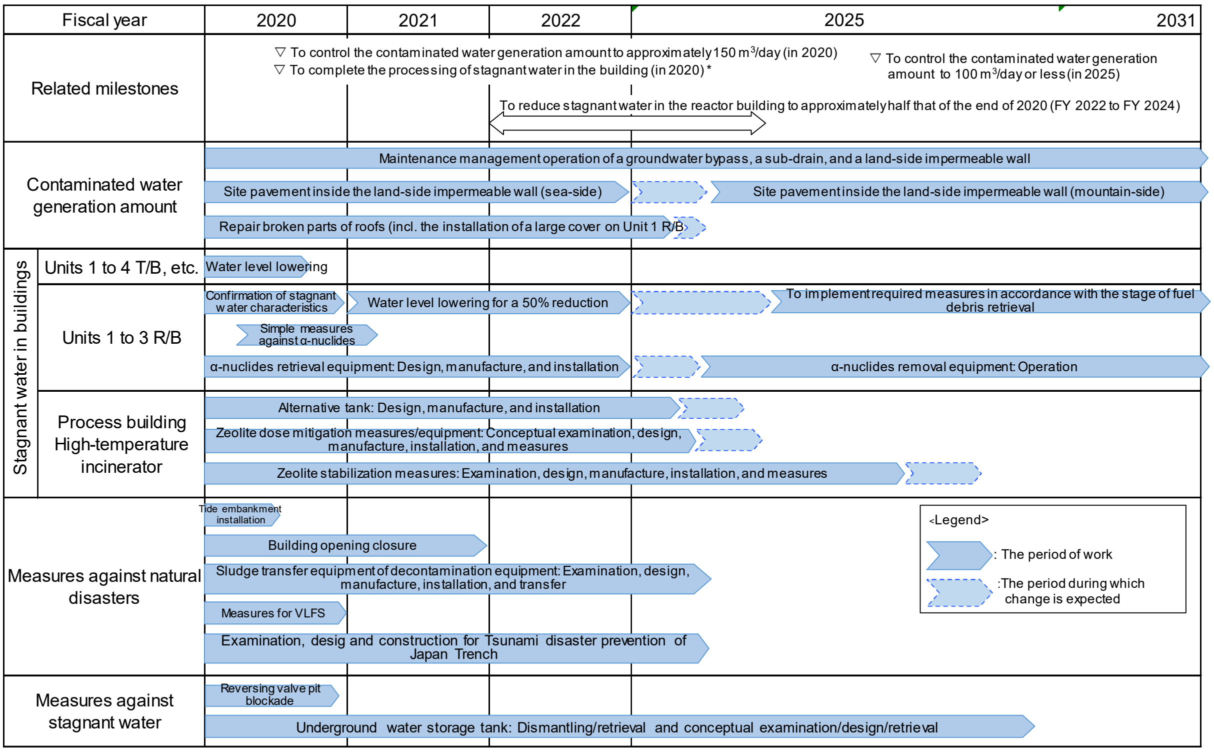
The expansion of the treatment capacity of the water treatment system and the system construction to realize continuous stable operation will be the issues in the further expansion of fuel debris retrieval. Here, it is required to examine downsizing of equipment in consideration of an installation space, operation and maintenance under higher radiation dose, utilization of existing purification equipment, etc., in addition to the removal system of α-particles and other radioactive materials.

Also, it is required to ensure that a periodical inspection and update of equipment is carried out in order to maintain the effect of contaminated water management over a long period. Furthermore, as for the risk of large-scale natural disasters such as tsunamis and heavy rain, according to the "Review on Large Earthquake Model along the Japan Trench and Krill Trench (Summary Report)" published by the Cabinet Office in April 2020, the impact was re-assessed for tsunamis and the tide embankment of Japan trench is scheduled to be newly installed by 2023. Going forward, the measures should be taken in light of resilience (robustness) based on the re-assessment results.

While the current contaminated water management is shifting to a certain stable state, a long period is required to complete fuel debris retrieval. It is important to see a medium-to-long period, overlook the current contaminated water management anew, and examine the principles of more stable contaminated water management and more appropriate maintenance and management.

3.3.2.3 Summary of key Technical issues

The summary of the key technical issues and future plans mentioned in this section is shown in Fig.13 and Fig 19.



*Except Units 1 to 3 reactor buildings, process buildings and high-temperature incinerator building.

Fig.19 Key technical issues and future plans on contaminated water management (progress schedule)

3.4 Fuel removal from spent fuel pools

3.4.1 Targets and progress

(Targets)

(1) While the return of residents and reconstruction in the surrounding area is gradually advanced, to carry out a risk assessment and ensuring safety certainly including preventing dispersion of radioactive materials and to start the removal of fuel in SFPs (Spent Fuel Pools) in FY 2027 to FY 2028 for Unit 1 and FY 2024 to FY 2026 for Unit 2. To complete the removal of fuel in SFPs in FY 2020 for Unit 3.

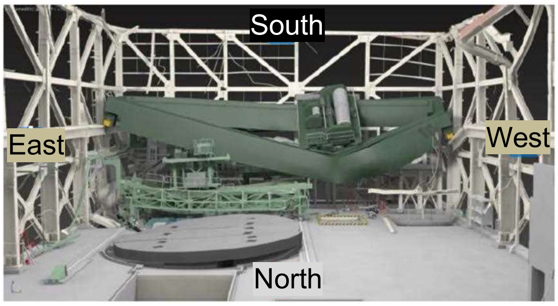
(2) The fuel in Units 1 to 4 that were affected by the accident are taken out of the SFPs and transferred to the Common Spent Fuel Storage Pool, etc., where they are appropriately stored so that they are in a stable management state. In order to secure the Common Spent Fuel Storage Pool capacity, the fuel stored in the Common Spent Fuel Storage Pool is transferred and stored in the Dry Cask Temporary Custody Facility.

(3) To carry out the evaluation of long-term integrity and the examination for treatment for the removed fuel and to decide the future treatment and storage method.

(Progress)

TEPCO is working on the new work plan indicated in the Mid-and-Long-term Roadmap and the Mid-and-Long-term Decommissioning Action Plan.

In Unit 1, due to the hydrogen explosion, a roof stab, building materials, such as a steel frame, which constituted the upper part of the building, an overhead crane, etc., have collapsed as rubble on the operating floor as shown in Fig.20. While the residents were returning, from the viewpoint of further reduction of radioactive dust dispersion risk, the whole operating floor was covered with a large cover for the removal of fuel in Unit 1 SFP. The removal method was changed to one in which rubble removal and the removal of fuel in SFP are carried out inside the cover. Fig.21 shows a conceptual drawing of this method. At present, the preparation to install the large cover is advanced, and the operating floor work such as rubble removal is continuing.

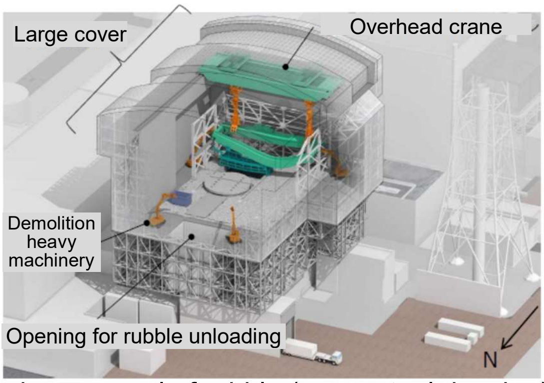


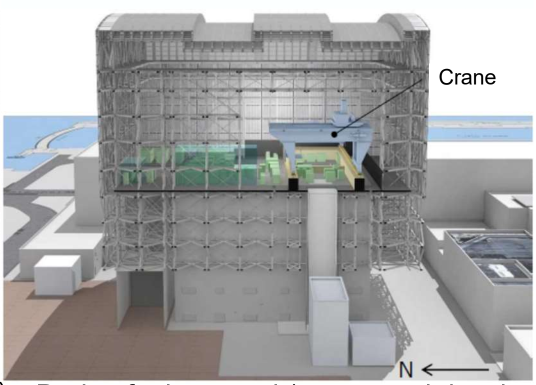
State of the existing installations under the collapsed roof (conceptual drawing)

State of the collapsed south-side roof

(TEPCO material edited by NDF)

Fig.20 Condition of the collapsed rubble on the Unit 1 operating floor



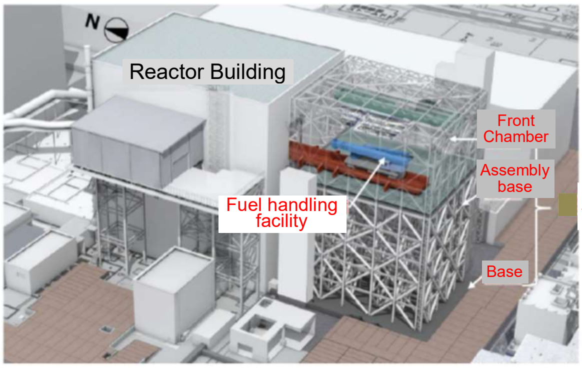


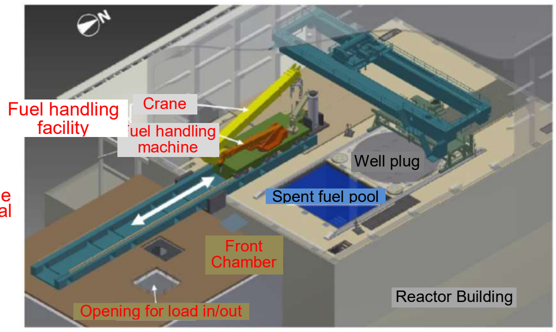
During removal of rubble (conceptual drawing) During fuel removal (conceptual drawing)

(TEPCO material edited by NDF)

Fig.21 Removal method of fuel from Unit 1 SFP

For Unit 2, new method that the upper part of the operating floor will not be dismantled and access from the south side of the reactor building was adopted from the viewpoint of further reduction of radioactive dust dispersion risk similar to Unit 1. Preparations are being advanced at present. Fig.22 shows a conceptual drawing of this method.





Fuel removal method (conceptual drawing) Fuel handling facility (conceptual drawing)

(TEPCO material edited by NDF)

Fig.22 Removal method of fuel from Unit 2 SFP

Also, for dismantling the Units 1 and 2 common exhaust gas stack, which was being carried out as part of the environmental improvement around Units 1 and 2, a local company worked as a principal contractor, and the work was completed in May 2020.

For Unit 3, fuel removal work is being advanced, considering safety the highest priority to complete the removal in FY 2020. As of August 2020, 315 fuel assemblies[17] are removed, and transfer to the Common Spent Fuel Storage Pool is being continued.

For Units 5 and 6, fuel will be appropriately stored in the SFPs of the units for the time being. Then, the fuel will be removed in a range so as not to affect the work in Units 1 to 3.

The securing the available capacity of the Common Spent Fuel Storage Pool and the transfer of some fuel in the Common Spent Fuel Storage Pool to the Dry Cask Temporary Custody Facility are required to remove all the fuel in SFPs, including Units 5 and 6, and store them in the Common

[17] TEPCO, “Storage status of spent fuel”, presented as Handout 3-2 at the 81st Meeting of the Secretariat of the Team for Countermeasures for Decommissioning and Contaminated Water Treatment, August 27, 2020

Spent Fuel Storage Pool. To achieve this, TEPCO is working on plans for expanding of storage capacity in Dry Cask Temporary Custody Facility and for off-site transportation of new fuel. The available storage capacity in the Common Spent Fuel Storage Pool and Dry Cask Temporary Custody Facility is shown in Fig.23.

Efforts will be made to complete the removal of fuel in all units in 2031.

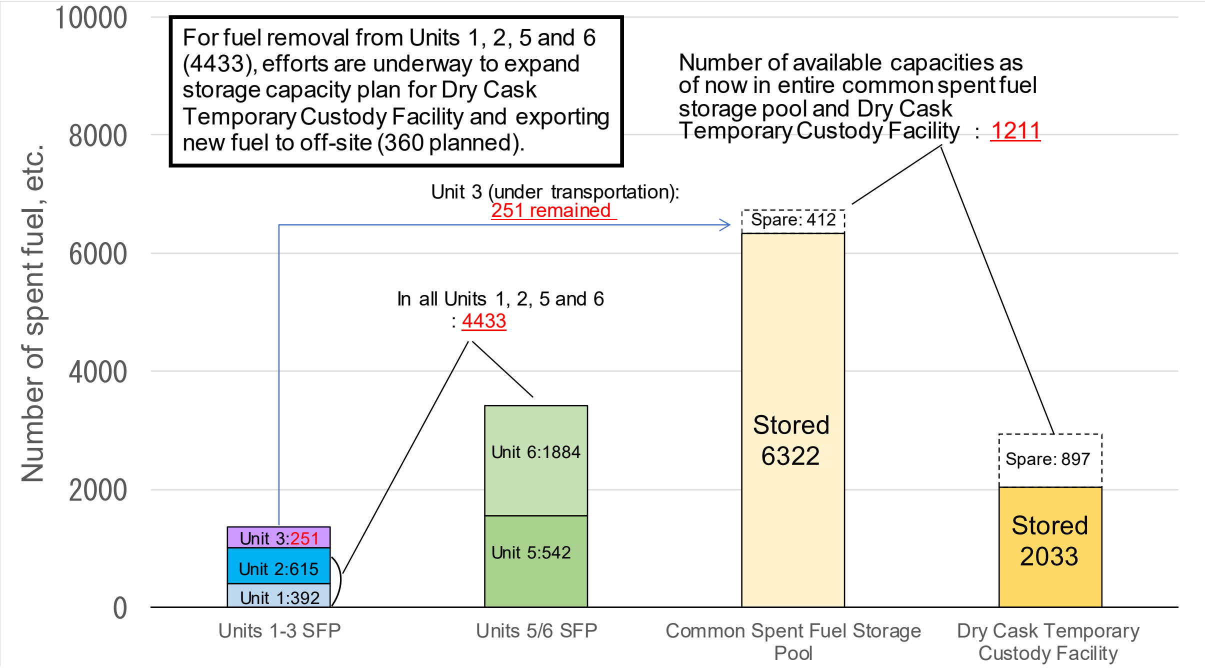


Fig.23 Storage status of spent fuel (as of August 2020)

3.4.2 Key issues and technical strategies to realize them

3.4.2.1 Fuel removal from SFPs

For Units 1 and 2, it is required to advance the work steadily to realize the determined new removal method.

In promoting the project, it is essential to comprehensively consider concerning technical certainty, reasonability, rapidity, actual site applicability, project risk, etc., and a work schedule to response to issues after making all evaluations of safety in association with work and confirming that required sufficient safety is ensured.

For Unit 1, the design and installation of the large cover, and the removal of leftover objects such as rubble on the operating floor will be promoted. There is an overhead crane in an unstable state on the operating floor. Therefore, removing the overhead crane safely and certainly is one of the main issues to prevent it from collapsing onto the fuel handling machine and falling into the spent fuel pool. Therefore, in the ongoing examination of how to remove the overhead crane, it is required to perform all safety assessments as an assumption, and it is important to carry out a comprehensive examination based on the viewpoints of (i) formulating concrete work procedures and work plans enabling the extraction of risk items, (ii) the risk scenario assumed from (i) and the measures, (iii) extraction of points to consider such as the exposure of workers, from an operator's perspective, and (iv) reasonability and impact on other work[18].

Regarding the 67 fuel assemblies in the cladding tube was damaged and stored in Unit 1 SFP before the accident, specific handling plan needs to be considered such as checking status of these after the accident, study and its development of handling method and risk study for handling.

In Unit 2, fuel in SFP will be removed from the opening on the south side of the outer wall of the operating floor using a fuel handling machine composed by a boom-type crane-system, which has not been used for nuclear facilities in Japan. Since it is a new system, the following is important: (i) to set up a design schedule with appropriate margins, (ii) to carry out a mockup test simulating the situation in the field and an operation method fully reflecting the results on the design/manufacturing certainly, and (iii) to be sufficiently familiar with the operation and functionality of systems beforehand since removal is carried out by remote operation[19].

For Unit 3, 16 fuel assemblies with deformed handle were confirmed, the status is shown in Fig. 24. Removing these fuel is scheduled in the second half of FY 2020. As for removal of fuel assemblies with deformed handle, it is important to load them reliably into transport cask by lifting safely from fuel rack. Fully based on the condition on site, TEPCO proceeds the following preparations while conducting analytical evaluation of impact of rubbles and strength test by considering deformation of handles.

- A tool for removing small rubbles on the top of fuel rack is manufactured to avoid interference between fuel and rubbles or fuel rack.
- For 4 fuel assemblies with significantly deformed handle that could not be lifted with existing grapple of fuel handling machine, new grapple is being designed and lifting test will be conducted when it is ready.
- For 11 fuel assemblies that can be lifted with existing gripper of fuel handling machine, lifting tests were conducted in May 2020, in which the lifting loads were limited to 700 kg in the test (the specified load is 1 ton in general). As a result, it was found that 7 fuel assemblies could be lifted (including of 3 fuel assemblies which their seating positions became higher than before testing), three could not be lifted, and there was 1 fuel assembly that the mast of fuel handling machine couldn't be approached. To reliably lift 3 fuel assemblies that have been confirmed to be-unliftable, multiple measures are being prepared as below.
    - ✓ Removing rubbles on the top of fuel rack using a tool that can remove small rubbles
    - ✓ Additional lifting tests in lifting load by the reassessed load based on the strength test of handles
    - ✓ Measures with a view to cutting fuel racks

  Moreover, regarding 1 fuel assembly that the mast of fuel handling machine couldn't be approached, it was verified to be able to lift in the lifting test in August 2020, by pushing the

[18] NDF, Evaluation on Selecting the Fuel Removal Method (Plan) for Unit 1 at the Fukushima Daiichi NPS, presented as Handout 3-2 at the 73rd Meeting of the Secretariat of the Team for Countermeasures for Decommissioning and Contaminated Water Treatment, December 19, 2019

[19] NDF, Evaluation on Selecting the Fuel Removal Method (Plan) for Unit 2 at the Fukushima Daiichi NPS, presented as Handout 3-2 at the 71st Meeting of the Secretariat of the Team for Countermeasures for Decommissioning and Contaminated Water Treatment, October 31, 2019

mast using a manipulator and approaching the fuel.

- Regarding 1 fuel assembly with deformed handle that was found after the lifting test conducted in May 2020, it was also verified to be able to lift in the lifting test in August 2020.

As mentioned so far, it is important to reliably execute the preparations for removal including, verifying in advance, giving these feedback and examining multiple responses.

Besides, it is also required to accumulate knowledge obtained, including these responses at Unit 3 and experiences at Unit 4, and to leverage it for the subsequent fuel removal from Units 1 and 2, as well as to improve quality assurance organization and reliably secure the backup supply based on the experience.

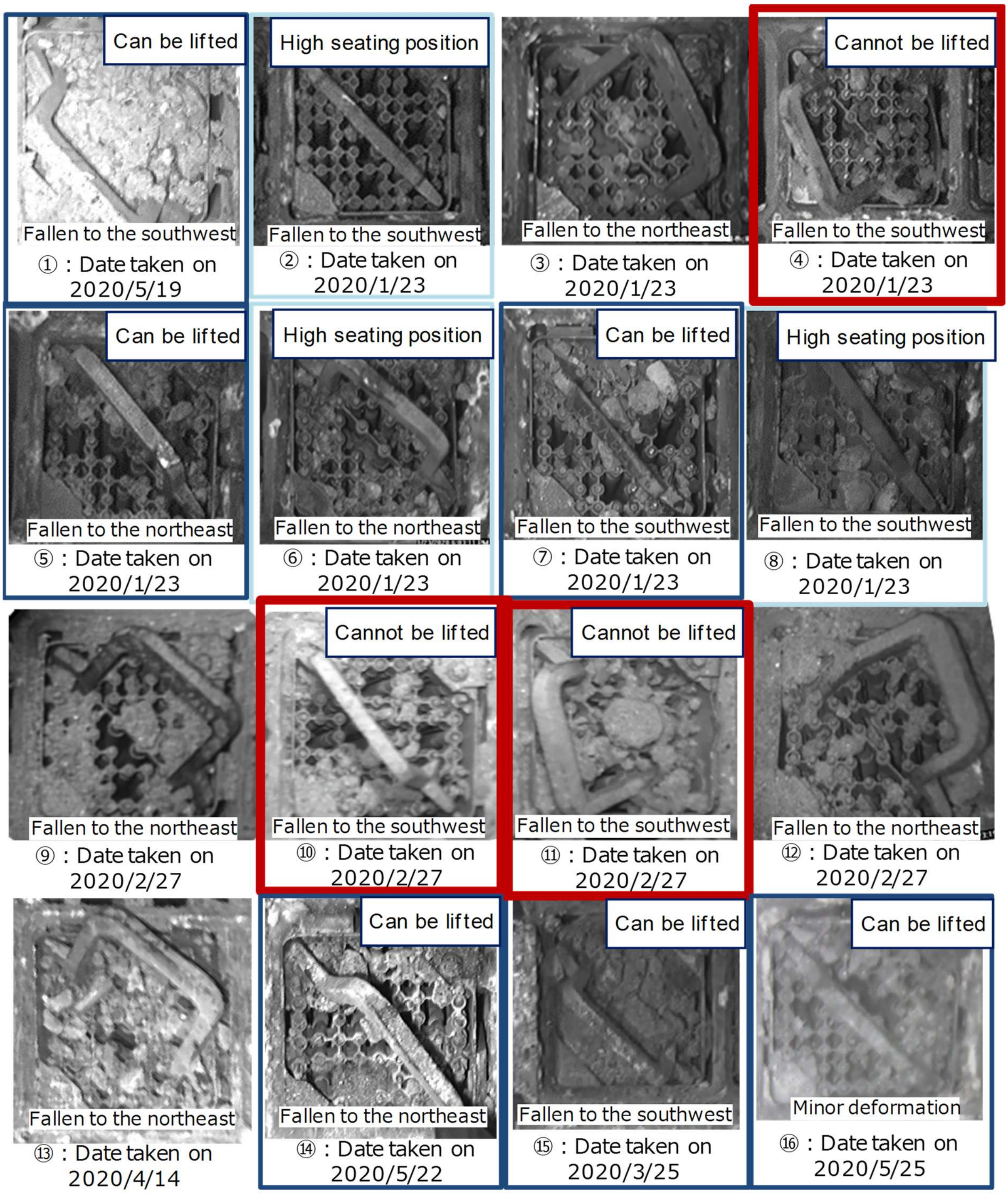


Fig.24 Status of 16 fuel assemblies with deformed handle[20]

[20] Extracted from Spent fuel pool management presented as Handout 3-2 at the 81st Meeting of the Secretariat of the Team for Countermeasures for Decommissioning and Contaminated Water Treatment, August 27, 2020

3.4.2.2 Decision of future treatment and storage methods

The future treatment and storage methods for the fuel in SFPs need to be decided after considering the impact of seawater and rubble exerted during the accident. The impact of seawater and rubble has been evaluated for the fuel removed from Unit 4, and it is expected that the impact is small. However, based on the situation of the fuel to be removed, it is required to advance the evaluation of long-term integrity and the examination for treatment and to decide the future treatment and storage methods.

3.4.2.3 Summary of key Technical issues

The main technical subjects and plans described in this section are summarized as shown in Fig.25.

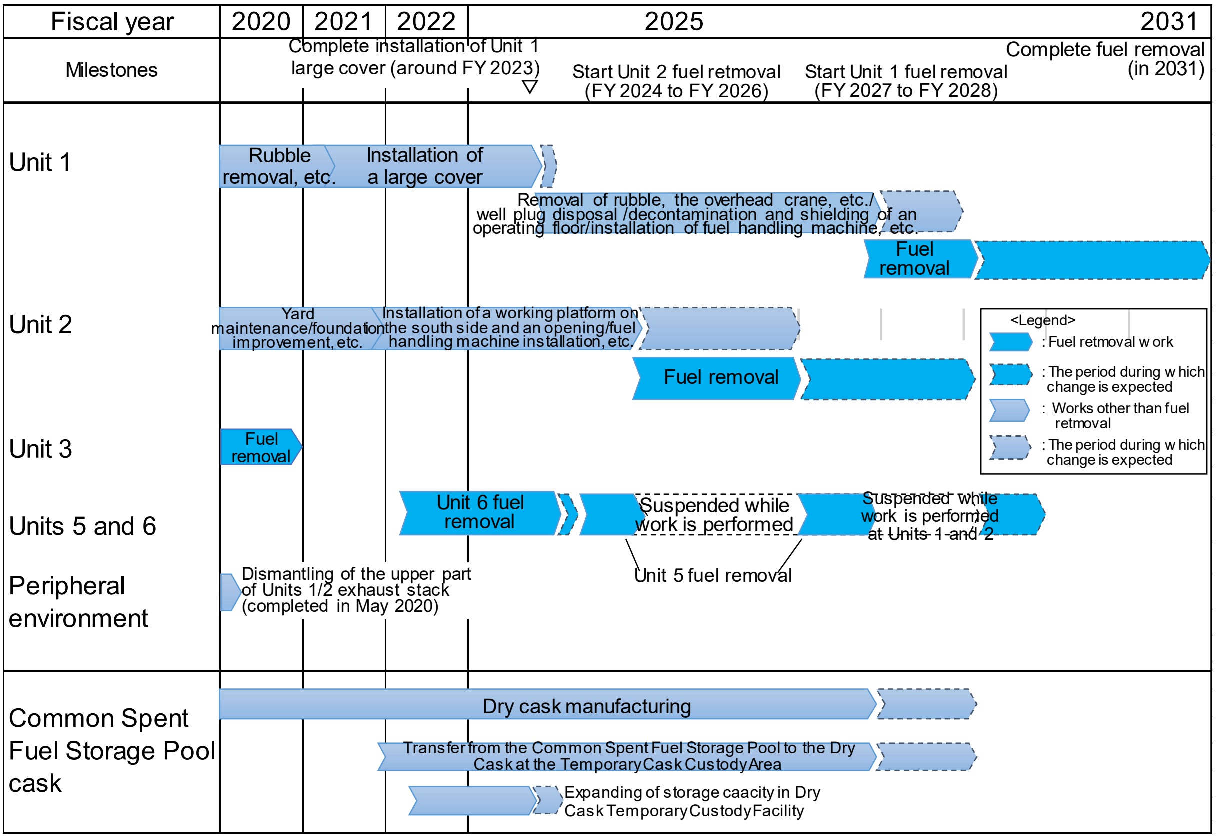


Fig.25 Key technical issues and future plans for fuel removal from SFPs (Progress schedule)

3.5 Utilization of Analysis Results for Smooth Promotion of Decommissioning

3.5.1 Significance and the current status of analysis

To safely and steadily proceed with decommissioning of the Fukushima Daiichi NPS, it is necessary to establish and develop analysis facilities and functions required for handling of waste or fuel debris. In addition, it is important to build a system to effectively utilize analyzed results for each decommissioning operation.

TEPCO currently utilizes three facilities including the laboratory for Units 5 and 6, the chemical analysis building, and the environmental management building, and performs analyses required for facility administration and decommissioning progress, while planning to establish an analytical facility necessary for smooth performance of routine analyses related to processing/disposal of waste and fuel debris retrieval in the future. Moreover, as fuel debris retrieval proceeds, risk of α contamination intake is supposed to be gradually increased, a bioassay function contributes to assessment of internal exposure is planned to be established.

The Radioactive Materials Analysis and Research Facility (Facilities Management Building, Building 1, and Building 2) is being developed by JAEA under an official supplementary budget as an essential analytical facility for decommissioning of the Fukushima Daiichi NPS. The analysis results obtained are required to contribute to facilitation of smooth decommissioning, reliable processing/disposal measures of radioactive material in decommissioning operation, and establishment of technical foundation, etc. Solid waste analysis under current conditions has been carried out at JAEA Ibaraki, Japan, and at private analytical facilities (Nippon Nuclear Fuel Development Co., Ltd. (NFD), Nuclear Development Co., Ltd. (NDC)), and is expected to be used effectively in the future.

3.5.2 Key issues and strategies

The analysis results of solid waste are important basic information for the study on processing/disposal measures for various kinds of waste generated by the accident. In addition, the analysis results of fuel debris are reflected in a number of areas, including retrieval methods, storage management, processing/disposal, investigation to determine the cause of the accident, and enhancement of nuclear safety. Their relationship changes with the progress made in decommissioning of the Fukushima Daiichi NPS (Attachment 7). It is necessary to correctly recognize that the analysis results are “an important piece” to reduce the range of uncertainties identified as above for the smooth decommissioning, and to establish and improve the analysis system, as well as facilities and functions for analysis for enabling efficient collection and assessment of analysis results. In particular, analytical data, as well as monitoring data, play an important role in the study on the retrieval method to mitigate excessive safety design while ensuring safety. Therefore, analysis shall be positioned at a higher level in the decommissioning project.

Role sharing among the facilities that are currently planning to conduct analysis shall be appropriately optimized based on the characteristics of each facility, taking into account that the content, quality, quantities, etc., of the analysis required will change with the progress of decommissioning. In doing so, the scalability of facilities and the flexibility of operations should be considered, taking into account a risk that the demand for analysis may increase.

In addition, due to the shortage of human resources required for stable operation of the above-mentioned facilities, consideration should be given to securing and retaining of the analytical engineers. In this respect, it is necessary to consider in advance the qualities expected for analytical engineers in various analytical works that are required for optimization as mentioned above, and to develop a plan so that the required roles are appropriately achieved. Regarding the fostering of field analysts and supervisors of commissioned analysis, although it is conceivable that TEPCO educates non-chemical personnel through OJT[21], etc., by referring to the approach taken by private facilities for analysis. However, since there are few talented personnel (analysis evaluators) who can design the analytical range and items in anticipation of how to use the analysis results in advance, it is important to make efforts in increasing them.

From the viewpoint of speeding up decommissioning, “immediacy” and “readiness” are required for operating the facilities that do not need off-site transportation, such as radioactive material analysis and research facilities. Although the analysis work for fuel debris retrieval is assumed to be very difficult, especially when unknown samples are handled, an important stance is that the decommissioning work shall be carried out on schedule by conducting analyses without delay. It is also important to pursue a reasonable analysis plan by comprehensively utilizing analysis results and on-site information, such as by taking note of the fact that analysis results have functions to benchmark the estimation results of internal conditions given by instrumentation monitoring, visual observation, in-situ measurement, and evaluation of calculations (simulation).

Considering that the content, quality, quantities, etc., of the analysis required will change in the process of the decommissioning project (engineering of construction methods and equipment, safety assessment and safety design, and decommissioning operations), TEPCO should establish a system where TEPCO itself will actively commit control and leadership of the whole of activities related to the analysis, by appropriately developing a role sharing of the organizations and facilities in line with this consideration and make decisions based on comprehensive evaluation. From this viewpoint, TEPCO is required, with the cooperation of outside experts, to start examining the overall strategy and a plan for the analysis of decommissioning work as early as possible.

[21] OJT (On the Job Training) means a occupational training by practicing in the workplace.

4. Efforts to facilitate research and development

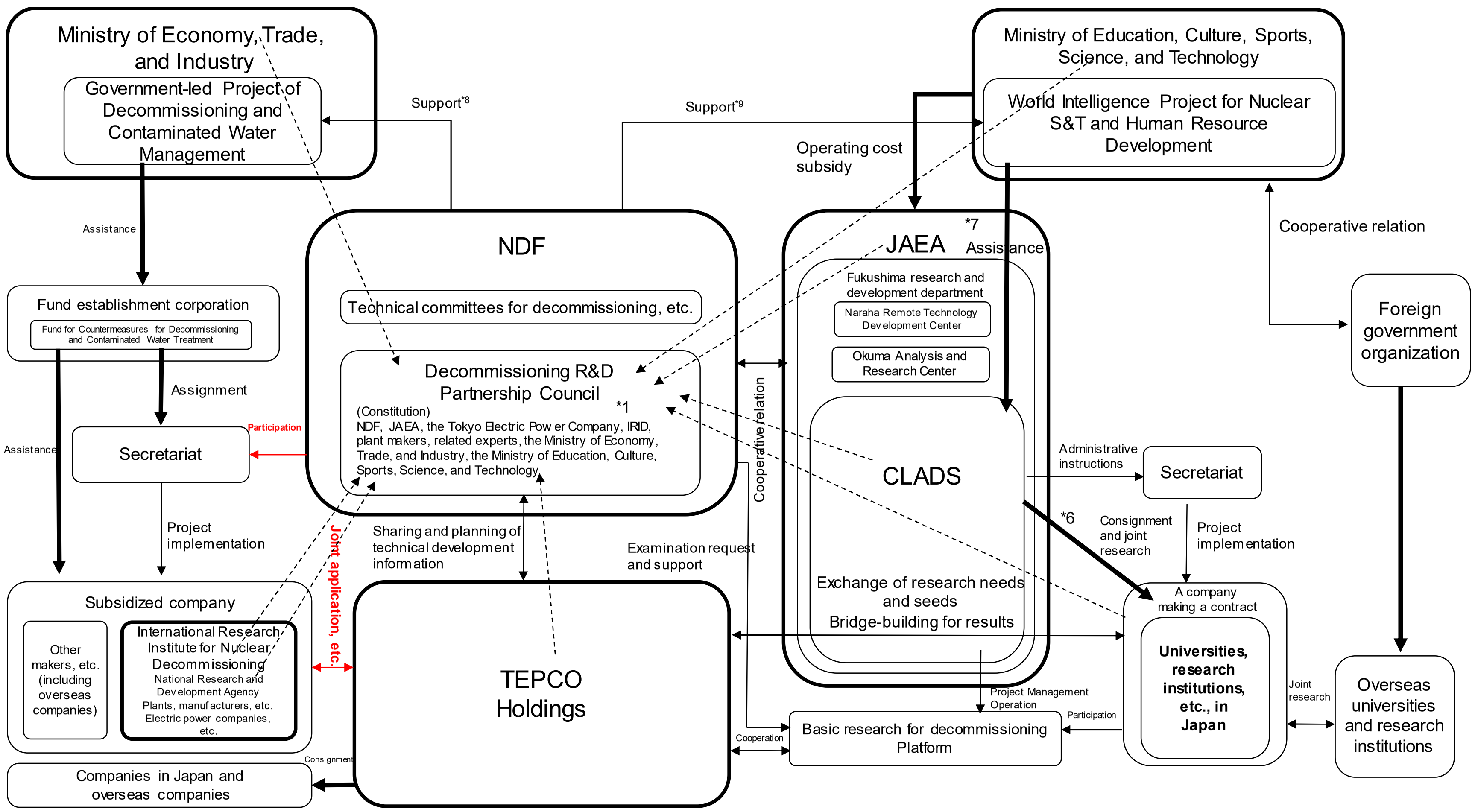
4.1 Significance and the current status of research and development

There are many difficult technical issues requiring research and development to promote the decommissioning of the Fukushima Daiichi NPS from the viewpoints of safety, certainty, reasonability, rapidity, and field orientation. At present, when trial retrieval of fuel debris in 2021 is imminent, it is required to accelerate research and development under the consideration of the application to the site for a gradual expansion of retrieval scale and further expansion of retrieval scale.

In order to solve these technical issues, basic fundamental research and application research by universities in and outside of Japan and research institutions such as the JAEA and practical application research and field demonstrations by IRID, overseas enterprises and TEPCO, etc., are being performed by various entities of industry/academia/government. In order to promote the research and development, the government is supporting highly-difficult ones among applied research, practical application research and field verification by the Government-led R&D program on Decommissioning and Contaminated Water Management, and ones regarding basic and fundamental research by the World Intelligence Project for Nuclear Science & Technology and Human Resources Development (hereinafter referred to as "World Intelligence Project"). TEPCO is also working on the research and development directly linked with actual site applicability. The outline of the research and development organization is shown in Fig.26.

NDF established a “Decommissioning R&D Partnership Council”, which examines the issues, such as the information sharing of R&D needs and seeds, the arrangement of research and development based on the needs of decommissioning work, and the promotion of cooperation for research and development and human resources development, with the related organizations as members.

Also, in promoting research and development, it is important to make use of the Naraha Remote Technology Development Center, the Okuma Analysis and Research Center, and Collaborative Laboratories for Advanced Decommissioning Science (hereinafter referred to as “JAEA/CLADS”) and arrange the decommissioning R&D base, including international viewpoints.



*1 The Decommissioning R&D Partnership Council is established in the NDF based on the determination by Team for Countermeasures for Decommissioning and Contaminated Water Treatment.
*2 The arrow drawn in a thick solid line indicates expenditures such as research expenses and operating expenses (excluding facilities expenses), the arrow drawn in a thin solid line indicates a cooperative relation, etc., and the arrow drawn in a dotted line indicates the participation in the Decommissioning R&D Partnership Council.
*3 Some organizations such as JAEA are located at two or more places.
*4 Each organization has cooperative relations with foreign organizations based on MOU, etc., respectively.
*5 Research and development uniquely conducted by the Central Research Institute of Electric Power Industry, etc., are omitted in this figure.
*6 Although among the World Intelligence Project for Nuclear S&T and Human Resource Development the part adopted up to FY 2017 is the consignment from the Ministry of Education, Culture, Sports, Science, and Technology to a company making a contract, it is omitted in this figure.
*7 Although the subsidy for the World Intelligence Project for Nuclear S&T and Human Resource Development is delivered to JAEA, it is expressed as what is delivered to CLADS, to make it easier to understand.
*8 With regard to the Government-led Project of Decommissioning and Contaminated Water Management, based on the policy in the Mid-and-Long-term Roadmap or Strategic Plan and the progress situation of research and development, the NDF formulates a draft plan of the next research and development, and the Ministry of Economy, Trade, and Industry determines it.
*9 The NDF participates as a member in a steering committee of the World Intelligence Project for Nuclear S&T and Human Resource Development.

Fig.3 Overview of the R&D structure of the decommissioning of Fukushima Daiichi NPS (As of FY 2020) (Red: Areas with strengthened systems)

4.2 Key issues and strategies

4.2.1 Strengthening the research and development management organization in the Government-led R&D Program on Decommissioning and Contaminated Water Management

4.2.1.1 Decommissioning and contaminated water management project

The Ministry of Economy, Trade and Industry is providing support through the Government-led R&D program on Decommissioning and Contaminated Water Management for research and development to solve technical issues that are difficult to solve in decommissioning. As shown in Fig.26, in the Government-led R&D program on Decommissioning and Contaminated Water Management, necessary assistance is provided through corporations with funds and the secretariat, including for the selection of project operators, such as IRID, and other companies conducting R&D. Through the Government-led R&D program on Decommissioning and Contaminated Water Management, significant results have been obtained in the progress of decommissioning work and progress is being made in the investigation of the inside of the PCV and understanding the internal conditions. Attachment 12 outlines the implementation of the Government-led R&D program on Decommissioning and Contaminated Water Management up to now.

4.2.1.2 Strengthening the R&D Management System

Although TEPCO focused on the research and development for immediate decommissioning work, it has been transferring to strategic efforts based on the mid-and-long-term plan in research and development, such as publishing the Mid-and-Long-term Decommissioning Action Plan. Based on this situation, for the Government-led R&D program on Decommissioning and Contaminated Water Management, it is required to strengthen the research and development under the consideration of needs and actual site applicability by TEPCO. Therefore, it was decided that NDF and TEPCO should be further involved in the Government-led R&D program on Decommissioning and Contaminated Water Management in the future.

Specifically, in the Government-led R&D program on Decommissioning and Contaminated Water Management, the organization resulted in one in which NDF participated in the secretariat of the Government-led R&D program on Decommissioning and Contaminated Water Management and clarified the involvement of TEPCO as an actual site applying party, with the recognition of issues that the functions of both planning and status control of a project should be strengthened. TEPCO reflects requirements from the viewpoint of actual site applicability by jointly applying for subsidy with R&D implementation entities, and carries out status control cooperating with project management.

As a result, the Government-led R&D program on Decommissioning and Contaminated Water Management has become more needs-driven research and development, and the site applicability of the research and development has become high. In addition, the role of NDF in planning research and development in the Government-led R&D program on Decommissioning and Contaminated Water Management has become clearer.

TEPCO is required to construct such a scheme and strive to focus on research and development it performs. While strengthening communication by means of information exchange and dialogues with TEPCO, NDF will plan matters considering needs in the field and actual site applicability and manage status control of research and development to achieve research and development conforming to the purpose of research and development and the target period for achieving results.

4.2.2 Formulating the R&D medium-to-long-term plan foreseeing about ten years for the time being

4.2.2.1 Formulating the R&D medium-to-long-term plan

The Mid-and-Long-term Roadmap indicated the course of action for about ten years for the time being and the promotion of research and development to support it. With regard to this matter, based on the Mid-and-Long-term Decommissioning Action Plan, NDF and TEPCO decided to formulate the R&D medium-to-long-term plan overlooking the overall research and development for about ten years for the time being in order to appropriately manage the extraction and execution of the required research and development for achieving the further expansion of fuel debris retrieval (Attachment 13). In the R&D medium-to-long-term plan, the items and content of research and development assumed at present in each stage of fuel debris retrieval are identified in a manner linked with the TEPCO's Mid-and-Long-term Decommissioning Action Plan. Also, formulated based on this R&D medium-to-long-term plan, the Next-term R&D plan formulated every fiscal year will clarify how and where each research and development project corresponds to the decommissioning process. The R&D medium-to-long-term plan will be updated and expanded continuously based on the information made clear by the progress of Internal investigations of PCV, etc., and fuel debris analysis, the progress of research and development, the revision of the TEPCO's Mid-and-Long-term Decommissioning Action Plan, etc.

4.2.2.2 Preparation of the Next-term R&D Plan

In order to support the Government-led R&D program on Decommissioning and Contaminated Water Management, every fiscal year NDF drafts the Next-term R&D Plan for the decommissioning research to be carried out in the upcoming two years from the next fiscal year. The plan is first deliberated on by Fuel Debris Retrieval Expert Committee and Waste Management Expert Committee, and then by Decommissioning Strategy Committee. After this, it is summarized as NDF proposal. The Ministry of Economy, Trade and Industry reports this Next-term R&D Plan to the Meeting of the Secretariat of the Team for Countermeasures for Decommissioning and Contaminated Water Treatment, and the decommissioning research will be conducted in accordance with this plan from the next fiscal year. In the Government-led R&D program on Decommissioning and Contaminated Water Management, decommissioning research and development is carried out by selected operators who have been invited to participate in public solicitations based on this Next-term R&D Plan.

4.2.3 Matching of needs and seeds of decommissioning work site and universities /research institutions

4.2.3.1 Important R&D tasks derived from the needs and the overall map of the basic foundation research

Universities/research institutions bearing basic infrastructure research are expected to maintain and develop human resources and knowledge/infrastructure to make a quick response when technical issues requiring scientific knowledge occur. It is important that universities/research institutions deeply share recognition of issues of decommissioning work site.

In addition, to facilitate the long-term decommissioning project of the Fukushima Daiichi NPS, it is important to conduct scientific and technological investigations based on understanding of the principles and theories from the mid-and-long term perspectives. Based on the discussions at the Decommissioning R&D Partnership Council, NDF set up a “task force on research collaboration” for discussion, and identified six important R&D tasks to be addressed with priority strategically, including investigation of issues, problem awareness on the side of the needs, and the assumed research image (Attachment 14). At present, these important R&D tasks are being further examined in the Platform of Basic Research for Decommissioning[22]. These important R&D tasks have been used to solicit applications for the World Intelligence Project launched by JAEA/CLAD in May 2018. In soliciting applications for the current World Intelligence Project, JAEA/CLAD is using the “overall map of the basic foundation research”, which provides an overview of the entire decommissioning process from contaminated water management to the processing/disposal of waste, including these important R&D tasks, and identifies the R&D needs and seeds required.

4.2.3.2 Establishment of the centers of basic research/research infrastructure

In order to make the long-term decommissioning of the Fukushima Daiichi NPS proceed steadier in technical aspects, it is essential to work on developing R&D infrastructure and accumulate technological knowledge, develop generic technologies and collect basic data, including the important R&D tasks, building up research centers, facilities and equipment, and human resource development. Decommissioning of the Fukushima Daiichi NPS is an opportunity for trial of state-of-art science and technology and such the accumulation of such activity is expected to become a source of innovation.

The building for International Research Collaboration of JAEA/CLADS (Tomioka-machi, Fukushima Prefecture) is a place where universities, research institutions, industries, etc., in and outside Japan form a network and promote research and development and human resource development in an integrated manner. TEPCO and universities are also moving into the building to conduct research. In the future, it is expected that a network will be formed for the exchange of diverse human resources from Japan and abroad, such as universities, research institutions, and industries, and that JAEA/CLADS will become a central organization serving as a hub for such

[22] Promotion council of basic and generic research jointly managed by JAEA/CLADS and MEXT the Center of the World Intelligence Project: Decommissioning Research and Human Resource Development Promotion Program selection agency. See https://fukushima.jaea.go.jp/initiatives/cat05/haishi05.html.

activities. Following this idea, the World Intelligence Project has shifted from the project commissioned by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) to a subsidy project intended for JAEA/CLADS (a subsidy project for Nuclear S&T and Human Resource Development). The project is implemented by a system centered on JAEA/CLAD from the newly adopted tasks in FY 2018. The “Program for Decommissioning Research by Human Resource Development” was newly established in the Center of World Intelligence Project in FY 2019. It created a basis of research and human resource development (Collaboration laboratory) in both educational research institutions and JAEA/CLADS[23], and has started R&D and a human resource development project that connects these organizations by cross-appoint system. It contributes to functional enhancement of JAEA/CLADS. From FY 2020, while focusing on “problem-solving decommissioning research program” to provide R&D that directly relates to the needs at the decommissioning site, quota for young person under the age of 39 was established in the program to promote the participation of younger researchers.

4.2.3.3 For strengthening the matching of needs and seeds

Some basic fundamental research contributing to problem-solving in the on-site decommissioning have obtained outstanding research results mainly in the World Intelligence Project. It is an important issue to reflect the results in the on-site of decommissioning directly. In order to achieve this, it is essential to match the needs of the decommissioning site with the seeds of universities and research institutions, build bridges for excellent results obtained, while making use of the overall map of the basic foundation research by JAEA/CLAD. Based on this recognition, in the World Intelligence Project, JAEA/CLAD has been tackling assessment of actual site applicability for its adopted subjects to date and acceleration of on-site application as the result of such assessment with the help of knowledge of TEPCO. The “steering committee[24]” that presents the basic policy for the operation of the World Intelligence Project has been strengthening to further reflect the viewpoint of needs in the Project with the participation of members, such as the Ministry of Economy, Trade and Industry in charge of the Government-led R&D program on Decommissioning and Contaminated Water Management, and domestic decommissioning operators, along with TEPCO as Program Officer (PO) that is newly responsible for research management. In addition, joint research with universities was newly started in TEPCO from FY 2019 to find the technical seeds for decommissioning owned by universities[25] based on the result of the World Intelligence Project. The related organizations, such as the government (the Ministry of Education, Culture, Sports, Science, and Technology, the Ministry of Economy, Trade, and Industry), JAEA/CLADS, NDF, and TEPCO, need to strengthen cooperation towards further matching of the needs and seeds and bridging for the results.

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[23] JAEA can use bases in Tokai and Oarai as well as a base in Fukushima

[24] Consisting of program directors, experts from universities and research institutions, NDF, and TEPCO, it was established in the Ministry of Education, Culture, Sports, Science and Technology.

[25] Tohoku University, Fukushima University, the University of Tokyo, and the Tokyo Institute of Technology (It was started from FY 2020 other than Tokyo University.)

5. Activities to support our technical strategies

5.1 Further strengthening of project management and improvement of capability required as a decommissioning executor

5.1.1 Significance and the current status of project management

Individual work in each field of decommissioning work is generally carried out through processes such as research and development → conceptual design → detailed design → production → site installation work → inspection → operations. In addition, inspections by the Nuclear Regulation Authority and other examinations will be conducted as necessary. In order to carry out this series of processes without omission or delay, it is effective to set up the large work flow defined in the long-term plan as an individual project as a management unit of appropriate scale. In addition, it is important to promote a comprehensive approach under a sophisticated project management system so that correlation and time-series relationships between the projects can be optimized and risks inherent in the project can be appropriately managed.

5.1.1.1 Formulating the Mid-and-Long-term Decommissioning Action Plan

Since the accident at the Fukushima Daiichi NPS, TEPCO has conducted decommissioning project in accordance with the requests based on the Act on Special Measures Concerning Nuclear Emergency Preparedness and the Nuclear Reactor Regulation Law[26] and the target process of the Mid-and-Long-term Roadmap determined in the Inter-Ministerial Council for Contaminated Water and Decommissioning Issues. By formulating and publishing the Mid-and-Long-term Decommissioning Action Plan showing the processes for how to achieve such targets, in light of the ten years that have passed since the accident, TEPCO made transparent the decommissioning project to local areas and society, made clear its attitude toward tackling decommissioning independently, and materialized the complicated work prospect over a long period.

The decommissioning work for the Fukushima Daiichi NPS is a project with significant uncertainty. However, since the plan under the consideration of the medium and long term can be formulated for research and development, human resources, and procurement by thinking of the Mid-and-Long-term Decommissioning Action Plan, the meaning of formulating the Mid-and-Long-term Decommissioning Action Plan is significant. It is also important to carry out constant review based on new knowledge, the on-site situation, etc., for utilizing the Mid-and-Long-term Decommissioning Action Plan effectively in the future.

5.1.1.2 Further strengthening of project management

As “a condition that must be urgently addressed” such as contaminated water management and the removal of fuel from SFP has been settling down, TEPCO is currently faced with “a phase of tackling uncharted territory systematically” in the “stage of addressing situations proactively and strategically.”

[26] The Act on the Regulation of Nuclear Source Material, Nuclear Fuel Material, and Reactors

During this, in April 2020, TEPCO converted the decommissioning project into a project management type by changing the organization of Fukushima Daiichi D&D Engineering Company. TEPCO, however, has just started as a project management type organization, and is accelerating efforts with extremely high levels of uncertainty and technical difficulty, such as retrieval of fuel debris. Even under such circumstances, in order to proceed with complex and multi-layered large-scale projects such as simultaneous execution of multiple tasks under an environment with high radiation level in a safe, reliable, and prompt manner, the following efforts will be thoroughly implemented to further strengthen project management.

- Clarify the authority and responsibility of project implementation divisions with regard to budget management, etc., as well as instill in project managers a sense of responsibility to carry out the project and improve their project management capabilities.
- The project manager carries out the integrated management of the project budget, process, work, risk, quality, personnel, etc., to accomplish the project. The project manager will integrate engineering and R&D into the project to ensure the execution of projects with a high level of uncertainty and technical difficulty.
- The project management division appropriately updates the Mid-and-Long-term Decommissioning Action Plan based on the actual situation and progress of the site. It also issues monitors the progress of each project, gives instructions on necessary corrections according to the progress, and controls resources based on the progress in the project. The project manager coordinates the relevant projects to accurately implement the instructions of the project management division. During this, when the project manager acknowledges that it would be adequate to change the region of each project from the viewpoint of optimizing the overall decommissioning work, the project manager will make a proposal to the project management division accordingly to review the project mission.
- Effective project management will be carried out by aggressively introducing the necessary project management methods and tools from inside and outside Japan.

5.1.2 Key issues and strategies

5.1.2.1 Reinforcement of “safety and operator's perspectives” in project activities

When promoting efforts such as design examination (engineering) for construction method and equipment, there is a tendency to focus on realizing a construction method, equipment, etc., physically, especially for issues with severe technical difficulty. However, in order to realize the results of efforts in the field, it is indispensable to fully reflect the following in the construction method and equipment in addition to a physical realization:

- “The safety perspective” as a project executor handling dangerous substances[27] of nuclear fuel material, etc.

[27] Although the fuel debris is in a certain safe state now, the fuel debris retrieval work will cause disturbances to this stable state. Namely, since α-radioactive material is handled in an unsealed state in fuel debris retrieval work and a criticality risk may be increased temporarily, more elaborate work management than before (criticality control, radiation protection, operation management, monitoring strengthening, etc.) is required.

- "The operator's perspective"[28] familiar with the field of the Fukushima Daiichi nuclear power plant decommissioning

Therefore, these perspectives need to be fully reflected in the project activities until a construction method and equipment are realized in the field. Without sufficient feedback, the results of the construction method and equipment that are unsuitable to the site will be brought about, and safe and stable decommissioning will be disturbed.

To avoid such a situation, a business process to incorporate a "safety perspective" and an "operator's perspective" in the upstream of project activities needs to be established at an early stage.

5.1.2.2 Promulgating the "Safety First" principle that safety perspective comes first

The handling of nuclear fuel materials that still remain in large amounts at Fukushima Daiichi NPS is permitted only if the operator sufficiently suppresses the potential hazards of these potentially hazardous materials, and ensures conditions that pose no problems with regard to accident prevention. This must be clearly understood for the decommissioning project as well, now that operations at Fukushima Daiichi NPS have transitioned from the emergency evacuation and emergency response phase in the immediate aftermath of the accident to the phase where long-term issues are being addressed in a planned manner.

The use of any method or device is basically unacceptable unless the safety perspective is sufficiently reflected in them. Therefore, it is important that all who work in the processes (projects) leading up to the realization of methods and devices on the site, keep the safety perspective first in mind as they engage in their work (safety first). The specific application of the general "safety first" principle in projects is about, "Conducting extensive assessments on safety matters associated with methods and devices when reviewing any project and, upon verifying that necessary and sufficient levels of safety have been ensured, comprehensively taking into account factors such as technical reliability, reasonableness, speed, actual site applicability and project risks to decide which methods or devices to use, and which attendant safety approach to apply".

Since the accident at Fukushima Daiichi NPS, leaders of nuclear operations at TEPCO have stepped up to the plate and continue to work hard to raise awareness on the issue of nuclear safety, such as through dialogue amongst themselves, as well as through messages that they communicate to other TEPCO employees. In order to thoroughly promulgate the "safety first" principle to all persons who work on projects including on-site, the attitude of top management (the approach to reiterates the special nature of nuclear safety and how it must be approached with an accordingly special kind of awareness) is important.

5.1.2.3 Improving the owner's engineering capability

(1) Role of TEPCO as project executor (Requestor)

To ensure that the complex and extensive engineering, such as retrieval of fuel debris, proceeds

[28] An operator is a collective term for the people and organizations handling the site (operation, maintenance, radiation control, instrumentation, analysis, etc.)

without any rework, it is effective for the project executor (Requestor), TEPCO, to clearly communicate the requirements to the supply chain supplier candidate (manufacturers, general contractors, etc.) at the upstream of the project in order to prevent rework in the project. In the requirement specifications, the performance requirements for the entire system are first described, followed by the functional requirements for individual equipment and facilities necessary to meet the performance requirements. TEPCO, the requestor, needs to describe at least the performance requirements of the entire system, and if the company entrusts the function requirements to the supply chain supplier candidates or prepares it with them, there should not be significant problems.

(2) Importance of “safety and operator's perspectives” in Owner's Engineering

Engineering for the retrieval of fuel debris on the expanded scale is complex and extensive. Besides, the conventional engineering approach[29] does not necessarily apply to unprecedented work of high uncertainty and difficulty due to the limited information obtained, and it is highly likely that it does not.

Since fuel debris retrieval has never been conducted before, the target setting and required specifications by TEPCO, the executor of the decommissioning project, are not necessarily clarified at the time of the commencement of engineering. With this, it is inevitable that the defining performance requirements, and the degree of physical feasibility and performance assurance for the construction method and equipment will be based on trial-and-error. Therefore, the project executor's performance requirements and supply chain's function setting and engineering need to be carried out by iteration[30] to some extent (Fig.27 routes 1 through 3).

For iteration-type engineering, the contract between a project executor and a supply chain is not conventional[31]. Therefore, it is strongly required that TEPCO, as a project executor, “make a judgment on engineering and is responsible for the results.” Therefore, it is required to improve the engineering capability (owner's engineering capability) carried out independently by TEPCO, a project executor as an owner[32], such as the project management capability, the capability to optimize the whole supply chain that should be owned as a project executor, specifically, the capability to make an engineering judgment, the capability to evaluate business risk, the capability to materialize order specifications.

The retrieval of fuel debris is not work to be delivered by guaranteeing the performance of completed products like the design and construction of nuclear power plants. Therefore, the cost will reach astronomical figures unless TEPCO, the project executor, eventually bears the technical and business risks. When the project executor is responsible for the technical risks, they need to

[29] A supply chain advances engineering based on requirement specifications provided by TEPCO, a project executor.
[30] A method of gradually increasing the completeness of engineering by finding the next result based on a certain result and repeating this cycle.
[31] In the conventional construction of nuclear power stations, a supply chain has delivered completed products to a project executor after guaranteeing the performance (Full turnkey contract).
[32] An owner here has three positions of a party responsible for disaster occurrence, a specified nuclear facility licensee, and a facility owner. TEPCO is executing the decommissioning project from these three positions. (A project executor of decommissioning)

have the insight to assess reliability related to the establishment of the function and engineering design, which means that TEPCO is required to improve existing technical skills. The most important thing in Owner's Engineering is to incorporate “safety and operator's perspectives” as upstream as possible in engineering.

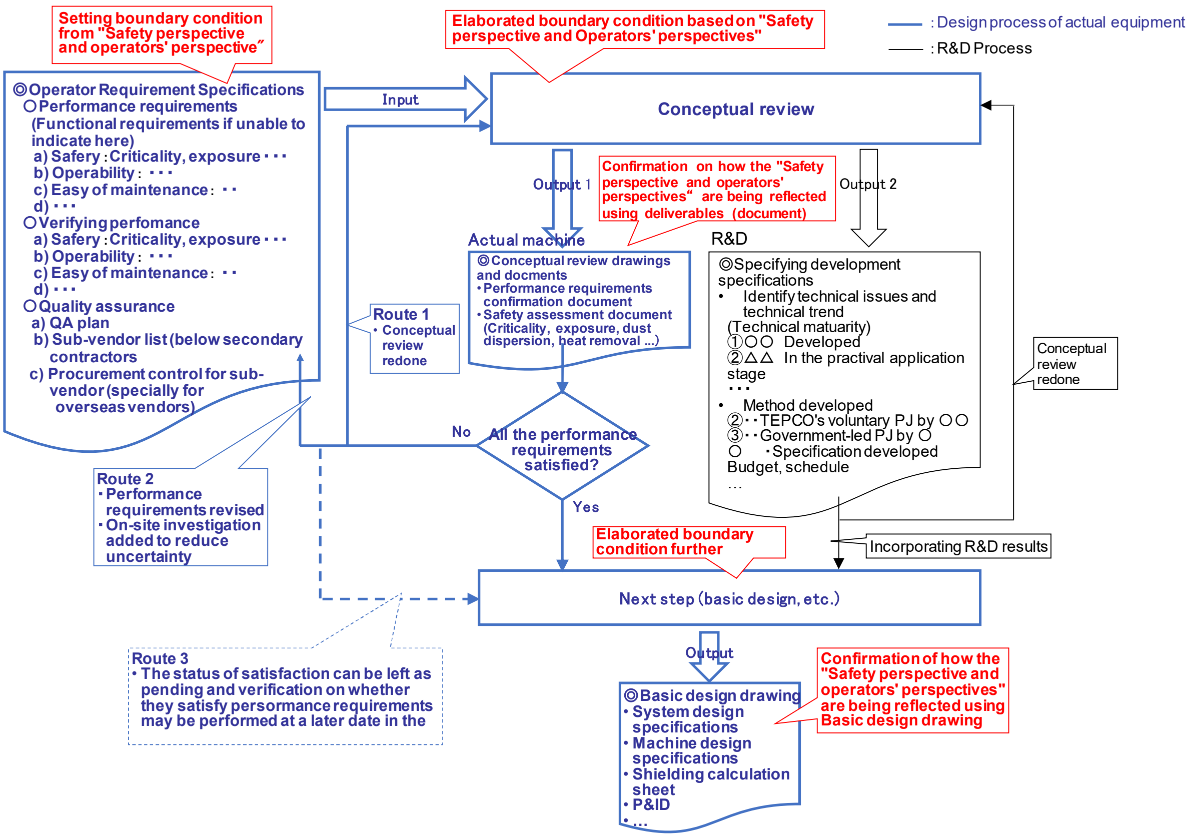


Fig.27 Design flow of fuel debris retrieval (Image)

(3) ALARP judgment based on safety

For safety, there is a minimum level of safety standards that must be met before the relevant construction method or equipment can be used. At levels above the level that meets this minimum level, there is a range of choices and, within this range, construction methods and equipment to be adopted will be determined based on trade-off between the safety level to be achieved and project cost and duration (note that construction method and equipment involving long-term large safety measures are not necessarily beneficial to safety, especially at Fukushima Daiichi NPS), a kind of ALARP[33]. There is also an issue as to whether such construction methods and equipment are feasible in the field.

Based on this, in determining construction methods and equipment, it is important that construction methods and equipment to be adopted in the end will be decided through the cycle of “define the safety standards (safety perspective)”, “indicate the feasibility on-site (operators' perspective)”, and “examine and discuss at project (project management)” as shown in Fig.28. As shown in this figure, the safety perspective and the operator’s perspective are not independent

[33] It is that radiation impact must be as low as reasonably practicable.

from each other. The ALARP judgement made by the project based on the safety perspective will be linked to the decision of the construction method and equipment after going through the feasibility check based on the operator's perspective. The operator's perspective is necessary to actually incorporate the safety perspective into the site, and the judgment based on the safety perspective is needed to utilize the operator's perspective.

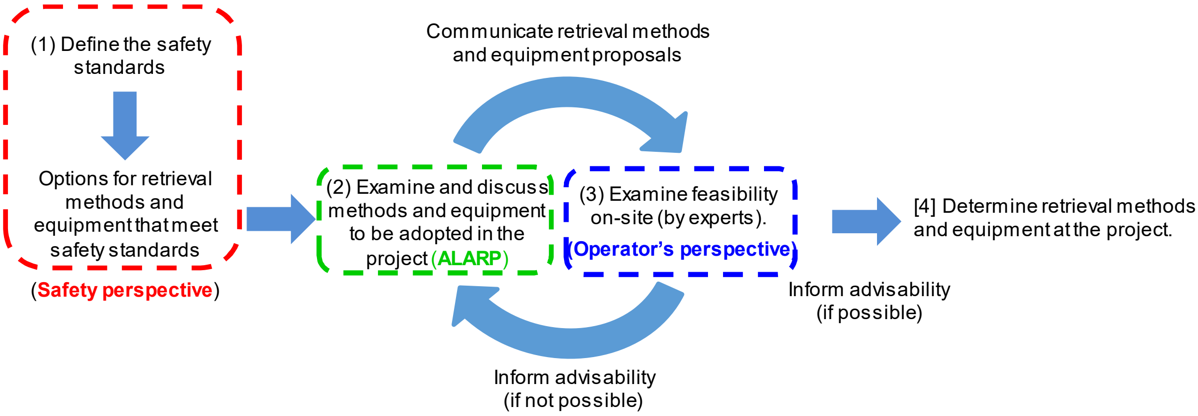


Fig.28 ALARP centered on safety (Image)

5.1.2.4 Developing and securing human resources

(1) Human resources development based on the Mid-and-Long-term Decommissioning Action Plan

Human resources development is indispensable as infrastructure to implement decommissioning project over a long period smoothly. Therefore, it is important to assume occupational categories, the number of engineers and the time to be required in the future (design, operation, maintenance, chemical analysis, safety assessment, radiation control, etc.) in light of the Mid-and-Long-term Decommissioning Action Plan, to summarize them as the medium-to-long term human resources development plan, and to promote human resources development and staff securing systematically. Fuel debris retrieval is the work of remotely handling unsealed radioactive materials, and we have never done this in the operation of power plants before. In particular to such work, we need to consider securing and developing human resources in individual cases through operations at mock-up facilities in Japan and overseas, and actual work of trial retrieval to the retrieval on gradually expanded scale.

In addition, the development of human resources such as engineers and researchers from manufacturers who support the decommissioning project is also a critical issue. It is important to develop human resources with training, such as the decommissioning human resource development course that was planned and executed by NDF in FY 2019 based on the On-the-Job Training (OJT) through the implementation of the decommissioning research, engineering and decommissioning work. (Attachment 15)

(2) Fostering the next generation to handle the decommissioning of the Fukushima Daiichi NPS

In order to continue decommissioning the Fukushima Daiichi NPS for a long period of time and to continue R&D activities for a long period of time, it is essential to train and secure future researchers and engineers. For this purpose, it is important for industrial-academic-governmental institutions relating to nuclear power, as a whole, to steadily promote making efforts.

It is necessary for the industry and educational institutions such as universities to continuously carry out activities to promote understanding of the nuclear industry for students at the higher education level. It is also necessary to convey the idea that the decommissioning of the Fukushima Daiichi NPS is an extremely advanced technical challenge, which is unprecedented in the world, and to establish and demonstrate various career paths for researchers and engineers to thrive.

To be more specific, stable production of researchers and engineers is of paramount importance for the development of human resources that will lead the next generation. From this perspective, a program for a research group consisting of research representatives under the age of 39 has been implemented in the World Intelligence Project. In addition, at the "Conference for R&D Initiative on Nuclear Decommissioning Technology by the Next Generation (NDEC)" a conference for students, and the Creative Robot Contest for Decommissioning for Technical College Students, students present their research results, awards are given to recognize excellent performance, and there is an exchange of views with researchers and engineers involved in the decommissioning of Fukushima Daiichi NPS. Furthermore, NDF holds the "International Mentoring Workshop Joshikai in Fukushima" in cooperation with the Organization for Economic Cooperation and Development and the Nuclear Energy Agency (hereinafter referred to as "OECD/NEA") as an effort to raise awareness of decommissioning, etc., through exchanges with female researchers and engineers for middle and high school girls including Fukushima Prefecture in order to enhance understanding among women and help increasing the motivation to participate in development studies.

It is necessary to further promote and strengthen measures for securing human resources who will lead the next generation, such as children in elementary and secondary education stage, students in the higher education stage including universities or colleges of technology, young researchers and engineers, etc.

5.2 Strengthening international cooperation

5.2.1 Significance and the current status of international cooperation

In recent years, nuclear reactors and nuclear fuel cycle facilities, constructed in the dawn of nuclear power, are coming to the end of operating life and these decommissioning have already been progressing in the world. And, there are three nuclear reactors experienced severe accidents: Windscale Unit 1 in UK (Windscale Pile-1), Three Mile Island Unit 2 in the US (TMI-2), Chernobyl Unit 4 in Ukraine (ChNPP-4). Stabilization and safety measures have been taken in these facilities for a long time. In addition, for past overseas nuclear-related sites (legacy sites), it is expected that there was significant uncertainty in the management of a variety of radioactive substances and it would take a long period for decommissioning and environmental remediation. Despite facing technical difficulty called "unknown unknowns" (things we don't know we don't know), and issues such as longtime project management and securing a large amount of money, each country continues the challenge for overcoming them.

In order to steadily advance decommissioning of the Fukushima Daiichi NPS handling engineering issues with a high level of difficulty, it is important as a risk reduction strategy to learn lessons from examples such as precedent decommissioning activities and utilize them in decommissioning. Also, to maintain and develop continuous understanding/concern and cooperative relations with international society over decommissioning, it is important to return the knowledge, etc., which was obtained through the accident and decommissioning of the Fukushima Daiichi NPS to international society positively and strategically and to promote reciprocal decommissioning open to international society through information dissemination to international society and participation in the international joint activities.

Moreover, the decommissioning of the Fukushima Daiichi NPS is a process to solve unexplored engineering issues combining various fields of knowledge not limited to nuclear field. It can be interpreted as which the decommissioning of Fukushima Daiichi NPS may be an influential ground to create innovation. Assembling diverse wisdom and experiences to Fukushima from all over the world is primary an important effort to steadily proceed with decommissioning itself of Fukushima Daiichi NPS. It is also an important effort from the perspective of that innovation to be created through the decommissioning process leads to the reconstruction of the local industries and to establish the local community engagement that is essential to continue decommissioning over a long period of time.

In international cooperation, it is important to advance bilateral cooperation based on each country's situation and utilize the framework of multilateral cooperation through the IAEA, OECD/NEA, etc. These international organizations have an important role, such as formulating the international standard for decommissioning. It is important to take part in formulating the international standard, etc., based on the experience of decommissioning in Japan for advancing the decommissioning of the Fukushima Daiichi NPS in form open internationally. It is also expected that part of Japan's responsibility to international society is fulfilled since each country shares Japan's experience. From such a viewpoint, based on these matters, NDF is making efforts to provide information on decommissioning through opportunities, such as participation in a side event of the IAEA general meeting and the rostrum in main international conferences, including the OECD/NEA steering committee. (Fig.29) (Attachment 16)

Fig.29 Presenting at a side event of the IAEA General Conference (September 2019)

5.2.2 Key issues and strategies

5.2.2.1 Disseminating information to the international community and participating in international joint activities

We will soon mark ten years since the accident. From the viewpoint of concentrating the wisdom in the world for the decommissioning of the Fukushima Daiichi NPS, since a recipient's concerns, etc., may change a little from the time of the accident, it is important to provide information considering this point even if it is the same information. Specifically, in addition to providing detailed exact information for experts, it is also necessary to provide intelligible information for non-experts or devise appropriately considering recipients' intelligibility concerning the circumstances of the accident.

In addition, in order to gather the wisdom of the world toward decommissioning and to give back the knowledge gained through decommissioning to the international community, it is also important to take part in international joint activities in addition to disseminating information to the international community. In joining in international joint activities, it is necessary to work in such a way as to secure the interests of the international community on the major premise that steady implementation of decommissioning, which is the top priority issue for our country, is ensured. In particular, in terms of the return of results, it is important to strive to maintain the level of interest while responding to changes in the international community, such as growing interest not only in the aspects of accidents and decommissioning itself but also in the aspects of application to other issues.

5.2.2.2 Integrating and utilizing wisdom and knowledge from around the world

Decommissioning of the Fukushima Daiichi NPS is expected to last for a long time, and decommissioning of legacy sites has many technical and operational implications as a leading model. In countries with legacy sites, these activities are mainly promoted by public decommissioning organizations in order to deal with issues, such as the need for expertise, ideas and new technologies that are different from the operation and maintenance of nuclear reactors and nuclear fuel cycle facilities. Therefore, NDF will continuously establish and reinforce long-term partnerships with public institutions related to decommissioning that play a central role in each nation, such as the UK's Nuclear Decommissioning Authority (NDA), Commissariat a l'energie atomique et aux energies alternatives (CEA), United States Department of Energy, Office of Environmental Management (DOE), etc., based on the government-level framework.

Additionally, in regard to decommissioning of the Fukushima Daiichi NPS, wisdom and knowledge from around the world that our country should obtain are 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 aspects but operational aspects. For that reason, with the assistance of the international community, Japan received a variety of support from overseas governmental organizations and experts, such as the DAROD project by the IAEA and the joint project by the OECD/NEA. It is therefore necessary to continue reciprocal relationships while working to return the results through information dissemination to the international community and participation in international joint activities.

Moreover, regardless of whether it is inside or outside the country, decommissioning is implemented under a contract between many companies and the decommissioning operator for which the global market is widely expanding. While the engineering of the Fukushima Daiichi NPS is put into practice, it is important to always keep up the latest situation of world's superior technologies and human resources and effectively exploit them. Therefore, it is necessary to understand the latest global information, including even the private sector situation, make efforts for continuous communication with these private enterprises, and form an environment in which required technology is accessible when required while sharing information on the progress of decommissioning work.

5.3 Local community engagement

5.3.1 Significance and the current status of local community engagement

5.3.1.1 Basic approach

While the residents are returning and reconstruction is progressing gradually in the surrounding area of the Fukushima Daiichi NPS, the confidence from the communities is indispensable to advance decommissioning safely and steadily. Therefore, it is important to listen to uneasiness and questions of the local residents sincerely and make efforts to have them understand and feel ease about the decommissioning work through bidirectional communication of delivering exact information intelligibly and quickly. In addition, to accomplish the long-term decommissioning, it is essential to have continuous cooperation from local businesses and other companies. At the same time, participation of local businesses in the decommissioning project is a crucial pillar for TEPCO to contribute to the reconstruction of Fukushima, because it will revitalize the decommissioning related industry, create jobs and technologies in this area, and spread the results to other regions and industries.

Under the fundamental principle of "coexistence of reconstruction and decommissioning", TEPCO will also cooperate with efforts to realize the "Fukushima Innovation Coast Framework" holding up decommissioning related industry accumulation to the Hamadori region as priority areas and accomplish decommissioning while coexisting with the region.

5.3.1.2 Specific measures under the current situation

The government has been working on careful communication by providing information to and strengthening communication with various people including local residents by holding “The Fukushima Advisory Board” as an occasion to discuss public relations, by dissemination of information through videos, a website, and brochure that summarize the decommissioning status, as well as by active explanations to and conversations with local residents and officials of related municipalities.

NDF holds the “International Forum on the Decommissioning of the Fukushima Daiichi NPS”, that focuses on interactive communication with local residents, provides clear information on the decommissioning, and exchanges honest opinions with the participants, while sharing the latest progress and the technical results of the decommissioning efforts among both Japanese and foreign experts. In addition, NDF makes efforts to gain attention and interest in decommissioning by holding workshops targeted at future generations who are to face decommissioning.

TEPCO is continuously working on explanations and conversations through management and the risk communicators with the local representatives at the “The Fukushima Advisory Board” hosted by government and “Prefectural Safety Assurance Conference for the Decommissioning of the Fukushima Nuclear Power Station” sponsored by Fukushima Prefecture, and so on. The company is also working to provide timely and accurate information on the status of decommissioning through nuclear power regular press conferences, regular lectures at the Fukushima Prefectural Government Press Club, and meetings they attend, while trying to provide easy-to-understand information through public relations tools, such as websites and information magazines.

In formulating a common understanding of decommissioning, it is also very effective to have people observe the real state of progress of the decommissioning tasks on the site. TEPCO has been proactively accepting visitors to the Fukushima Daiichi NPS, including evacuees, and 18,238 visitors were accepted in FY 2019, although there were impacts of typhoons and covid-19. In addition, the “TEPCO Decommissioning Archive Center” was built in Tomioka-machi as a place to learn about the nuclear power plant accident and the progress of decommissioning work and, as of the end of August in 2020, about 60,000 people have visited.

Last fiscal year, while obtaining the Fukushima Innovation Coast Framework Promotion Organization's cooperation, TEPCO held a decommissioning project matching event for local businesses. Also, at the end of March 2020, it formulated the “commitment to Fukushima residents for the coexistence of reconstruction and decommissioning” (hereinafter referred to as "Commitment") summarizing the efforts, such as the participation of local businesses in decommissioning project, the attraction of companies outside the area, support for local companies toward human resources development and cooperation with universities, etc. It re-expressed the determination to fully address decommissioning project as a member of the community.

Moreover, for the purpose of strengthening a structure for local engagement, TEPCO established Promotion of Partnership with local communities Group under the Fukushima Daiichi Decontamination and Decommissioning Engineering Company in April 2020, as well as Hama-dori Decommissioning Industry Project Office under the direct control of the president in October 2020.

To undertake the efforts of the "Commitment," TEPCO has set up a joint consultation counter for local companies who are interested in participating in the decommissioning project in cooperation with the Fukushima Innovation Coast Framework Promotion Organization and the Fukushima So-So (Soma and Futaba regions) Reconstruction Promotion Agency, and is preparing to hold business fairs between the prime contractor and local companies. To provide support to help local companies participate in the projects, TEPCO subdivided the medium-to-long-term outlook in the decommissioning project as well as the detail, timing and scale of the project orders to be placed as much as possible, and formulated "Medium-to-long-term outlook in the decommissioning" that specifically states equipment or technology required for each project in September 2020. Now, TEPCO is explaining the outlook to the prime contractor and the local governments and association of commerce and industry.

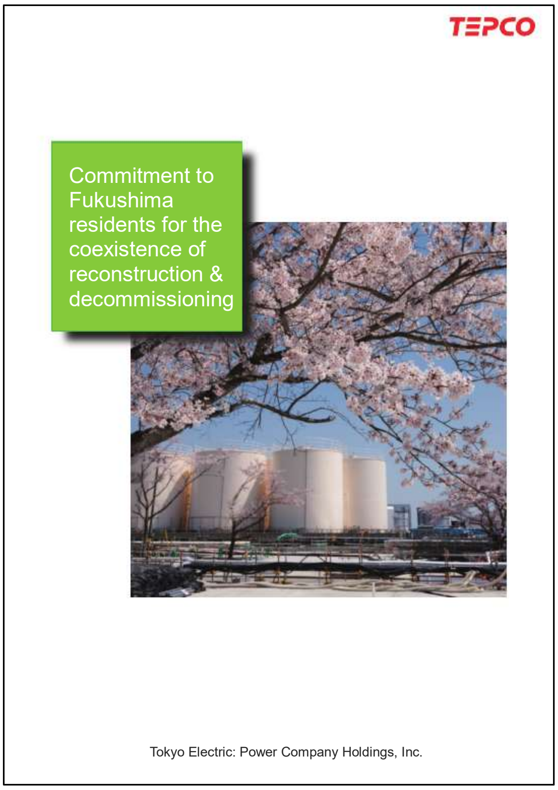
5.3.2 Key issues and strategies

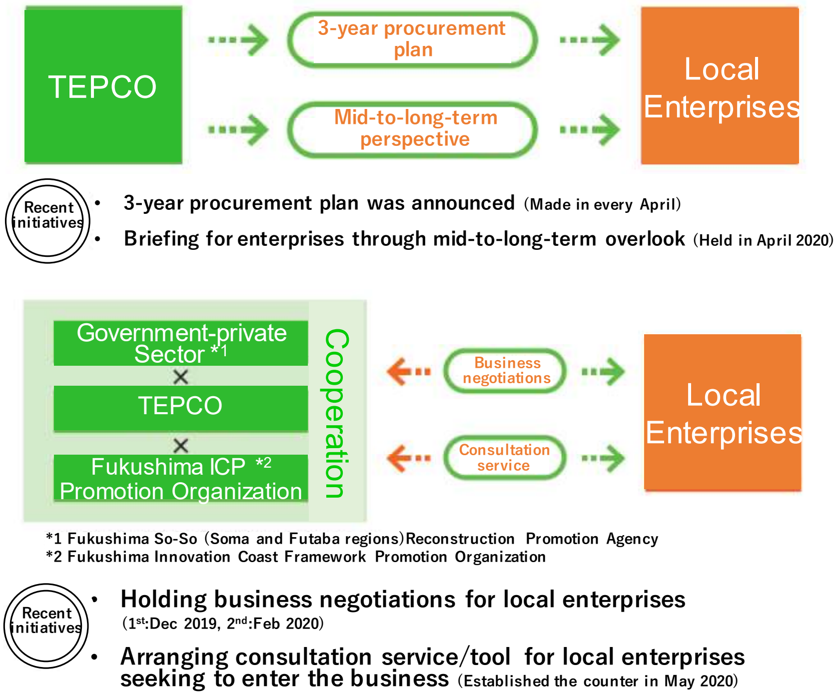
Misunderstanding, concern, and rumors are caused by inappropriate information transmission about decommissioning, which ruins appreciation and confidence in the decommissioning project of the regions and the whole society and leads to the delay of decommissioning. Therefore, TEPCO needs to utilize various tools, such as informational magazines, WEB sites, and motion videos, in addition to the visit of the Fukushima Daiichi NPS and the decommissioning museum (Tomioka-cho), and inform as to the present situation and progress status of decommissioning intelligibly and quickly.

Also, the government, NDF, and the TEPCO, under suitable cooperation, need to provide information more carefully and make efforts to build confidence with regions. Therefore, we need to positively arrange an opportunity to communicate directly with the people in regions. We also need to make efforts for bidirectional communication by dialog, such as listening to uneasiness and questions of the participants sincerely through the events of the International Forum on the Decommissioning of the Fukushima Daiichi NPS, etc., held by NDF, and deliver exact information intelligibly and quickly.

TEPCO must not end this "Commitment" just as a shape, but secure effectiveness. Therefore, the specialized department working on community symbiosis plays a key role to update and add the detail of "Medium-to-long-term outlook in the decommissioning project" as required with the progress of the decommissioning project. In addition, they will positively provide coordination with the local communities by carefully explaining it continuously via the local governments or the association of commerce and industry through dedicated joint consultation centers and business fairs targeting local companies. (Fig.30). TEPCO itself is providing support to local companies to enhance their technical capabilities, while inviting companies from outside the region to do business with them. In addition, TEPCO establishes a system where the local companies are encouraged to offer technical guidance to the primary contractors and, if certain results are achieved, incentives are to be given. Efforts are being made to build a foundation for the local economy and foster local businesses and human resources through the decommissioning project. Furthermore, not only the research and development on decommissioning, but as companies outside the region expand their businesses in the area and technical support to local companies progresses, it is expected that the number of engineers and researchers visiting and staying from outside the region will increase. It is required to develop the necessary environment and support so that such external human resources can fit into the regional society and play an active role as a member of the local community. As for the environmental improvement, in particular, it is necessary to consider a wide range of living functions and educational functions so that their whole family can stay with peace in mind.

For carrying out the work of community symbioses, it is also required to strengthen organizations if needed since close cooperation is required between each department. In addition, NDF needs to continue and strengthen cooperation and collaboration with local governments, including Fukushima prefecture, the Fukushima Innovation Coast Framework Promotion Organization, and the Fukushima So-So (Soma and Futaba regions) Reconstruction Promotion Agency, etc. NDF will support TEPCO's community symbiosis efforts and work on cooperation strengthening with local governments and related organizations.





(TEPCO material edited by NDF)

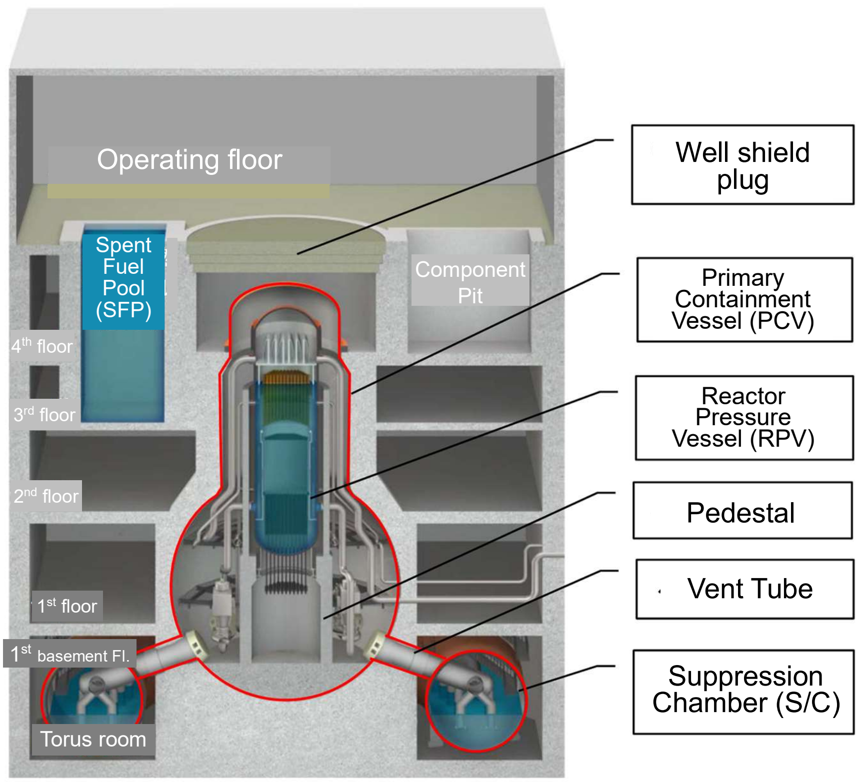
Fig.30 Example of commitment to Fukushima residents for the coexistence of reconstruction and decommissioning

List of Acronyms/Glossaries

Acronym	Official Name
CEA	Commissariat à l'énergie atomique et aux énergies alternatives
D/W	Dry Well
DOE	United States Department of Energy
FP	Fission Products
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
IRID	International Research Institute for Nuclear Decommissioning
JAEA	Japan Atomic Energy Agency
JAEA/CLADS	JAEA Collaborative Laboratories for Advanced Decommissioning Science
MCCI	Molten Core Concrete Interaction
NDA	Nuclear Decommissioning Authority
NDF	Nuclear Damage Compensation and Decommissioning Facilitation Corporation
OECD/NEA	OECD Nuclear Energy Agency
PCV	Primary Containment Vessel
RPV	Reactor Pressure Vessel
S/C	Suppression Chamber
SED	Safety and Environmental Detriment
TMI-2	Three Mile Island Nuclear Power Plant Unit 2
Penetration X-6	Penetration PCV X-6
Center of the World Intelligence project	The project that promotes nuclear science and technology and human resource development gathering wisdom and knowledge
Operating Floor	Operating Floor of the buildings
Submersible ROV	A remotely operated submersible survey vehicle (Remotely Operated Vehicle)
Strategic Plan	Technical Strategic Plan for Decommissioning of the Fukushima Daiichi Nuclear Power Station of Tokyo Electric Power Company Holdings, Inc.
Matters to be addressed	As a specific nuclear facility, “the matters for which measures should be taken” that The Fukushima Daiichi NPS must have the necessary safety measures in place that are required by the NRA.
Mid-and-Long-term Roadmap	Government-developed “Mid-and-long-term Roadmap” toward the decommissioning of TEPCO’s Fukushima Daiichi Nuclear Power Station Units 1 to 4
TEPCO	Tokyo Electric Company Holdings, Inc.
Withdrawal Plan	Withdrawal plan for reserve fund
The Policy of Preparation of Withdrawal Plan	The Policy of preparation of withdrawal plan for reserve fund for decommissioning

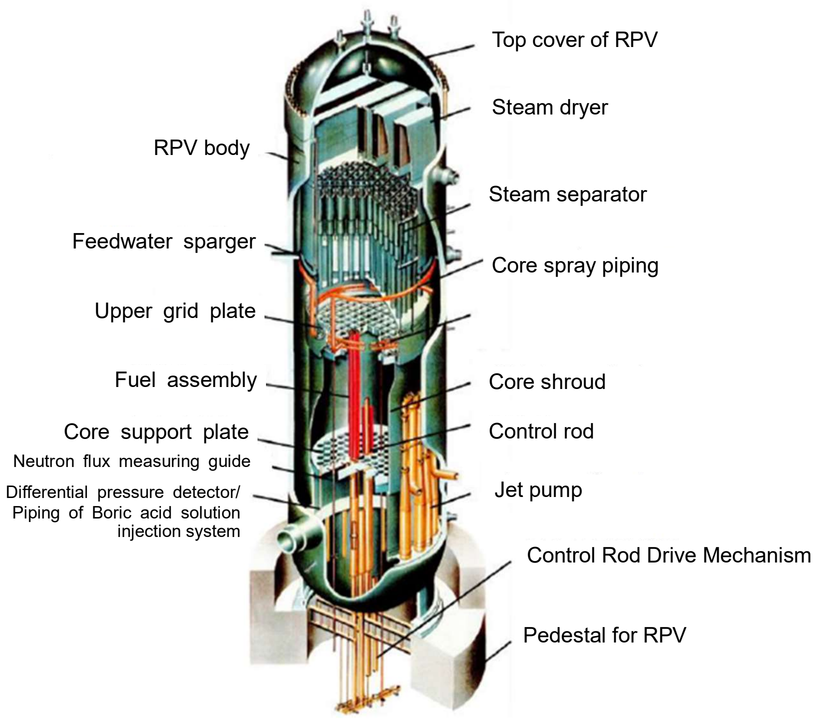
Fukushima Daiichi NPS	Fukushima Daiichi Nuclear Power Station of Tokyo Electric Company Holdings, Inc.
ALARP	As Low As Reasonably Practicable：Risk should be reduced as far as reasonably practicable including risk/benefit criteria or cost while taking feasibility of risk reduction measures into account.
ALARA	As Low As Reasonably Achievable：The principle of radiological protection in which it advocates that all radiation exposure must be maintained as low as reasonably achievable in consideration of social and economic factors.

Glossary	Description
CRD housing	Housing that contains Control Rod Drive mechanism
MCCI Product	A product generated by high temperature molten core and concrete interaction (MCCI)
T.P.	A height from the average surface of the bay of Tokyo (Tokyo Peil) as a standard of elevation. (cf. O.P: Onahama Port construction level (the lowest position of the water surface)
Well plug	A top cover to screen upper part of Primary Containment Vessel made of concrete (It is the floor face of the top floor of reactor building in operation)
Basis seismic ground motion	A magnitude of shake associated with earthquake that may affect greatly to nuclear facilities. Based on the latest scientific and engineering knowledge, it is provided in accordance with the geological structure or ground structure, etc.
Submersion method	A method to retrieve fuel debris by submerging all fuel debris in watering up to upper part of Primary Containment Vessel
Partial submersion method	A method to retrieve fuel debris in a state that a part of fuel debris is exposed in the air without watering
Grating	A lattice-type scaffolding used for side ditch lid or work scaffold
Sludge	Muddy substance, dirty mud
Slurry	A mix of dirty mud and mineral, etc. in water
Fuel debris	Nuclear fuel material molten and mixed with a part of structure inside reactor and re-solidified due to loss of reactor coolant accident condition
Platform	Footing for work installed under RPV inside pedestal
Pedestal	A cylindrical basement that supports a body of reactor
Measurement by muon (fuel debris detection technology with muon)	A technology to grasp location or shape of fuel in using characteristics by change of number or track of particle depending on the difference of density, when muons (muonic atoms) arrive from the cosmos and atmospheric air and pass through a substance
Mock-up debris	An artificial fuel debris, its chemical composition and chemical form were estimated based on the case of Unit 2 of Three mile Island Nuclear Power Plant accident
Mock-up	A model which is designed and created as close to real thing to possible



（Courtesy of IRID）

Fig. 31 Structural drawing inside Reactor building



（Courtesy of IRID）

Fig. 32 Structural drawing inside Reactor Pressure Vessel (RPV)

List of Attachment

Attachment 1 Revision of the Mid-and-Long-term Roadmap and the earlier published Strategic Plan

[1st Edition of the Mid-and-Long-term Roadmap (December 21, 2011)]

- In response to completion of Step 2 described in "the Roadmap towards Restoration from the Accident at the Fukushima Daiichi NPS" compiled by the government and Tokyo Electric Power Company (TEPCO) after the accident, the necessary measures to be progressed over the mid-and-long-term, including efforts to maintain securely stable conditions, fuel removal from spent fuel pools, fuel debris retrieval, etc. were compiled by three parties of TEPCO, Agency for Natural Resources and Energy, and Nuclear and Industrial Safety Agency and conclude at The Government and TEPCO's Mid-to-Long-Term Countermeasure Meeting.
- Basic principles towards implementation of mid-to-long efforts were proposed and targets with time schedules were established by dividing the period up to completion of decommissioning into three parts; the period up to spent fuel removal start (1st period), the period up to fuel debris retrieval start from completion of the 1st period (2nd period) and the period up to completion of decommissioning from completion of the 2nd period (3rd period).

[Mid-and-Long-term Roadmap Revised 1st Edition (July 30, 2012)]

- "Specific plan on the matters to be addressed with priority to enhance mid-and-long-term reliability" developed by TEPCO after completion of Step 2 was reflected and revised targets based on the state of work progress were clearly defined.

[Mid-and-Long-term Roadmap Revised 2nd Edition (June 27, 2013)]

- Revised schedule was studied (multiple plans were proposed) based on the situation of each Unit concerning fuel removal from the spent fuel pool and fuel debris retrieval, and R&D Plan was reviewed based on the above.

[Strategic Plan 2015 (April 30, 2015)]

- The 1st edition of the Strategic Plan was published to provide a verified technological basis to the Mid-and-Long-term Roadmap from the viewpoint of proper and steady implementation of decommissioning of the Fukushima Daiichi Nuclear Power Station.
  (NDF was inaugurated on August 18, 2014 in response to reorganization of existing Nuclear Damage Compensation Facilitation Corporation)
- Decommissioning of the Fukushima Daiichi Nuclear Power Station was regarded as "Continuous risk reduction activities to protect human beings and environment from risks caused by radioactive materials generated by the severe accident", and Five Guiding Principles (Safe, Reliable, Efficient, Prompt, Field-oriented) for risk reduction were proposed.
- Concerning the field of fuel debris retrieval, feasible scenarios were studied by regarding the following methods as the ones to be studied selectively; the submersion-top entry method, the partial submersion-top entry method, and the partial submersion-side entry method.
- Concerning the field of waste management, policies for storage, control, etc. were studied from a mid-and-long-term viewpoint based on the basic concept for ensure safety during disposal or for a proper treatment method.

[Mid-and-Long-term Roadmap Revised 3rd Edition (June 12, 2015)]

- While much importance was placed on risk reduction, priority-setting for actions was performed so that risks could definitely be reduced in the long term.
- Targets for several years from now were concretely established including policy decision on fuel debris retrieval (two years later from now was targeted), reduction of amount of radioactive materials contained in the stagnant water in the buildings by half (FY2018), etc.

[Strategic Plan 2016 (July 13, 2016)]

- In response to the progress state of decommissioning after publication of the Strategic Plan 2015, concrete concepts and methods were developed based on the concept and direction of the efforts of the Strategic

Plan 2015 to achieve the target schedule specified in “Policy decision on fuel debris retrieval for each unit” which is expected to be completed by about summer 2017 defined in the Mid-and-Long-term Roadmap, “Compiling of the basic concept concerning processing/disposal of radioactive waste” which is expected to be complete in FY2017, etc.

[Strategic Plan 2017 (August 31, 2017)]

- Feasibility study was conducted on the three priority methods for fuel debris retrieval. Recommendations for determining fuel debris retrieval policy were made and efforts after policy decision including preliminary engineering were recommended as strategic recommendations.
- Recommendations were made for compiling the basic concept concerning solid waste processing/disposal.

[Mid-and-Long-term Roadmap Revised 4th Edition (September 26, 2017)]

- Policy on fuel debris retrieval and immediate efforts were decided based on NDF technical recommendations.
- Basic concepts concerning solid waste processing/disposal were compiled.
- Individual work was defined based on the viewpoint of “Optimization of total decommissioning work”.

[Strategic Plan 2018 (October 2, 2018)]

- The Plan added contaminated water management and fuel removal from SFP, and presented the direction from mid-to-long-term perspective that overlooks entire efforts of decommissioning of Fukushima Daiichi NPS.

[Strategic Plan 2019 (September 9, 2019)]

- The plan presented the strategic recommendation for determining fuel debris retrieval methods for the first implementing unit as well as the direction from mid-to long-term perspective that overlooks entire efforts of decommissioning of Fukushima Daiichi NPS including waste management, etc.

[Mid-and-Long-term Roadmap Revised 5th Edition (December 27, 2019)]

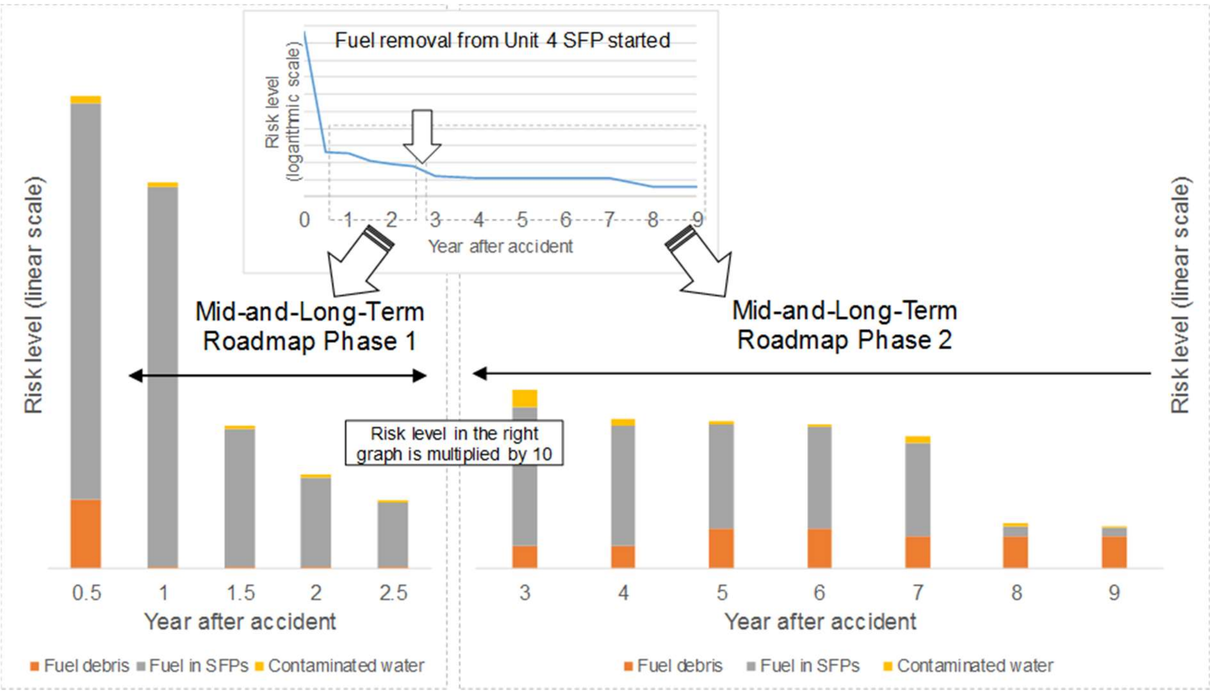
- The first implementing unit and the method of fuel debris retrieval were determined.
- The methods of fuel removal from SFP in Units 1 and 2 were changed.
- TEPCO maintains the current target to suppress the amount of contaminated water generation to about 150m3/day within 2020, in addition, set the new target to less than 100m3/day within 2025.

Attachment 2　Major risk reduction measures performed to date and future course of action

Change in the risk level over time assessed and expressed by SED for the entire Fukushima Daiichi NPS is shown in Fig. A 2-1. The vertical axis in the top graph in the figure shows the risk level in common logarithmic scale and the horizontal axis shows number of years after the accident.

Although the risk level at the time of zero year after the accident was at high level caused by the fuel in SFP which lost its cooling function and the molten nuclear fuel, over the time of 0.5 years after the accident the risk level has been reduced with a significant decrease in both Hazard Potential and Safety Management, because of implementation of safety measures including cooling function restoration of the spent fuel pools, cooling of fuel debris with water injection by core spray system, nitrogen injection, etc. (in 2011) as well as the contribution of inventory and decay heat decrease due to decay of radioactive materials.

The risk level in 0.5 to 2.5 years after the accident is shown in the enlarged graph (the vertical axis is in linear scale) with the breakdown of major risk source (fuel debris, fuel in SFP and contaminated water) at the bottom left in the figure and the similar graph since 3 years after the accident is given in the bottom right with the risk level multiplied by 10. These graphs demonstrate that a continuous risk reduction has been achieved.



Evaluation of fuel in SFP 8 years after the accident occurred reflects the results of water temperature rise in the testing on SFP cooling shutdown. (For detail, see Fig. 3 in Chapter 2 of main part.)

Fig. A 2-1 Reduction of risks contained in the Fukushima Daiichi NPS

Change in the risk level with further breakdown of major risk sources over time since 0.5 years after the accident is shown in Fig. A 2-2. With a logarithmic scale, risk sources can be indicated that are too small to be displayed in the linear scale of Fig. A 2-1. Fuel in the Common Spent Fuel

Storage Pool and the Dry Cask Temporary Custody Facility are not shown which stay in the region of sufficiently stable management. The “stagnant water in buildings + zeolite sandbags” shown in Fig. A 2-2 was assessed based on the information on the stagnant water in buildings for the period of 0-8 years after the accident. However, since 9 years after the accident, the condition of zeolite-containing sandbags placed in the basement of the process main building and the high-temperature incinerator building has become clear, and this information was incorporated into the assessment.

Among the major risk sources, fuel debris, fuel in SFPs, and the stagnant water in buildings and zeolite-containing sandbags have relatively high risk levels. Although, in recent years, the treatment of the stagnant water in buildings has progressed and the risk level of the “stagnant water in buildings + zeolite sandbags” has been on a declining trend, attention should be paid to zeolite sandbags laid with a high dose because they may hinder future decommissioning work. In addition, as for the water stored in tanks (flange-type tank and welded tank), the risk of leakage and consequently the risk level has been greatly reduced as a whole because the treatment of the water stored in the flange-type tanks, which have a higher risk of leakage than welded tanks, has proceeded well.

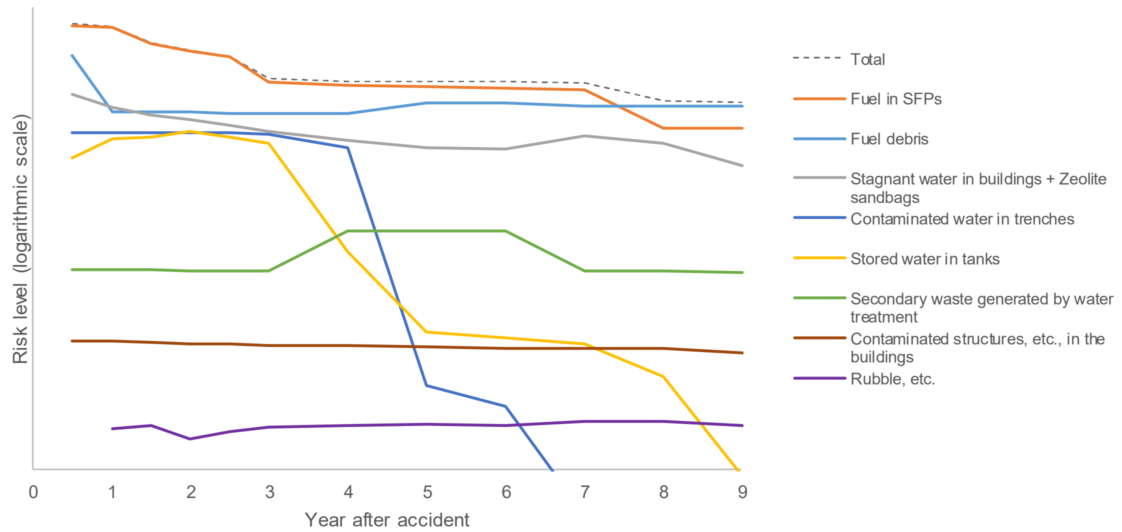


Fig. A 2-2 Change in the risk level for each major risk source

(1) Fuel in SFPs

From one year after the accident, rubble was removed and a cover for fuel removal was installed at Unit 4 in preparation for fuel removal, thereby enhancing the functions of reducing the risk of fuel damage by rubble in SFP and controlling the dispersion of damaged fuel. Further, 2.5 years after the accident, fuel removal was started and the fuel was transferred into the Common Spent Fuel Storage Pool with low Safety Management, and the risk level was lowered (completed in 2014)[34].

[34] Decommissioning project, Status of the decommissioning work, Fuel removal work of Unit 4, (Website), Tokyo Electric Power Company Holdings, Inc.

Although the effect of risk level reduction was observed due to the downgrading of Safety Management through the diffusion control function of the building cover at Unit 1 (installed in 2011), this effect has been currently lost because the building cover was removed (in 2015) in preparation for removal of fuel in SFPs[35].

In Unit 3, rubble removal was also performed in preparation for fuel removal from SFP, and the cover for fuel removal was installed in 2018. Moreover, fuel removal from SFP was started from April 2019, resulting in lowering of risk level[36].

In case cooling fuel in SFPs is stopped, the pool water temperature may rise and the pool water level may lower due to decay heat. In and after the 8th year after the accident, as a result of incorporating the observation that the rise in water temperature after cooling shutdown of SFPs was slower than expected, the risk level of fuel in SFPs is lower than previously estimated, because the time margin before the risk of water level lowering becomes apparent increases.

(2) Fuel debris

Although fuel debris was at a high risk level just after the accident because it was at molten state, and in addition, radioactive materials were released, the risk level was reduced, not only by decay of the radioactive materials, but also by reduction of Hazard Potential and Safety Management because of restoration and strengthening of cooling function.

As described above, the diffusion control function of the building cover of Unit 1 reduced the risk associated with the dispersion of fuel debris, and lowered the risk level due to downgrading of Safety Management; however, this effect is currently lost.

(3) Stagnant water in buildings + Zeolite sandbags

Although stagnant water in buildings is generated by cooling of fuel debris and immersion of groundwater into the buildings, etc., the risk level has been lowered due to the start of operation of cesium adsorption apparatus (KURION and SARRY), the effect of subdrains and land-side impermeable walls, water drainage in condensers, and the start of the operation of cesium adsorption apparatus (SARRY-II). This stagnant water treatment in the buildings so far significantly contributes to risk level reduction of the total site following contribution by fuel removal in SFP.

(4) Contaminated water in trenches

Although the contaminated water of high concentration has been stagnated in the seawater pipe trenches in Units 2 to 4 since immediately after the accident, the trenches were blocked and the treatment of the stagnant water has been completed (in 2015)[37]. With regard to the seawater pipe

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35 Decommissioning project, Status of the decommissioning work, Fuel removal from spent fuel pool in Unit 1, (Website), Tokyo Electric Power Company Holdings, Inc.

36 Decommissioning project, Status of the decommissioning work, Fuel removal from spent fuel pool in Unit 3, (Website), Tokyo Electric Power Company Holdings, Inc.

37 Decommissioning project, Status of the decommissioning work, Removal of contaminated water in seawater pipe trenches, (Website), Tokyo Electric Power Company Holdings, Inc.

trench of Unit 1, the concentration of which is lower than that of Units 2 to 4, purification of the stagnant water is under consideration[38].

(5) Stored water in tanks

In each tank, there are several types of stored water with different radioactive material concentration. Although the concentrated liquid waste generated by the operation of the evaporation-enrichment system immediately after the accident had a high concentration of radioactive materials, the evaporation-enrichment system stopped after a short period of operation and concentrated liquid waste is not generated at present. In addition, the concentrated liquid waste slurry is separated from the concentrated liquid waste and transferred to the secondary waste generated by water treatment, and the remaining concentrated waste fluid is transferred to a safer welded tank and its inventory is decreased, thereby reducing the risk of water leakage and lowering the risk level.

The treatment of the concentrated salt water generated from the treatment with the cesium adsorption apparatus was completed in 2015 through the operation of multi-nuclide removal equipment and the advanced multi-nuclide removal equipment[39].

Risk levels are also lowered by raising and duplexing the weir (for the existing tanks completed in 2014), transferring from flange-type tanks to welded tanks, and treating the remaining water at the bottom of the flange-type tanks where the Sr-treated water is stored (in 2019). The remaining water at the bottom of other flange-type tanks is being treated for dismantling the tanks.

(6) Secondary waste generated by water treatment

Many radioactive materials have moved from contaminated water to secondary waste through water treatment. What has been generated includes the sludge from decontamination device, the waste adsorption vessel by operation of the cesium adsorption apparatus (KURION and SARRY) (in 2011) and by the cesium adsorption apparatus (SARRY-II) (in 2019), HIC slurry by operation of the multi-nuclide removal equipment (in 2013), the waste adsorption vessel by the advanced multi-nuclide removal equipment (in 2014), waste adsorption vessel by the mobile-type treatment system that treated seawater pipe trenches, etc. Although the sludge from decontamination device greatly contributes to the risk level, sludge is not newly generated at present, and thus, the risk level of the total secondary waste generated by water treatment is not on an increasing trend.

Although the concentrated liquid waste slurry separated from the concentrated liquid waste was stored in horizontal welded tanks without the weir and placed on the ground without the base, its risk level has been lowered due to the approach to safety taken by installing the reinforced-concrete base and the weir.

(7) Contaminated structures, etc., in the buildings

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[38] The 82nd Study Group on Monitoring and Assessment of Specified Nuclear Facilities "Reference 3: Roadmap for Instruction Items to be Considered Based on the Measures for Mid-term Risk Reduction at TEPCO's Fukushima Daiichi NPS at TEPCO (Risk Map), (March 2020 Edition)"

[39] Decommissioning project, Status of the decommissioning work, Purification of contaminated water, (Website), Tokyo Electric Power Company Holdings, Inc.

There is no significant change at the present moment in the risk level of contaminated structures, etc. in the buildings comprised of structures, piping, components, etc. in the reactor buildings, PCVs or RPVs that are contaminated by dispersed radioactive materials caused by the accident since fuel debris retrieval is not started yet.

(8) Rubble, etc.

Rubbles, etc. as solid waste are stored under a variety of conditions such as in solid waste storage, in temporary waste storage and by outdoor accumulation. Each has different Safety Management, and the rubbles stored in outdoor sheet covered storage and outdoor accumulation are of the highest risk level. In the past, the facilities with better management condition have been enhanced by soil covered temporary storage facilities (in 2012), fallen tree temporary storage pool (in 2013), expansion of solid waste storage facilities (in 2018), etc. In addition, the rubble from temporary storage facilities is being transferred to the better-controlled solid waste storage facility for risk reduction. Furthermore, outdoor temporary storage is planned to be discontinued by the end of FY 2028 by increasing incinerators, volume reduction installations and solid waste storages, etc., in accordance with the Solid Waste Storage Management Plan[40].

[40] The Solid Waste Storage Management Plan at the Fukushima Daiichi NPS (July 2020 Edition), Tokyo Electric Power Company Holdings, Inc.

Attachment 3 Overview of SED indicator

Risk analysis targeting various risk sources, which have diverse characteristics and exist all over the site, was conducted in reference to the SED indicator[41] developed by the NDA. The SED indicator is an important factor to decide priority to implement risk reduction measures. It was partially modified (refer to the following pages) so that unique characteristics of the Fukushima Daiichi NPS could be easily reflected when it was applied to the Fukushima Daiichi NPS. Overview of the SED indicator and the modified part to be applied to the Fukushima Daiichi NPS are described below.

The SED indicator is expressed by the following formula. The first formula is the one widely used for waste assessment and the second is for contaminated soil assessment. In each formula, the first term is referred as to "Hazard Potential" and the second as "Safety Management" of risk sources.

$$SED = (RHP + CHP) \times (FD \times WUD)^4$$

or

$$SED = (RHP + CHP) \times (SSR \times BER \times CU)^4$$

Each indicator is explained below. Although CHP stands for "Hazard Potential" of the chemical substance, details are not given here as it is not used in this section.

(1) Hazard Potential

Radiological Hazard Potential (RHP) is an indicator representing the potential impact of radioactive materials and represents the impact to the public by the following formula when the total amount of radioactive materials is released.

$$RHP = Inventory \times \frac{Form\ \ Factor}{Control\ \ Factor}$$

Inventory is defined as shown below by Radioactivity of risk sources and the Specific Toxic Potential (STP) and corresponds to the effective radiation dose[42]. The STP is defined as the volume of water required to dilute 1TBq of radioactive materials and corresponds to the radiation dose coefficient. Ingestion of a certain amount of such diluted water throughout the year will result in a radiation exposure dose of 1mSv. The SED indicator conservatively uses the larger radiation dose coefficient between ingestion and inhalation.

$$Inventory(m^3) = Radioactivity(TBq) \times STP(m^3/TBq)$$

Form Factor (FF), as shown in Table A3-1, is an indicator representing how much radioactive material is actually released depending on material form, such as gas, liquid, solid, etc. The

[41] NDA Prioritization – Calculation of Safety and Environmental Detriment score, EPGR02 Rev.6, April 2011.
[42] Instruction for the calculation of the Radiological Hazard Potential, EGPR02-WI01 Rev.3, March 2010.

indicator is set assuming that 100% of radioactive material is released in the case of gas and liquid when containment function is totally lost and that 10% of radioactive material is released in the case of powder based on the measurement data. Because of no clear basis, the indicator in case of solid is set to a sufficiently small value assuming that the solid materials are less easily released.

In Table A3-1, several expected forms, especially for fuel debris, are added to the definition used by the NDA. The scores for the form of No.4 and No.5 are newly established.

Control Factor (CF), as shown in Table A3-2, is an indicator representing time allowance available before restoration when safety functions maintaining current stable state are lost. CF is taking into account exothermicity, corrosivity, flammability, hydrogen generation, reactivity with air or water, criticality, etc. which are typical characteristics of risk sources. CF is the same as the one defined by the NDA.

(2) Safety Management – FD and WUD

Facility Descriptor (FD) is an indicator representing whether containment function of the facility is sufficient or not. Risk sources are ranked by score based on a combination of the factors including integrity of the facility, redundancy of containment function, safety measure condition, etc.

Waste Uncertainty Descriptor (WUD) is an indicator representing whether any impact is generated or not when the risk source removal is delayed. Risk sources are ranked by score based on a combination of the factors including degradation or activity of the risk source, packaging state, monitoring condition, etc.

As these indicators are difficult to be applied to the Fukushima Daiichi NPS if they are used as defined by the NDA, they are re-defined as shown in Table A3-3 and Table A3-4 respectively.

(3) Safety Management - SSR, BER and CU

The definition of SSR, BER and CU used for Safety Management assessment for contaminated soil is the same as the one defined by the NDA and each score is shown in Table A3-5.

Speed to Significant Risk (SSR) is an indicator concerning the time until the public is affected through such as distance to the site boundary, groundwater flow conditions, etc. and to assess urgency of taking measures.

Benefit of Early Remediation (BER) is an indicator to assess benefits obtained from early implementation of measures against risks.

Characterization Uncertainty (CU) is an indicator to assess reliability or uncertainty in the risk assessment model.

Table A3-1 Definition and score of FF

No.	Form	FF
1	Gas, liquid, watery sludge* and aggregated particles*	1
2	Other sludge	1/10 = 0.1
3	Powder and removable contaminants (surface contamination, etc.)*	1/10 = 0.1
4	Adhesive* or penetrating contaminants (surface penetrating contamination)*	1/100 = 0.01
5	Fragile and easily decomposable solid (porous MCCI (Molten Core Concrete Interaction), etc.)*	1/10,000 = 1E-4
6	Discrete solid (transportable size and weight by human power such as pellets, etc.)	1/100,000 = 1E-5
7	Large monolithic solid, activated component	1/1,000,000 = 1E-6

* : Form which is added to the NDA definition to enhance applicability to the case of the Fukushima Daiichi NPS

Table A3-2 Definition and score of CF

No.	Time allowance available before any risk is realized	CF
1	Hours	1
2	Days	10
3	Weeks	100
4	Months	1,000
5	Years	10,000
6	Decades	100,000

Table A3-3 Criteria and score of FD

Category	Criteria (NDA definition is modified to enhance applicability to the case of the Fukushima Daiichi NPS)	NDF Score
1	No component for diffusion control function exists. Therefore, no assessment for containment function is available.	100
2	“Safety assessment criteria*2” are not satisfied at “the time of assessment*1” caused by the accident effects, etc. The component for diffusion control function is single.	91
3	“Safety assessment criteria” are not satisfied at “the time of assessment” caused by the accident effects, etc. The component for diffusion control function is multiple.	74
4	“Safety assessment criteria” are not satisfied until “the time of work (such as transfer, treatment, recovery, etc.) *3” for the risk source contained in the component for diffusion control function. The component or diffusion control function satisfying “safety assessment criteria” exists at “the time of assessment”.	52

5	Integrity of diffusion control function has been assessed and "safety assessment criteria" are satisfied until "the time of work (such as transfer, treatment, recovery, etc.)" for the risk source. Frequency of occurrence of "contingency*4" is high, and when contingency occurs countermeasures preventing diffusion of the risk source contained in the component are not sufficient. The component for diffusion control function is single.	29
6	"Safety assessment criteria" is satisfied until "the time of work (such as transfer, treatment, recovery, etc.)" for the risk source. Frequency of occurrence of "contingency" is high, and countermeasures preventing diffusion of the risk source contained in the component are not sufficient. The component for diffusion control function is multiple.	15
7	"Safety assessment criteria" are satisfied until "the time of work (such as transfer, treatment, recovery, etc.)" for the risk source. Facilities dissatisfying "safety assessment criteria" exist in the surrounding area, and the potentiality is high to make (receive) the diffusion impact*5 of the risk source to (from) these adjacent facilities. The component for diffusion control function is single.	8
8	"Safety assessment criteria" are satisfied until "the time of work (such as transfer, treatment, recovery, etc.)" for the risk source. The potentiality is high to make (receive) the diffusion impact of the risk source to (from) these adjacent facilities. The component for diffusion control function is multiple.	5
9	"Safety assessment criteria" are satisfied until "the time of work (such as transfer, treatment, recovery, etc.)" for the risk source. The potentiality is low to make (receive) the diffusion impact of the risk source to (from) these adjacent facilities. The component for diffusion control function is single.	3
10	"Safety assessment criteria" are satisfied until "the time of work (such as transfer, treatment, collection, etc.)" for the risk source. The potentiality is low to make (receive) the diffusion impact of the risk source to (from) these adjacent facilities. The component for diffusion control function is multiple.	2

*1. This refers to "at the time" of study on SED score, i.e., "at the present time" of assessment.
*2. "Safety assessment criteria" described in this sentence refer to "the matters for which measures should be taken" or "securing of diffusion control function within the scope of design basis event".
*3. This refers to the time of "recovery" of the risk source for disposition and carrying out for which SED score shall be studied.
*4. External events (natural disasters, etc.) are postulated as contingencies.
*5. The potentiality of diffusion of the risk source exists to (from) adjacent facilities when facilities receive external impact caused by contingencies or impact caused by any events (fire, etc.), etc.

Table A3-4 Criteria and score of WUD

Category	Criteria (NDA definition is modified to enhance applicability to the case of the Fukushima Daiichi NPS)	NDF Score
1	The material is fuel (which contains fissile material) and active*1. Necessary information (existent amount, existent location, radioactivity, etc.) for work including treatment, recovery, etc. is insufficient (cannot be confirmed or estimated), and control and surveillance with monitoring, etc. are unavailable. Handling is impracticable for the current form or condition because of reasons where the form is not proper for handling, or that it is not stored in a special container.	100
2	The material is fuel and active (which has fissile properties). Necessary information for work including treatment, recovery, etc. is insufficient, and control and surveillance are unavailable. Handling is practicable for the current form or condition because of reasons where the form is proper for handling or that it is stored in a special container.	90
3	Although the material is active, it is not fuel (but waste). Necessary information for work including treatment, recovery, etc. is insufficient.	74
4	The material is fuel and active (which has fissile properties). Necessary information for work including treatment, recovery, etc. is obtained (can be confirmed or estimated), and control and surveillance with monitoring, etc. are available. Handling is impracticable for the current form or condition.	50
5	The material is fuel and active (which has fissile properties). Necessary information for work including treatment, recovery, etc. is obtained, and control and surveillance are available. Handling is practicable for the current form or condition.	30
6	Although the material is active, it is not fuel (but waste). Necessary information for work including treatment, recovery, etc.	17
7	Although the material is inactive*2, it has physical or geometrical instability. Handling is impracticable for the current form or condition.	9
8	Although the material is inactive, it has physical or geometrical instability. Handling is practicable for the current form or condition.	5
9	The material is inactive and has no physical or geometrical instability or has sufficiently low level of instability. Handling is impracticable for the current form or condition.	3
10	The material is inactive and has no physical or geometrical instability or has sufficiently low level of instability. Handling is practicable for the current form or condition.	2

*1 "Active" refers to possession of activity defined by CF at such a significant level as that activity affects control and work.
*2 "Inactive" refers to non-possession of activity or possession of sufficiently low level of activity.

Table A3-5 Definition and score of SSR, BER and CU

<table>
<tr><th>Indicator</th><th>Score</th><th colspan="2">Criteria</th></tr>
<tr><td rowspan="3">SSR</td><td>25</td><td colspan="2">Risks may be realized within 5 years.</td></tr>
<tr><td>5</td><td colspan="2">Risks may be realized within 40 years.</td></tr>
<tr><td>1</td><td colspan="2">40 years or over (There is very little possibility that risks are realized.)</td></tr>
<tr><td rowspan="3">BER</td><td>20</td><td colspan="2">Implementation of measures can reduce risks by 2 or more orders of magnitude or can facilitate control stepwise.</td></tr>
<tr><td>4</td><td colspan="2">Implementation of measures can reduce risks by 1 or more order of magnitude, but cannot facilitate control.</td></tr>
<tr><td>1</td><td colspan="2">Implementation of measures can only bring negligible risk reduction effects, and cannot facilitate control, either.</td></tr>
<tr><td rowspan="3">CU</td><td>20</td><td>(1)+(2)= 5 to 6 points</td><td rowspan="3">(1) Assessment for the present state
1 point: Major nuclear types and diffusion pathways are monitored.
2 points: Monitored, but insufficient data for construction of assessment model
3 points: Not monitored
(2) Assessment on future prediction
1 point: Sufficient site characteristics are obtained for construction of assessment model.
2 points: Major characteristics representing the site are obtained.
3 points: There is no model usable for future prediction</td></tr>
<tr><td>4</td><td>(1)+(2)= 3 to 4 points</td></tr>
<tr><td>1</td><td>(1)+(2)= 2 points</td></tr>
</table>

Attachment 4 Risk sources containing radioactive materials except major risk sources on the site of Fukushima Daiichi NPS

Table 4-1 Risk sources containing radioactive materials except major risk sources (1/2)

Item		Descriptions
Liquid radioactive materials	Underground water tank	The residual water in all the underground water tanks were completely recovered[43]. Dismantling and removal policies are under consideration.
	Accumulated water on site	Extracted by the comprehensive risk inspection performed in 2015. Since then, the concentration of radioactive materials and volume of water are checked accordingly[44].
	Drainage	In drainage A, Cs-137: lowered to ND ~ 23 Bq/L.[45] In drainage K, the contamination source on the roof of the Unit 2 R/B was removed, and the contamination level fell to 67 Bq/L. In addition, purification materials were installed[46] and measures such as operation of PSF monitors were taken[47].
Spent fuel pool	Spent control rods	Spent control rods, etc.: 24,030. Shroud fragments, etc.: 193 m^3[48]. The major nuclide is Co-60.
	In-pool water	Salt removal in Units 2 to 4 was completed in 2013.
	Rubbles on operating floor	Investigation was conducted in Unit 1 and Unit 3. In Unit 1, a high radiation dose was measured near the lower plug[49]. In Unit 3, scattered radiation from Cs-134 and Cs-137 were measured[50]. In Unit 2, leftover objects were removed[51] and a measurement of 683 mSv/h was taken in the clearance of the upper plug[52].
Solid radioactive materials	Waste before the earthquake	185,816 drums are stored[53]. The major nuclide is Co-60.
	Contaminated soil	As a result of the topsoil analysis, more than half of the samples are in excess of the designated standards (8,000 Bq/kg) based on the Act on Special Measures Concerning the Handling of Environmental Pollution by Radioactive Materials[54].
	Rubbles around buildings	Dismantling of rubbles scattered on the roof floor of the buildings due to hydrogen explosions is now in operation and planned. The physical quantity has not been confirmed.

43 The 44th Team for Countermeasures for Decommissioning and Contaminated Water Treatment/Secretariat Meeting “Reference 3-6: On-site Monitoring Status (Conditions of Water Discharge Channels in Units 1 to 3 and Underground Water Storage Tanks)”

44 Comprehensive Risk Inspection of Fukushima Daiichi NPS that impacts outside the Site Boundary - Review Results - (April 28, 2015) Tokyo Electric Power Co., Inc.

45 The 32nd Study Group on Monitoring and Assessment of Specified Nuclear Facilities “Reference 2: Status of measures for reducing the concentration of waste water in drainage K”

46 The 63rd Study Group on Monitoring and Assessment of Specified Nuclear Facilities “Reference 2: Measures for rainwater inflow control (Progress status of installing purification materials for rainwater drainage in turbine buildings)”

47 The 74th Team for Countermeasures for Decommissioning and Contaminated Water Treatment/Secretariat Meeting “Reference 3-6: Starting of operation of PSF monitor in the drainage K”

48 Nuclear Regulation Authority, Material of interview with the licensee “Solid Waste at Fukushima Daiichi NPS” September 21, 2018, Tokyo Electric Power Company Holdings, Inc.

49 The 69th Team for Countermeasures for Decommissioning and Contaminated Water Treatment/Secretariat Meeting “Reference 3-2: Investigation of Obstacles in SFPs in Reactor Building of Unit 1 and Well Plug Investigation”

50 The 38th Study Group on Monitoring and Assessment of Specified Nuclear Facilities “Reference 5: Radiation Source Investigation on the Operating Floor of Unit 3 Reactor Building (Flash Report)”

51 Completion of Work to Move and Clear Leftovers on the Operating Floor of Unit 2 Reactor Building at Fukushima Daiichi NPS (November 7, 2018), Tokyo Electric Power Company Holdings, Inc.

52 The 10th Review Meeting on the Accident Analysis at TEPCO's Fukushima Daiichi NPS “Reference 3: Field Investigation Results”

53 Nuclear Regulation Authority, Material of Interview with Licensee “Restoration Status of Exhaust Radiation Monitor at Auxiliary Common Facilities for Common Spent Fuel Storage Pool and Ventilation & Air Conditioning System at Fuel Storage Area of Fukushima Daiichi NPS” September 21, 2018, Tokyo Electric Power Company Holdings, Inc.

54 Daily Analysis Results of Radioactive Materials at Fukushima Daiichi NPS, (Website), Tokyo Electric Power Company Holdings, Inc.

Table A4-0 Risk sources containing radioactive materials except major risk sources (2/2)

Item		Descriptions
Response to external events, etc.	Exhaust stack of Units 1/2	Dismantlement work was carried out since August 2019, and the upper part of 61 m out of the total height of 120 m was divided into 23 blocks in total for dismantling. On May 1, 2020, a lid was installed on a barrel 59 meters above the ground to prevent rainwater inflow, and dismantling was completed[55].
	Megafloat	The work of bottoming and internal filling is in progress[56]. Measurement on the entire surface inside the megafloat is less than 4 Bq/cm^2[57]. Measurement of one location at No. 1 VOID is approx. 1.4 Bq/cm^2.
	Dust in operating floor	Below the target value of release control (1×10^7 Bq/h). Gradually declining[58].
	Rainwater inflow into buildings	Rubble on the roof was removed and waterproofing was newly provided. Purification materials were installed in the gutters. Check valves were installed in the drain pipes. The roof drain was repaired and closed[59]. Facing of the T.P.8.5m board is to be completed[60].
Important matters in promoting decommissioning work	Vent line	High air dose rate was measured in each filter and exhaust stack of Units 1 to 4. A value of 4.35 Sv/h was measured in the vent line leading to the exhaust stack of Units 1/2[61]. Investigation and measurement are ongoing for removal.
	The 3rd and 4th floors of Unit 3 R/B	On the 3rd floor, beams at several locations were damaged. A maximum of 50 mSv/h was measured[62]. On the 4th floor, a strong radiation source was observed by a gamma camera. Other details are unknown.

55 “Completion of Dismantling of Exhaust Stack of Units 1/2 at Fukushima Daiichi NPS” (May 1, 2020), Tokyo Electric Power Company Holdings, Inc.

56 Progress Status of Megafloat Project at Fukushima Daiichi NPS to Reduce Tsunami Risks (Starting of Step 2) (March 5, 2020), Tokyo Electric Power Company Holdings, Inc.

57 The 75th Team for Countermeasures for Decommissioning and Contaminated Water Treatment/Secretariat Meeting “Reference 3-1: Progress Status of Megafloat Project to Reduce Tsunami Risks”

58 Daily Analysis Results of Radioactive Materials at Fukushima Daiichi NPS, (Website), Tokyo Electric Power Company Holdings, Inc.

59 The 78th Team for Countermeasures for Decommissioning and Contaminated Water Treatment/Secretariat Meeting “Reference 3-1: Progress Status in Rooftop Rainwater Measures”

60 The 74th Study Group on Monitoring and Assessment of Specified Nuclear Facilities “Reference 1: Progress Status in Rainwater Inflow Measures”

61 The 81st Study Group on Monitoring and Assessment of Specified Nuclear Facilities “Reference 4-2: Implementation Status of On-site Investigation for Removal of SGTS Piping of Units 1/2”

62 The 9th Review Meeting on Analysis of the Accident at TEPCO's Fukushima Daiichi NPS “Reference 2: Investigation Results on the 3rd Floor of Reactor Building of Unit 3 - Results of On-site Investigation on December 12, 2019, etc. -”

Attachment 5 Change in risk over time

Overview of the concept of risk management in the UK is shown in the conceptual diagram below. Even if the current risk level is plotted in the white region of the graph, it does not mean such risk level can always be accepted over time, but the time will come when such risk level cannot be accepted in the future (yellow region). In addition, as time passes, the risk level may increase caused by degradation of facilities and risk sources (represented by the dotted line). On the other hand, when risk reduction measures are taken, the risk level can be reduced so that it may not reach the unacceptable region (red region) with careful preparation and thorough management, although it may be temporarily increased. In this way the risk level shall be targeted to be sufficiently reduced (represented by the solid line) so that it may not reach into the unacceptable or intolerable region.

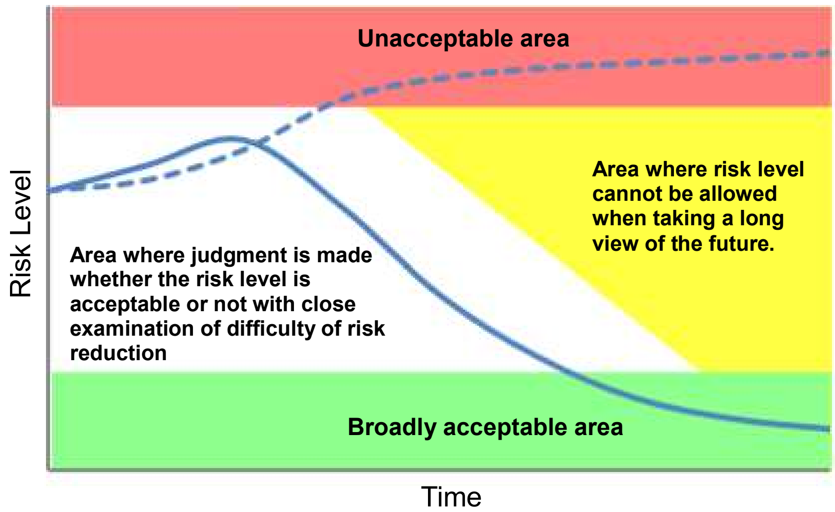

Fig. A5-1 Change in risk over time[63]

[63] V. Roberts, G. Jonsson and P. Hallington, "Collaborative Working Is Driving Progress in Hazard and Risk Reduction Delivery at Sellafield" 16387, WM2016 Conference, March 6-10, 2016. M. Weightman, "The Regulation of Decommissioning and Associated Waste Management" 1st International Forum on the Decommissioning of the Fukushima Daiichi Nuclear Power Plant (April 2016)..

Attachment 6　Coverage of fuel debris retrieval

In the Mid-and-Long-term Roadmap issued in December 21, 2011, fuel debris is described as "material in which fuel and its cladding tubes, etc. have melted and re-solidified", namely, fuel debris is "fuel assembly, control rod and structures inside reactor have melted and solidified together" according to the report by IAEA[64],[65].

The condition inside PCV is as shown in Fig. A6-1, as the comprehensive estimations from the inside investigation of reactor, the past accidents including TMI-2 or ChNPP-4, and the result of the simulation test. It does not show any of specific unit. For more detail, as shown in the Fig A6-1, fuel debris can be classified by form such as damaged pellets, debris, crust, etc.

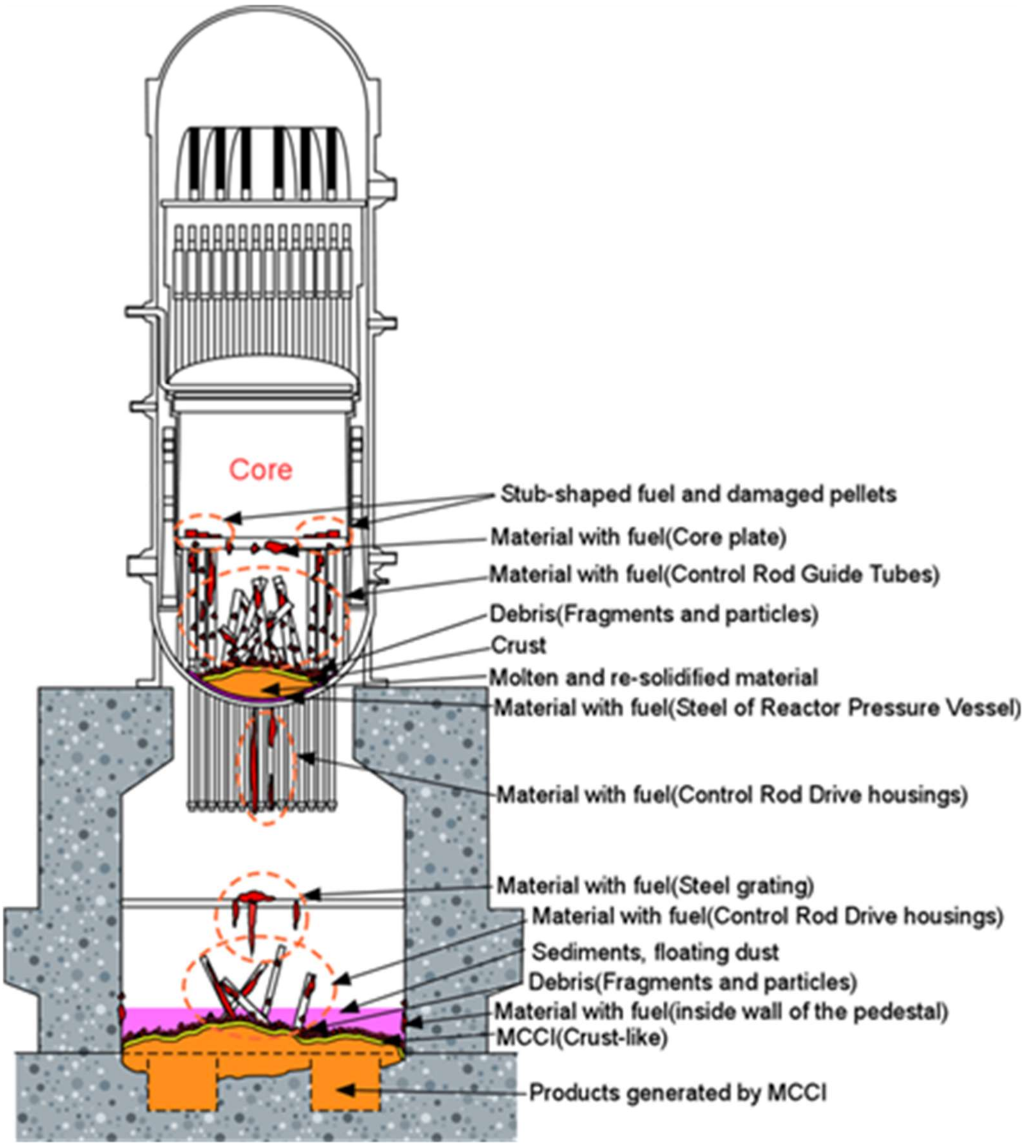

Fig. A6-1 Estimated inside of the PCV of the Fukushima Daiichi NPS

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64 International Atomic Energy Agency Experiences and Lessons Learned Worldwide in the Cleanup and Decommissioning of Nuclear Facilities in the Aftermath of Accidents, IAEA Nuclear Energy Series No. NW-T-2.7, Vienna (2014)

65 Managing the Unexpected in Decommissioning, IAEA Nuclear Energy Series No. NW-T-2.8, Vienna (2016)

Since nuclear fuel material requires considerations to prevent criticality, it is rational that objects which exist inside PCV should be broadly sorted into two from the viewpoint of retrieval, containment, transfer and storage. The one includes nuclear fuel material and the others. The one that does not include nuclear fuel material is to be treated as a radioactive waste in case radioactive cesium or cobalt are contained or adhered.

Based on this, an example of fuel debris concept as a retrieval target of fuel debris is as shown in Fig. A6-2. Objects generated by core damage have been classified depending on necessity of criticality measures and the content of fuel, in spite that a lot of names are used according to the content of fuel component or form in appearance.

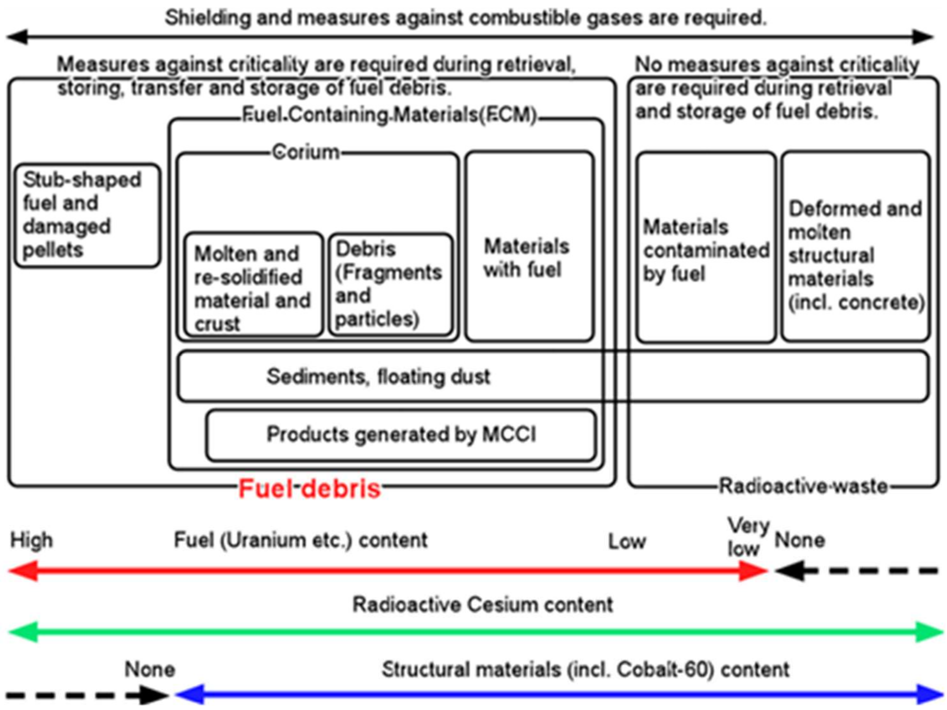


Fig. A6-2 An example of organized concept of fuel debris as fuel debris retrieval target at the Fukushima Daiichi NPS

【Glossaries and Terms】

FCM : Fuel Containing Materials. It refers broadly that molten fuel component comes to solidify in conjunction with structural materials. It is also called lava-like FCM due to its appearance.

Corium : A substance that mainly fuel assembly and component of control rod as core component have molten and solidified.

Crust : A hard outer layer or shell on the surface. When molten fuel is solidified, it may become a hard solid state of shell because of higher cooling speed on the surface layer.

MCCI product : A product generated by Molten Core Concrete Interaction, that includes calcium, silicone, etc. which are concrete component.

Material with fuel : A substance that molten fuel has adhered to material that does not include fuel component originally, like CRD housing, grating and s, then solidified. It is possible to confirm fuel adhesion state by sight.

Material contaminated by fuel : A substance that adhering molten fuel cannot be confirmed by sight, but fuel component can be detected with α ray detector. It is impossible to locate fuel component other than using by electron microscope because particle of adhered fuel component is extremely small and whit.

Attachment 7 Analysis and investigation plan

1 Purposes of the analysis and the investigation

Safe and steady decommissioning of the Fukushima Daiichi NPS is a top priority and to accomplish the decommissioning work is needed as early as possible. To proceed with decommissioning safely and reliably, it is important to understand the current situation and what has happened by analyzing fuel debris and conducting investigations on the on-site condition. The results obtained from the analyses and investigations can be reflected in the following three areas, including decommissioning.

① Analyses and investigations of fuel debris should be carried out in the process of decommissioning so that they can directly contribute to “the accomplishment of decommissioning” through the retrieval process, safeguards, storage, treatment and disposition.

② To contribute to “the accomplishment of decommissioning”, an accident history investigation represented by analyses and investigations of fuel debris, etc., shall be conducted, and the cause of the accident at Fukushima Daiichi NPS shall be clarified to disseminate the knowledge obtained overseas and to future generations.

③ As a by-product of the analyses and investigations on fuel debris, etc., improvement of the severe accident progression analysis code, emergency response and the facilities has been made, which can indirectly contribute to the improvement of the safety of nuclear power reactors.

Fig. A7-1 shows the relationship between analyses/investigations and decommissioning, clarification of the cause of the accident, and studies on safety. Needless to say, the information obtained through the analyses and investigations will not only directly contribute to the future “decommissioning at Fukushima Daiichi NPS” but also play a part in the investigation of the accident’s history. Adequate understanding, examination, and consideration of the information obtained from historical investigations on past accidents will ensure the advancement in “the understanding of phenomena”. Knowledge gained through the understanding of phenomena will, in turn, contribute to “clarification of the cause of the accident” and “decommissioning”, and, in the end, indirectly contribute to “Improving Nuclear Safety” through improvements in the severe accident progression analysis code, emergency response and the facilities.

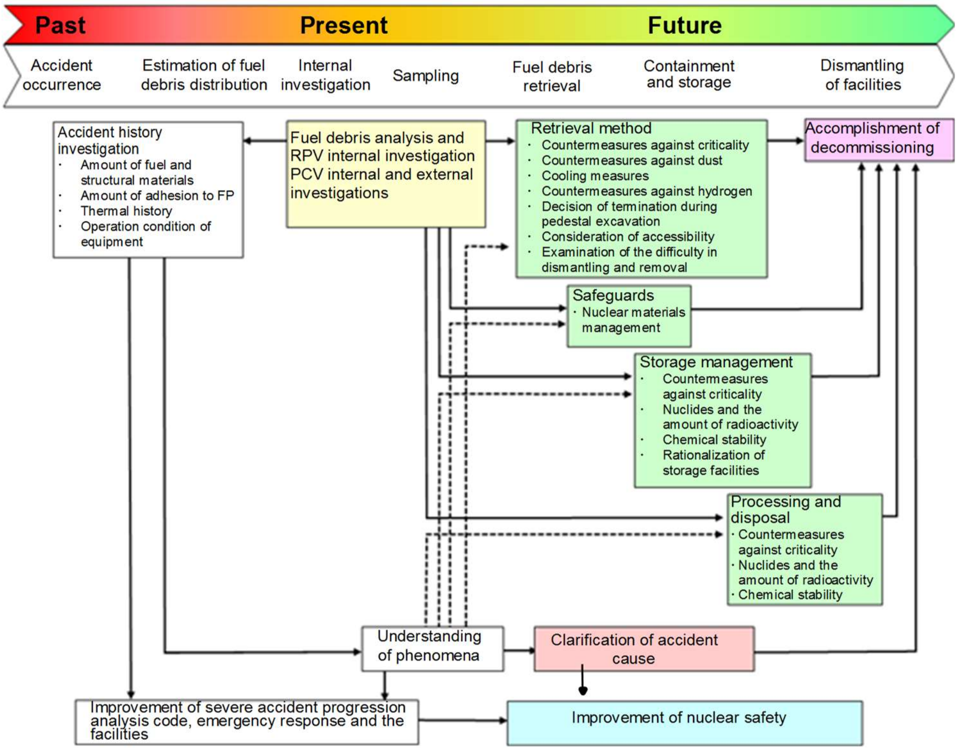


Fig. A7-1 Where analyses and investigation results are reflected and their relationships

2 Basic principles toward the planned analysis and investigation

Analyses and investigations on the decommissioning and contaminated water management of Fukushima Daiichi NPS should be implemented within the range of efforts to proceed with decommissioning safely and steadily, since the top priority is to realize decommissioning safely and steadily as early as possible. The necessity to implement these analyses and investigations should be sufficiently considered from the viewpoint of investigating the cause of the accident and improving the safety of nuclear power in the future. After clarifying how the information obtained will contribute to decommissioning, these analyses and investigations should be conducted to the extent that it is reasonably acceptable as a decommissioning project based on the consideration of their significance and the associated burden. As described above, it is important to conduct analyses and investigations on decommissioning and contaminated water management at the Fukushima Daiichi NPS in a planned manner. A plan for the analyses and investigations needs to be developed in engineering in accordance with the following “Basic principles toward the planned analysis and investigation on the decommissioning and contaminated water management of Fukushima Daiichi Nuclear Power Station.

Basic principles toward the planned analysis and investigation on the decommissioning and contaminated water management of Fukushima Daiichi Nuclear Power Station

(1) To proceed with the decommissioning of Fukushima Daiichi NPS safely and steadily is of primary importance. With these efforts, it is necessary to achieve "decommissioning as soon as possible". For that sense, the analysis and the investigation on the decommissioning and contaminated water management of Fukushima Daiichi NPS (hereinafter referred to as "Fukushima Daiichi NPS Analysis and Investigation") should be conducted, to the extent that can proceed with the decommissioning in safe and steady.

(2) At the same time, it is also necessary to proceed with the Fukushima Daiichi NPS Analysis and Investigation from the viewpoint of ascertaining the causes of the Fukushima Daiichi NPS accident and improving the nuclear safety for future (hereinafter referred to as "Forensic"). Therefore, due consideration is to be given to the necessity of the Fukushima Daiichi NPS Analysis and Investigation from the viewpoint of Forensic, on the premise of the safe and steady decommissioning of Fukushima Daiichi NPS.

(3) The Fukushima Daiichi NPS Analysis and Investigation is to be planned on the premises of realistic working situations and difficulties of the site, giving the highest priority on the safety for local residents, surrounding environment and workers. In addition, it must be proposed after clarifying the concreteness of technology commensurate with it.

(4) While clarifying what is the information obtained from the Fukushima Daiichi NPS Analysis and Investigation used for and what will it contributes to, it must be conducted in reasonably acceptable range as Fukushima Daiichi NPS decommissioning project, considering its significance and the responsibility associated with it.

(5) Taking into account of Japan's responsibility to the international society, as a country where the Fukushima Daiichi NPS accident occurred, information obtained in the Fukushima Daiichi NPS Analysis and Investigation should be provided in a proactive way. There is a possibility for institutions requesting additional information to bear a reasonable burden.

Attachment 8 Concept of Safeguards

Safeguards are verification activities undertaken to ensure that nuclear materials are used only for peaceful purposes and not diverted to nuclear weapons, etc.

Japan has concluded the Safeguards Agreement between Japan and the International Atomic Energy Agency (IAEA) pursuant to the "Treaty on the Non-Proliferation of Nuclear Weapons" (NPT). In accordance with this Agreement, relevant domestic laws (the Law for the Regulations of Nuclear Source Materials, Nuclear Fuel Materials and Reactors (the Nuclear Reactor Regulation Law) and others) have been developed to establish a domestic safeguards system and accept the IAEA's safeguards.

Specifically, the Safeguards Office of the Nuclear Regulatory Agency (JSGO) has confirmed that all nuclear materials in Japan have not been diverted to nuclear weapons, etc., by conducting the following activities, and the IAEA has acknowledged this authorization through inspections, etc.

(1) Material accountancy by nuclear operators

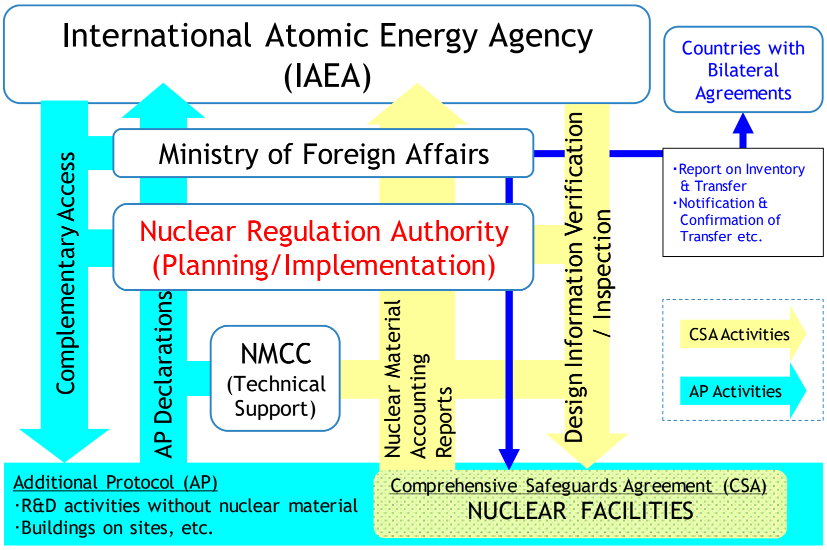
A nuclear operator shall determine the places where nuclear materials are handled at its facilities, shall perform a strict and accurate material accountancy including the amount of nuclear materials to be entered or transferred from its premises and the periodic inventory of nuclear materials, and shall report to the Nuclear Regulation Authority. The JSGO will compile these reports received from operators and submit them to the IAEA.

(2) Containment/Monitoring

To ensure that nuclear materials have not been secretly transferred, the JSGO and IAEA have attached a "seal" on the lids of containers in which nuclear materials are stored and on the gateway for fuel at nuclear power plants. At nuclear power plants, etc., "surveillance cameras" are installed to constantly monitor the movement of nuclear materials.

(3) Inspection

Inspectors from the JSGO and the IAEA will visit the nuclear facilities in person and conduct inspection activities such as verifying the consistency of reports and records, checking the quantity and volume of nuclear materials on site, collecting samples for analysis, and assessing the containment/monitoring data.



*1 : Except for complementary access occurred during regular domestic inspection
*2 : Based on Nuclear Power Plant Regulation, specify Nuclear Material Control Center (authorized foundation) as "Specified safeguards inspection Agency" and "Specified information processing Agency"

Fig. A8-1 Safeguards implementation system in Japan

The safeguards shall be applied to the Fukushima Daiichi NPS without exception. TEPCO, as a nuclear operator, will consult with the JSGO and IAEA to determine the method of implementing the safeguards (material accountancy, containment/monitoring, inspection) to be applied to Fukushima Daiichi NPS, and practically apply them on site.

Attachment 9 Terms related to radioactive waste management

IAEA Safety Requirements GSR-Part 5[66] explains that predisposal of radioactive waste encompass all stages of radioactive waste management from generation to disposal, including processing, storage and transportation. Terms related to the management of radioactive waste as defined in the IAEA glossary are shown in Fig A9-1. Within the pre-disposal management, processing of radioactive waste is classified into pretreatment, treatment and conditioning. Processing is carried out to be in the form of waste suitable for selected or anticipated disposal options. Radioactive waste may also be stored in for its management, therefore it is thought to be necessary that the form is suitable for transportation and storage.

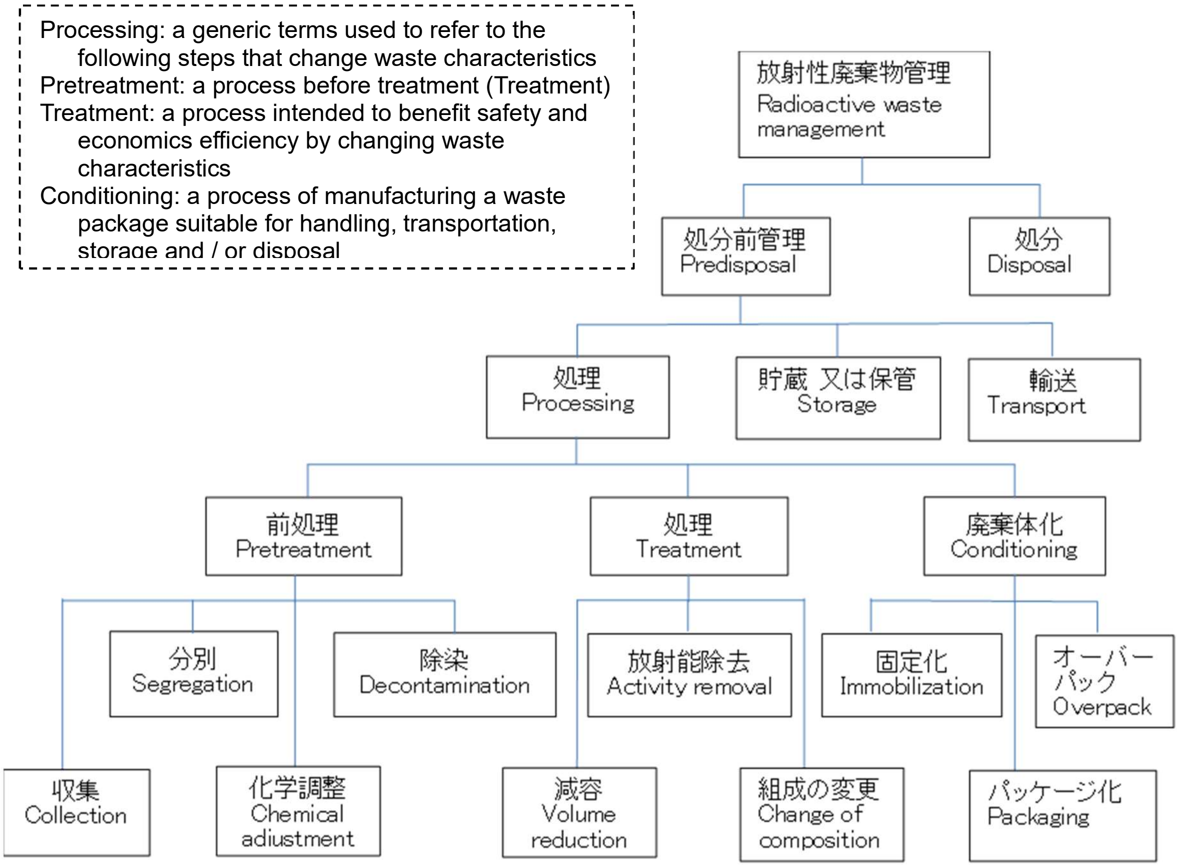


Fig. A9-1Terms related to radioactive waste management (IAEA)[67] and their translation examples (For the Japanese translation example, refer to the materials of the Japan Atomic Energy[68],[69])

[66] IAEA, Predisposal Management of Radioactive Waste, IAEA Safety Standards Series No. GSR Part 5, (2009). (NSRA, IAEA Safety Standard/Predisposal of Radioactive Waste/General Safety Requirement 5, No. GSR-Part5, July, 2012)

[67] IAEA, IAEA Safety Glossary Terminology Used in Nuclear Safety and Radiation Protection 2007 Edition, p.216, (2007).

[68] AESJ, The Report of 2013, - Organizing information of radioactive waste and matters to be considered for solving the issues (p.7), March 2014, the Expert Committee, "Processing /disposal of radioactive waste generated by the accident of Fukushima Daiichi NPS"

[69] AESJ, Seiya Nagao and Masafumi Yamamoto, "Introduction to radioactive waste - Management of radioactive waste from operation and decommissioning of nuclear and other facilities (!) Perspective of radioactive waste management, the 56 of (9) of Journal of the Atomic Energy Society of Japan, p.593, (2014).

Attachment 10 Disposal of radioactive waste[70,71,72]

1. International classification of radioactive waste

Radioactive waste contaminated with radioactive materials is generated through operation and dismantling of nuclear power plants and the use of radioisotopes in medical and industrial applications. Radioactive waste shall be classified appropriately according to the radioactivity level and properties of waste, types of radioactive materials, etc., and strictly controlled, and then shall be reasonably processed and disposed of so as not to affect the human living environment.

The IAEA's Specific Safety Requirements SSR-5 “Disposal of Radioactive Waste” (2011)[73] specifies that a preferred strategy for the management of radioactive waste that is internationally agreed is to contain the waste and isolate it from the living environment, while minimizing the generation of radioactive waste. The required isolation and containment depend on the magnitude of the hazards of the waste and the time, thereby a disposal option (design and depth of facilities) being selected accordingly.

The IAEA’s General Safety Guide GSG-1 “Classification of Radioactive Waste”[74] indicates the relationship between the classification of radioactive waste and disposal options depending on the magnitude of the hazards (amount of radioactivity) and the duration (the half-life) of the radioactive waste, as shown in Figure A10-1. Each classification is also shown in Table A10-1.

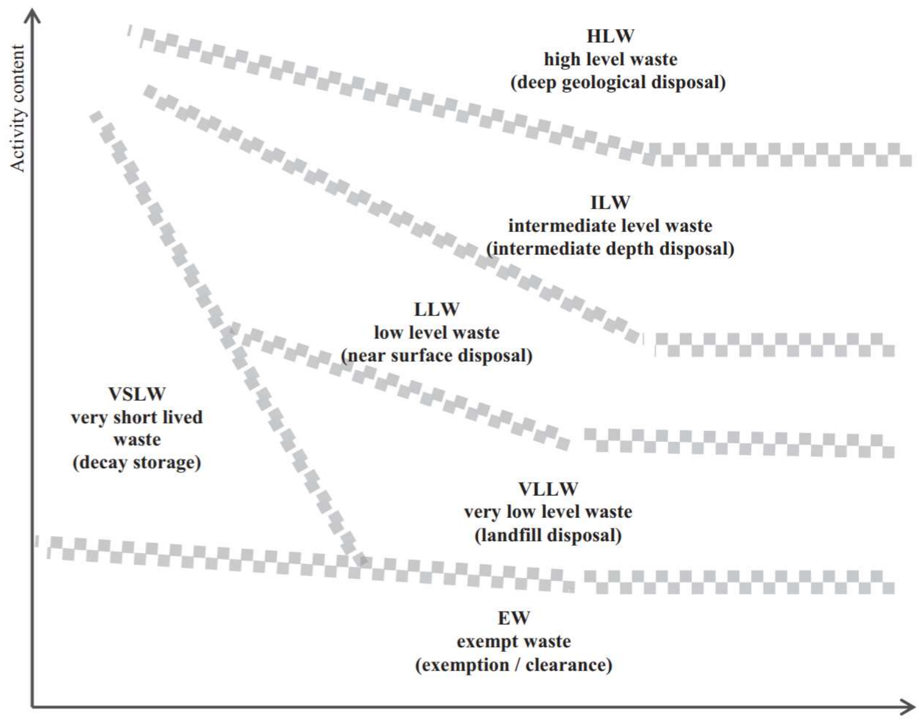


Fig. A10-1 Conceptual diagram of waste classification

70 Osamu Tochiyama, Principles and Basics of Radioactive Waste Disposal, Radioactive Waste Management Funding and Research Center (a Public Interest Incorporated Foundation) (2016)
71 https://www.enecho.meti.go.jp/category/electricity_and_gas/nuclear/rw/
72 https://www.fepc.or.jp/nuclear/haikibutsu/index.html
73 IAEA SSR-5 "Disposal of Radioactive Waste"(2011)
74 IAEA GSG-1" Classification of Radioactive Waste" (2009)

Table A10-1 Classification of radioactive waste in GSG-1

Classification	Description of Classification
Exempted waste (EW)	Waste satisfying the criteria for clearance, exclusion and exemption from regulatory control for radiation protection purposes
Very short-lived waste (VSLW)	Waste that is decay-stored for a limited period of time up to several years and then exempted from regulatory control, as approved by the regulatory body.
Very low level waste (VLLW)	Waste that does not necessarily satisfy EW standards but does not require high-level containment and isolation. Suitable for disposal in shallow landfills where regulatory control is limited.
Low level waste (LLW)	Waste that exceeds clearance levels but has a limited amount of long-lived nuclides. Rigid isolation and containment are required for periods of up to several 100 years and are suitable for disposal in engineering facilities in shallow soils.
Intermediate level waste (ILW)	Waste that requires higher-level containment and isolation than the near surface disposal because of the nuclides it contains, especially long-lived nuclides. However, considerations on heat removal are hardly required. Because ILW may contain concentrations of long-lived nuclides (especially α-nuclide) that are not manageable in near surface disposal, a depth of tens to hundreds of meters are required for disposal.
High Level waste (HLW)	Waste with a large amount of heat generation at high activity concentration levels or waste containing large amounts of long-lived nuclides for which a design equivalent to a disposal facility for such waste needs to be considered. Generally, waste is disposed of in a stable stratum at the depth of several hundred meters or more from the ground surface. In some countries, spent fuel is classified as HLW.

2. Classification and disposal in Japan

In Japan, radioactive waste is broadly divided into “low-level radioactive waste” (equivalent to VLLW to ILW in GSG-1), which is generated through the operation of nuclear power plants, and “high-level radioactive waste” (equivalent to HLW of GSG-1), which is generated through the reprocessing of spent fuel that is generated through the operation of nuclear power plants and is vitrified with a high level of radioactivity. When disposed of, waste shall be classified appropriately according to its radioactivity level and properties, types of radioactive materials, etc., and shall be strictly controlled, and reasonably processed and disposed of under the principle that responsibilities lie with those who have generated the waste.

“High-level radioactive waste” is a vitrified waste liquid with a high radioactivity level that is produced in the process of reprocessing spent fuel generated through the operation of nuclear power plants. In Japan, the act (the Designated Radioactive Waste Final Disposal Act (the Final Disposal Act)) stipulates that radioactive waste shall be disposed of in strata more than 300 meters deep underground.

The term “low-level radioactive waste” refers to all types of radioactive waste other than “high-level radioactive waste”, and is further divided into several categories depending on where it is generated and the level of radioactivity. In Japan, radioactive waste is broadly divided into “low-level radioactive waste” (equivalent to VLLW to ILW in GSG-1), which is generated through the operation of nuclear power plants, and “high-level radioactive waste” (equivalent to HLW of GSG-1), which is generated through the reprocessing of spent fuel that is generated through the operation of nuclear power plants and is vitrified with a high level of radioactivity. When disposed of, waste shall be classified appropriately according to its radioactivity level and properties, types of radioactive materials, etc., and shall be strictly controlled, and reasonably treated and disposed of under the principle that responsibilities lie with those who have generated the waste.

“High-level radioactive waste” is a vitrified waste liquid with a high radioactivity level that is produced in the process of reprocessing spent fuel generated through the operation of nuclear power plants. In Japan, the act (the Designated Radioactive Waste Final Disposal Act (the Final Disposal Act)) stipulates that radioactive waste shall be disposed of in strata more than 300 meters deep underground.

The term “low-level radioactive waste” refers to all types of radioactive waste other than “high-level radioactive waste”, and is further divided into several categories depending on where it is generated and the level of radioactivity.

The types of radioactive waste generated by the operation of nuclear power plants and the disposal methods assumed are shown in Table A10-2.

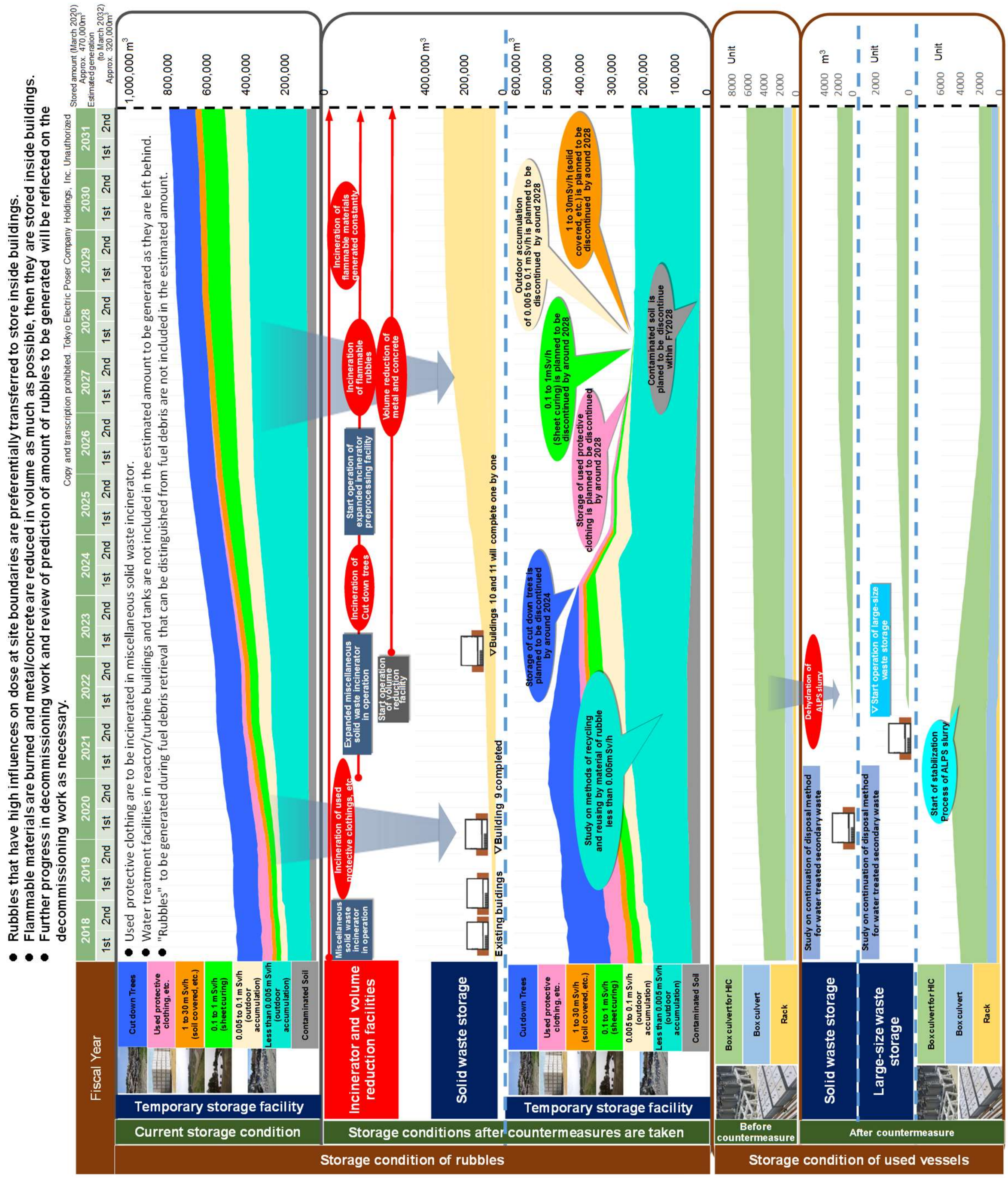
Of these, only waste with relatively low-level radioactivity generated through the operation of nuclear power plants has been subject to disposal in pits since 1992 at the Rokkasho Low-level Radioactive Waste Disposal Center of Japan Nuclear Fuel Limited in Rokkasho Village, Aomori Prefecture. Including the existing facilities, approximately 1 million drums of waste contained in 200-liter drums are planned to be buried, and eventually the scale will be enlarged to approximately 3 million drums using 200-liter drums.

Table A10-2 Types of Radioactive Waste Generated by the Operation of Nuclear Power Plants

Types of Radioactive Waste			Examples of Waste	Site generated	Disposal Method (example)
Low-level Radioactive Waste	Waste from Nuclear Power Plants	Waste with extremely low radiation level	Concrete, metal, etc.	Nuclear Power Plant	Trench disposal
		Waste with relatively low radiation level	Effluent, filter, waste equipment, solidification of consumables		Pit disposal
		Waste with relatively high radiation level	Control rod, structures inside reactor		Subsurface disposal
	Uranium Waste		Consumables, sludge, waste equipment	Uranium enrichment and fuel processing facility	Subsurface disposal, Pit disposal or Trench disposal, geological disposal in some cases
	Radioactive Waste includes Transuranic Nuclide (TRU Waste)		Parts of control rod, effluent, filter	Spent fuel reprocessing facility, MOX fuel fabrication facility	Geological disposal, Subsurface disposal or Pit disposal
High-level Radioactive Waste			Vitrified waste	Spent fuel reprocessing facility	Geological disposal
Waste below the clearance level			Most of demolition waste of nuclear power plants	All the above sites	Reuse / Disposal as general goods


Fig. A10-2 Japan Nuclear Fuel Ltd. Low-level Radioactive Waste Disposal Center

Attachment 11 Overall image of Storage Management Plan for the Fukushima Daiichi NPS[75]



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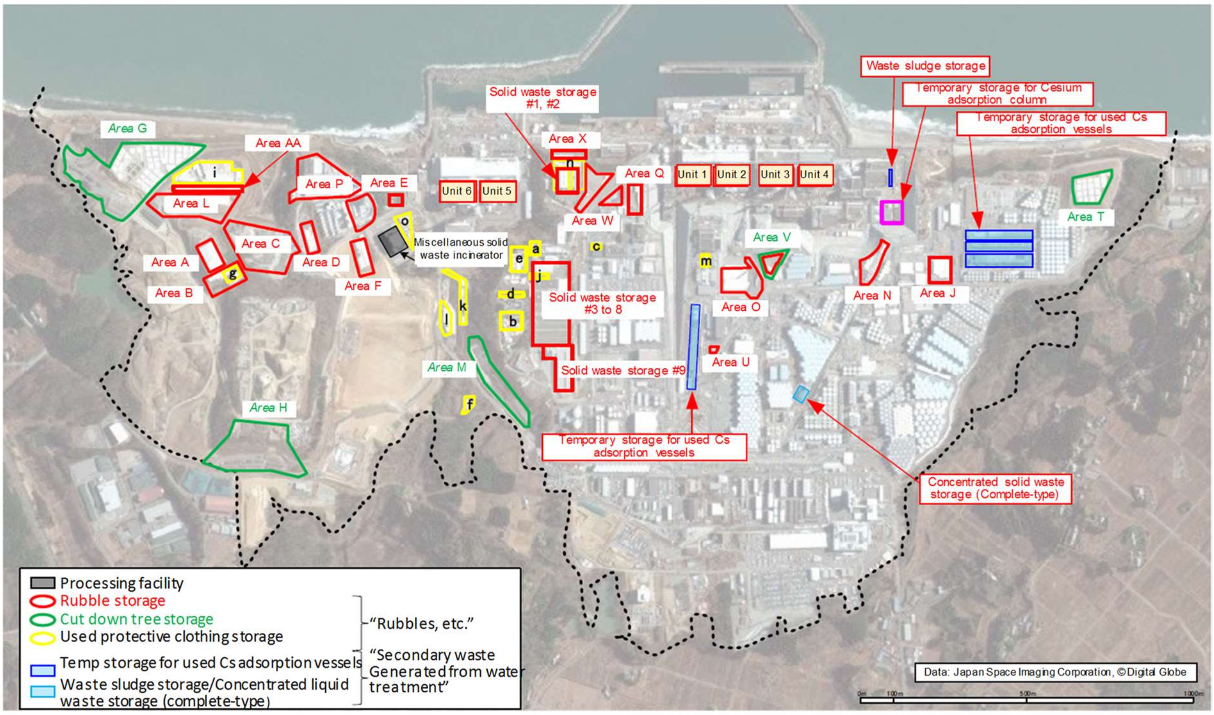
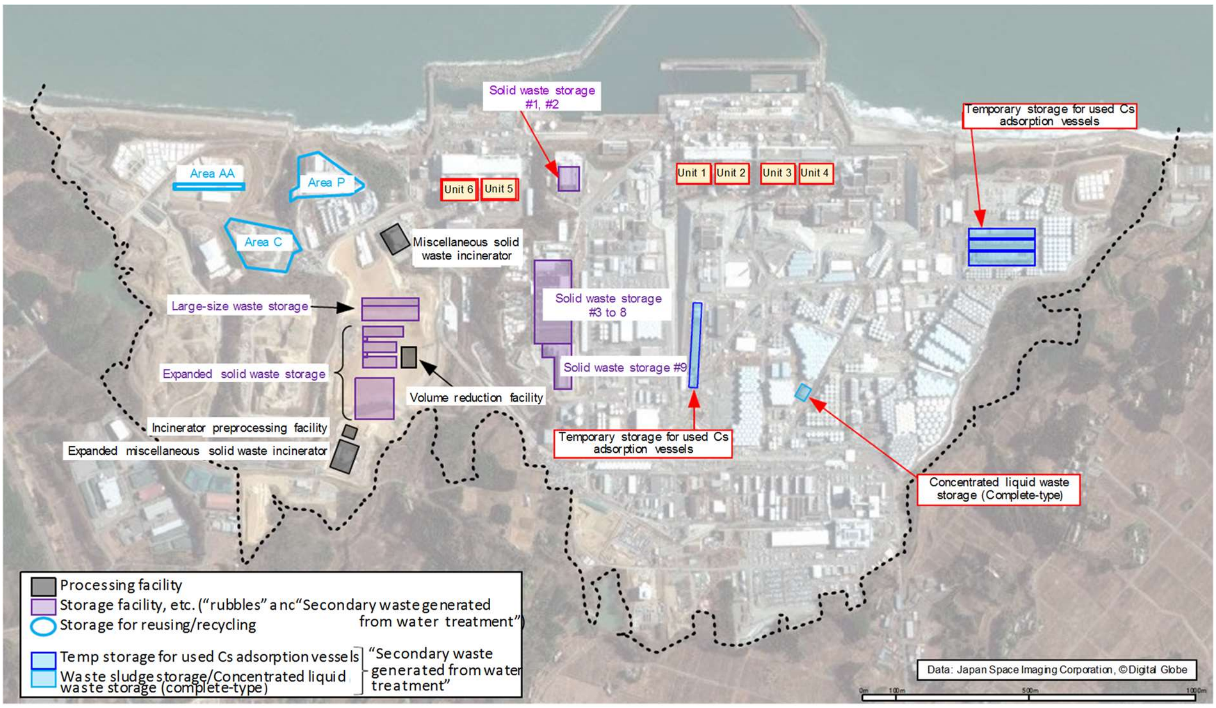
75 Solid Waste Storage Management Plan for Fukushima Daichi Nuclear Power Station of Tokyo Electric Power Company Holdings, Inc., July 2020 edition (issued on July 30, 2020)



(a) Present storage condition of "rubble, etc." and "secondary waste generated by water treatment"



(b) Future storage condition of "rubbles, etc." and "secondary waste generated by water treatment"

Fig. A11-1 Present and future storage conditions of "rubble, etc." and "secondary waste generated by water treatment" on site of the Fukushima Daiichi NPS

Attachment 12 Current Progress of the Government-led R&D program on Decommissioning and Contaminated Water Management[76]

1. Grasping state inside reactor, characterizing of fuel debris, and internal investigation

1-(1) Advancement of comprehensive grasping of state inside reactor (FY 2016 - 2017)

(Related projects) Advancement of accident progression analysis technology for assessing conditions inside reactor (FY 2011)

Assessing conditions inside reactor by advancement of accident progression analysis technology (FY 2012 - 2013)

Assessing conditions inside reactor through application of severe accident analysis code (FY 2014)

Advancement of grasping conditions inside reactor by accident progression analysis and actual data, etc. (FY 2015)

1-(2) Development of analytical and estimation techniques for characterization of fuel debris, Development of analytical and estimation techniques for characterization of fuel debris (Development of estimation technologies for variation character across the ages) (FY 2019 - 2020), Development of analytical and estimation techniques for characterization of fuel debris (Development of technologies for improving analytical accuracy and estimation of thermal behavior of fuel debris) (since FY2020)

(Related projects) Characterization of fuel debris using mock-up debris and development of fuel debris processing technologies (FY 2011 - 2014)

Construction of material accountancy method related to fuel debris (FY 2011 - 2013)

Property analysis of actual debris (FY 2014)

Grasping properties of fuel debris (FY 2015 - 2016)

Development of techniques for characterizing and analyzing fuel debris (FY 2017 - 2018)

1-(3) Development of technologies for in-depth investigation of PCV inside (On-site verification) (FY 2018 - 2020)

(Related projects) Development of investigation technologies of inside of PCV (FY 2011 - 2013)

Development of investigation technologies of inside of PCV (FY 2014 - 2015)

Development of investigation technologies of inside of PCV (FY 2016 - 2017)

Development of technologies for in-depth investigation of PCV inside (FY 2017 - 2018)

1-(4) Development of investigation technology inside RPV (FY 2016 - 2020)

(Related projects) Development of investigation technologies inside RPV (FY 2013 - 2015)

1-(5) Development of technologies for the detection of fuel debris inside reactors (using muon) (FY 2014 - 2015)

[76] Information Portal for the Research and Development for the Fukushima Daiichi Decommissioning (http://www.drd-portal.jp/)

2. Retrieval of fuel debris

2-(1) Development of technologies for retrieving fuel debris to be gradually expanded in scale (FY2020)[77]

(Related projects) Development of technologies for retrieval of fuel debris and internal structures (FY 2014)

2-(2) Technologies toward further expansion in scale for retrieval of fuel debris and internal structures (FY 2020)[76]

(Related projects) Development of fundamental technologies for retrieval of fuel debris and internal structures (FY 2015 - 2016)

Advancement of retrieval method and system of fuel debris and internal structures (FY 2015 - 2018)

Development of technologies for retrieving fuel debris and internal structures, Development of technologies for retrieving fuel debris and internal structures (development of technologies for dust collecting system) (FY2019 - 2020)

2-(3) Development of sampling technologies for retrieving fuel debris and internal structures (FY 2017 - 2018)

2-(4) Development of PCV closed water circulation systems (FY 2018 - 2019)

2-(5)-1 Development of repair methods for leak spots in PCV (FY 2016 - 2017)

(Related projects) Development of identification technology of leaks in PCVs (FY 2011 - 2013)

Development of repair method for PCVs (FY 2011 - 2013)

Development of repair (water stoppage) technology toward water filling in PCV (FY 2014 - 2015)

2-(5)-2 Full-scale test of repair methods for leak spots in PCV (FY 2016 - 2017)

(Related projects) Full-scale test of repair methods for leak spots in PCV (FY 2014 - 2015)

2-(6) Development of evaluation methods of seismic performances of RPV and PCV and the impacts of the damages (FY 2016 - 2017)

(Related projects) Development of evaluation methods for the structural integrity of RPV and PCV (FY 2011 - 2013)

Development of evaluation methods for the structural integrity of RPV and PCV (FY 2014 - 2015)

2-(7) Development of corrosion inhibition technology for RPV and PCV (FY 2016)

(Related projects) Full-scale test of repair methods for leak spots in PCV (FY 2014 - 2015)

2-(8) Development of criticality control technologies of fuel debris (FY 2012 - 2016)

2-(9) Development of technologies for non-destructive detection of radioactive material deposited in S/C, etc. (FY 2014)

2-(10) Development of remote decontamination technology in the reactor building (FY 2014 - 2015)

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[77] Renamed (In accordance with the revision of “Mid-and-Long-term Roadmap towards the Decommissioning of TEPCO’s Fukushima Daiichi Nuclear Power Station” on December 27, 2019)

(Related projects) Development of remote decontamination technology in the reactor building (FY 2011 - 2013)

2-(11) Formulation of comprehensive radiation dose reduction plan (FY 2012 - 2013)

2-(12) Development of technologies for containing, transferring and storing fuel debris (FY 2016 - 2020)

(Related projects) Development of containing, transferring and storing technologies of fuel debris (FY 2014 - 2015)

<u>3. Waste management</u>

3. Research and development of processing and disposal of solid waste (FY 2019 - 2020)

(Related projects) Development of technologies for processing/disposal of secondary waste by treatment of contaminated water (FY 2012)

Development of technologies for processing/disposal of radioactive waste (FY 2012)

Research and development of processing/disposal of solid waste (FY 2013 - 2014)

Research and development of processing/disposal of solid waste (FY 2015 - 2016)

Research and development of processing and disposal of solid waste

Research and development of preceding processing methods and analytical techniques

<u>4. Spent fuel management</u>

4-(1) Evaluation of long-term integrity of fuel assembly removed from spent fuel pools (FY 2015-2016)

(Related projects) Evaluation of long-term structural integrity of fuel assemblies removed from spent fuel pools (FY 2012 - 2014)

4-(2) Investigation of method for processing damaged fuel, etc. removed from spent fuel pools (FY 2013 - 2014)

<u>5. Contaminated water management</u>

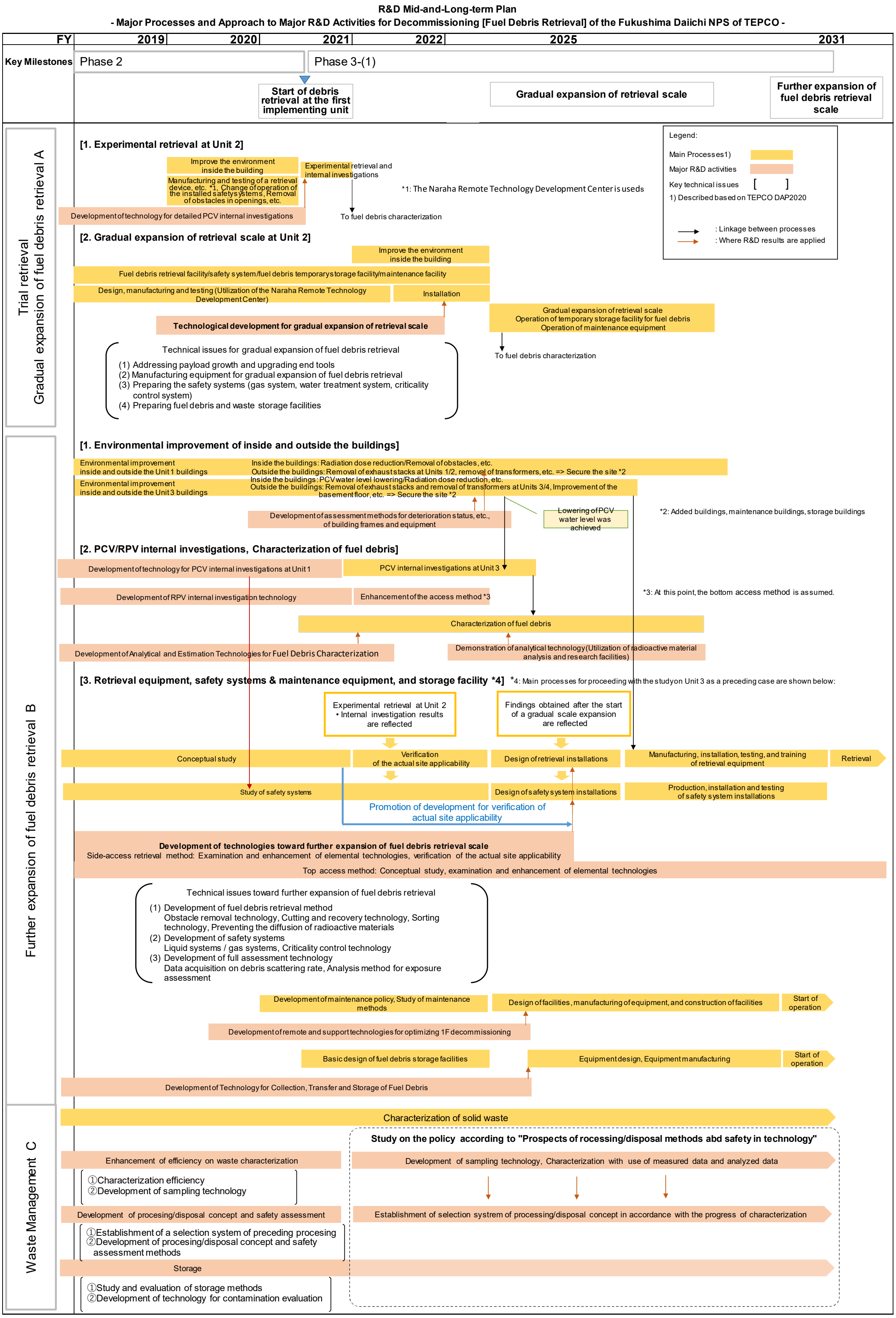
5-(1) Verification tests of tritium separation technologies (FY 2014 - 2015)

5-(2) Verification of technologies for contaminated water treatment (FY 2014)

5-(3) Large-scale verification of impermeable walls (frozen wall) (FY 2014)

5-(4) Development and verification of high-performance multi-nuclide removal equipment (high-performance ALPS) (FY 2014)

Attachment 13　R&D medium-to-long-term plan



Attachment 14　Basic Direction of 6 Essential R&D Themes

December 12, 2017
Nuclear Damage Compensation and Decommissioning Facilitation Corporation (NDF)

The Basic Direction of 6 Essential R&D Themes

The Mid-and-Long-Term Roadmap towards the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Station (September 26, 2017) specifies enhancement of the activities for matching the R&D required for decommissioning (Needs) with the basic and fundamental R&D (Seeds) and for human resource development. It also specifies enhancement of the functions of Japan Atomic Energy Agency's Collaborative Laboratories for Advanced Decommissioning Science (JAEA/CLADS) and promotion of joint researches with domestic and international universities and researching institutions to establish the international decommissioning research center with concentrated wisdom.

Following the above, the Ministry of Education, Culture, Sports, Science and Technology (MEXT) states in its budget request for FY2018 that they will reform the Center of World Intelligence Project for Nuclear Science and Technology and Human Resource Development ("World Intelligence Project") into a subsidy program intended for JAEA/CLADS and the program will be implemented under the system centered by JAEA/CLADS from the newly adopted proposals from FY2018.

On the occasion of this reform, MEXT showed NDF their intention to discuss how to proceed with the future R&D of the World Intelligence Project. This includes selection of the theme for the call for proposal considering the Essential R&D selected by the task force from the viewpoint of promoting basic and fundamental researches with satisfactory understanding of the Needs.

Therefore, concerning the 6 Essential R&D Themes which are described in the interim report of the Task Force on Research Collaboration (November 30, 2016), the Basic Direction of the 6 Essential R&D Themes was compiled including the background of the issues, the problem consciousness, and the expected research image, with consulting the discussions in the working group for each theme.

Theme	(1) To identity process of characteristic change in fuel debris over time
"Descriptions / Background issues" on the interim report	The fuel debris retrieval is scheduled for 2021 onward, 10 years after the fuel debris production. And since it is anticipated that the retrieval will require a long period of time, the fuel debris will remain inside the reactors over 10 years. In addition, the retrieved debris must be stored safely. Choosing the best possible methods of retrieve/transmission/storage of fuel debris requires predictions of characteristic changes of fuel debris over time.
Basic direction	In relation to the accident of Chernobyl nuclear power plant, detection of particulates of the micron order which contain fuel components from around the fuel debris has been reported and the national report of the Ukrainian government showed concerns about the increase risk of radioactive dust emergence over time through self-decay. One of the possible reasons is that the fuel debris with high radioactivity exposed to rich humidity caused rapid progress of aging which quite slowly proceeds with normal uranium mineral in the geological environment. It results in oxidation activated by radioactive dissolution and generate hexavalent uranium compound. On the other hand, because the PCV of the Fukushima Daiichi NPS (hereinafter referred to as "1F") is currently in the nitrogen atmosphere under subtle positive pressure, oxidation is unlikely to proceed immediately. In the future, such an event similar to the above may occur because the air that contains oxygen may flow into the PCV when a negative pressure control is applied to retrieve the fuel debris. Since the radiation level is about one order higher in 1F than that of the fuel debris in the case of the Three Mile Island Unit 2 (TMI-2) accident (occurred in a short time after the operation started), it is under unexperienced condition. In addition, it should be noted that it will take a longer period to complete the retrieval of the fuel debris from the time of accident than in the case of TMI-2. Various factors are involved in the aging of such fuel debris in addition to the oxidation described above. Roughly classifying, those factors may include the chemical mechanism (oxidation-reduction, leaching of included components, changes in the chemical form or the phase state, etc.), physical mechanism (structural or characteristic changes by heat cycle etc., irradiation damage by α-ray), and coupled actions of these factors. Since decay or leaching of fuel debris due to aging lead to emission of FP particles or gas, or effluent of particles that contain α-nuclides that are confined in the fuel debris, they have significant impact on the system design and procedures. It includes the retrieval mechanism, the cooling and circulating system, the containment function, the criticality monitoring system, the PCV gas control system, exposure evaluation, containing, transferring and storing, and processing and disposal. In particular, as for the Mid-and-Long-term Roadmap, while the processing and disposal method of the fuel debris will be

	decided in the third period (from 2022) after the retrieval of the fuel debris is started, obtaining the aging information of the fuel debris is an urgent issue. While taking into consideration the permission and authorization about the safety regulation, to provide sufficient prediction and explanation of the risk changes resulted from the aging of the fuel debris, it is required to clarify the real situation of what are expected to have critical impacts on the decommissioning works preferentially. Therefore, it is necessary to build a fundamental theory of the aging model by clarifying the aging process while using the current knowledge of the actinoid chemistry. To do so, demonstration test should be performed using real uranium according to the matrix pattern of parameters (temperature, pH, etc.) to collect basic data, and it needs to establish the prediction method of aging. In this case, it is important to maintain the foundations for advancement of the actinoid chemistry, which provides the basis for examination of the physical property of fuel debris. In addition, heat analysis for 1F should be included in the basis of investigation since the temperature distribution of the fuel debris has to be understood by calculating the heat distribution and the impact of regional temperature rise due to the decay heat should also be required to be examined.

Theme	(2) To elucidate corrosion mechanisms under unusual/extreme circumstances
"Descriptions / Background issues" on the interim report	It is required to collect data on corrosion under a variety of circumstances with consideration of the circumstances specific to 1F decommissioning such as high radiation levels and unsteady routes of cooling water in order to prepare for potential corrosion during decommissioning.
Basic direction	A boiling water reactor (BWR) consists of various metallic material. While stainless steel, which is corrosion resistant, is used inside reactor where it is high temperature and high oxidizing environment, carbon steel, which is not corrosion resistant, is used for the PCV that is the confinement boundary and is assumed to be used in the normal atmosphere. On the other hand, substantial knowledge has been collected so far about corrosion of structure and piping for commercial electric generation reactors, and especially, data has been collected being focused on the corrosion data in the environment of high radiation, high temperature, and deionized water for the operation of BWR. However, after the accident, 1F has been in a special environment with high radiation, room temperature, suspended solids and deposited materials. The knowledge about such environment is not sufficient. Since water has been injected into PCV to cool the fuel debris, carbon steel is dipped in the water. In addition, it is known that chemical species of oxidation nature such as hydrogen peroxide and various radical species have been generated through radiolysis of water. Currently, since nitrogen has been injected into PCV to prevent hydrogen explosion and the oxygen density has been decreased, the densities of the oxygen and the hydrogen peroxide are considered to be decreased in the water and corrosion of PCV is also considered to be suppressed in some degree. In the future, since the air containing oxygen flows into PCV when a negative pressure control is applied to retrieve the fuel debris, it is important to maintain soundness of the structure and pipes that form the boundary for confinement of radioactive materials and it is also important to prepare countermeasures based on the knowledge on corrosion in such environment. Since the corrosion is essentially a kind of battery reaction, it is likely to happen if the electric conductivity of water raises, pH falls, and the electric potential raises under the condition of declining of surrounding water quality. Although corrosion has been suppressed by nitrogen injection in general, it is still under the condition of potential corrosion. Regional changes of the environmental condition may lead to an increase of corrosion speed at the part. It is quite a special environment surrounded by various factors that promotes corrosion such as a formation of liquid film of dew, a humid environment that repeats wet and dry conditions near the water surface, an irregular flow of cooling water, convection flow, or backwater due to irregular paths created by gaps between various shapes of fallen objects or deposited materials, a progress of corrosion on the anode side between different kinds of metals touching each other, a progress of acid-base reaction by microbes, or any other potential factors. In the future, further changes may occur in the internal environment when the air that contains oxygen flows into the PCV when a negative pressure control is applied to retrieve the fuel debris. Since the corrosion progresses over time during the decommissioning works under the special environmental conditions, estimation of corrosion phenomenon and investigation of countermeasures are required based on the consideration on the environmental changes resulted from the progress of the decommissioning process. Therefore, it is necessary to collect basic data related to the progress of corrosion phenomena and systematically clarify and understand the phenomena in order to provide satisfactory prediction and explanation of the risk changes that follow corrosion of

	structures taking the permission and authorization of the safety regulation into account with giving priority to the factors of higher needs that may have critical impacts on the decommissioning works from the viewpoint of the probability of occurrence such as the factors above and the impacts on the functionality (parts and severity), the scale and the timing. In this case, in order to examine various approaches including not only the use of existing anti-corrosive agents but also electric protection, it is important to accumulate and maintain the knowledge related to the corrosion phenomena in addition to the electronic state of materials in a special environment through principle analysis and clarification of the corrosion progression mechanism.

Theme	(3) Radiation measurement technologies adopting innovative approaches
"Descriptions / Background issues" on the interim report	The radiation levels are still extremely high inside the 1F reactors/buildings due to the accident and the existing measurement devices do not meet the capability/functional requirements to provide accurate figures. It is vital to develop an innovational device adopting brand-new ideas/principles based on 1F needs.
Basic direction	Currently, radiation measurement can be performed following a predefined operation procedure without detail knowledge of measurement since a number of radiation measurement products using various principles or materials including ionization chambers, counting tubes, semiconductor detectors, and scintillation detectors are already offered. However, it is very important to develop the human resources for measurement since it is necessary to understand the principles of the equipment in order to interpret the measurement data and address possible troubles such as the case of the disorder (inversion of data value) between the all β-radioactivity value and the value of Sr-90 because miss-counting has not been taken into account for the resolution time in the analysis of the sampled water at the under-ground water observation hole on 1F. In addition, general radiation measurement products are not able to offer satisfactory performance and functionality to inspect the conditions inside reactors and buildings at the decommissioning site of 1F. The decommissioning works on 1F must be performed by remote operation since the radiation level is extremely higher than the one in the work environment of existing nuclear facilities. It is necessary to develop highly radiation resistant and small sized measurement sensor, electronic circuits, and systems in order to be remotely operated. In addition, it is necessary to research on the basic mechanism related to radiation damages of materials in order to develop highly radiation resistant sensors and circuits. As for the specific examples of sensor development, it is necessary to develop measurement devices of neutron from the viewpoint of criticality prevention, real time measurement of α-ray from the viewpoint of identification of the fuel debris, and ϒ-ray measurement with high energy resolution for nuclide estimation under the background of high gamma radiation, those what satisfy various needs: radiation resistance, noise resistance, size (small size), counting rate and responsiveness, high radiation resistance, energy discrimination, space resolution (identification of radiation source position), ease of operation, and maintainability. As for the composition of the measurement targets, development of the technology so-called "on-site analysis" is required since there are needs of functions that can be used to analyze the target without transferring a sample to other facility or equipment and obtain rough results used to promptly judge if the target is debris or not, and if the target is debris, the function to judge co-existence of reactor internals and neutron poison is required. In addition, effective support tools for the decommissioning can be provided by developing the technology to visualize the radiation field and the contamination situation and clarify the profile of the fuel debris based on the information of the strength and the direction of the radioactive sources. It is necessary to develop the generic technologies for innovative measurement of radiation using new ideas and principles by considering on-site measurement requirements.

Theme	(4) To clarify behavior of radioactive airborne particle generated during decommissioning (incl. α-dust treatment)
"Descriptions / Background issues" on the interim report	As thermal cutting of the fuel debris via machine or Laser may produce a large amount of α-dust, it requires safety measures and dust confinement solutions. It is necessary to understand physical/chemical properties of α-dust, to predict the amount of dust to be produced for each method, and to consider how to seal the dust according to the results in order to make sure the retrieval will be conducted in a safe and effective manner.
Basic direction	As the fuel debris retrieval work will start, cutting the fuel debris will create a lot of radioactive airborne particles (α-dust) that contain α-nuclide and they will be dispersed

	within the boundary. When retrieving the fuel debris, since the work will be performed in the confinement boundaries which are the broken buildings, it is important to understand the property of the α-dust for studying how to secure the confinement capability, designing the filtering system, and performing the exposure evaluation of the surrounding environment and workers including the time of accident. With regard to the data about the scattering rate when α-dusts are generated, there is the data obtained at the decommissioning of JAEA's JPDR and the dismantling of glove box of JAEA's Nuclear Fuel Cycle Engineering Laboratories. However, the data has not been collected just for the nuclear fuels but collected for the objects polluted by the nuclear fuels, and the data has been collected for the amount of the radioactive materials and their densities from the viewpoint of radiation exposure control and it is not systematically organized. On the other hand, the radioactive airborne particles in 1F will be generated directly from the fuel debris when retrieving the fuel debris and from the polluted objects in the decommissioning process. The types of radioactive materials are α-nuclides and β (ϒ)-nuclides. While the α-nuclide of which typical element is plutonium is important from the viewpoint of internal exposure, the β(ϒ)-nuclide such as cesium should be well considered as well from the viewpoint of the total exposure evaluation. In order to study on collection of radioactive airborne particles, efficient filtering and purification, criticality prevention, etc., it is necessary to grasp the amount of generated particles, distribution of particle diameters, radioactive diameters, and the physical and chemical property of particles according to the differences of the target objects and the method of cutting. It is also important to understand the behavior of the generated particles in the gas phase, at the air-liquid interface, and in the liquid phase during transportation or transition. For example, it is important to understand the growth of particles through coagulation in the gas phase, evaluation of mist generation from the air-liquid interface, leaching behavior of the components into the water of the liquid phase, transportation behavior such as settling of particles in the water or filtering, etc. With regard to the exposure evaluation of radioactive airborne particles, it is important to evaluate the impact of exposure to radioactive materials derived from the fuel debris, especially the one of α-nuclides. In this case, it is important to decide whether the conventional exposure evaluation methods can be applied by judging if the chemical form and the particle diameter of the radioactive airborne particles represented by plutonium is consistent with the ones that have been used as the criteria of internal exposure evaluation for plutonium.

Theme	(5) To understand fundamentally mechanisms of radioactive contamination
"Descriptions / Background issues" on the interim report	To figure out the mechanism of radioactive contamination towards effective decontamination; it is critical to implement effective approaches of decontamination based on the mechanism of the contamination to radiation sources, and to decrease the volume of radioactive wastes as well.
Basic direction	With regard to reduction of the radiation in the buildings, the target object of decontamination are pipes and ducts, metals in the equipment, resins in cables and so on, paints, and concretes of the walls or floors. The contamination source includes molten high temperature fuels at the time of accident, steams that contain radioactive materials such as Cs leaked in consequence of hydrogen explosion and so on, dusts and contaminated water that contain radioactive materials. Currently, as for radiation reduction in the buildings on 1F, decontamination of floors and walls has only limited effects since there are other contamination sources such as objects remained in pipes, and hidden side behind the pipes located at high inaccessible positions. In the future, when considering each step in the long decommissioning process, it is expected that many situations that require decontamination will arise, therefore, effective and efficient decontamination is considered highly necessary. With regard to decontamination, not only reduction of radiation but also reduction of wastes should be taken into consideration. For decontamination, while engineering approaches are required, including physical methods such as dry ice blast, chemical methods such as chemical decontamination using chemicals such as acid or alkali, and decontamination methods using parting agents, it is indispensable to understand the contamination mechanism of target objects in order to perform such decontamination activities effectively. In the field of researches for clarifying the contamination mechanism, there are a sufficient number of existing researches on the metal materials, which are used in pipes, tanks and so on to confine radioactive materials. However, there is almost no research on the concrete of structures or radiation shields that does not directly touch radioactive materials.

	The inside the buildings of 1F is widely contaminated by the radioactive materials emitted by the accident. Since most parts of the buildings consist of concrete, it is important to clarify the contamination mechanism of both concrete and radioactive materials in principle in order to reasonably and effectively manage concrete wastes resulting from the decontamination and the process of decommissioning. Therefore, the contamination mechanism must be clarified in principle on the concrete exposed to the accident and the subsequent environment and the process of decommissioning by obtaining the basic data about sorption, penetration, and leaching of the typical nuclide (Cs, Sr, U, Pu, etc.) that should be well considered. In addition, from the mid-and-long-term viewpoint, it is necessary to establish the evaluation method based on the understanding of the contamination mechanism including the changes over time in the contamination state and the penetration behavior in the concrete. Even though a number of researches have been conducted on removal of contamination source in pipes during nuclear fuel reprocessing regarding the contamination mechanism of the metal of the piping and equipment by radioactive materials, few number of researches are found on the contamination mechanism of the metal of the piping and equipment in the environment of the 1F. While it is considered necessary to clarify the contamination mechanism inside PCV or RPV exposed to the high temperature environment at the time of accident, it is not necessary to take into consideration a special contamination mechanism such as penetrate into metals outside PCV. As for the decontamination mechanism of resins and paints of cables, it is considered that it not necessary to conduct a special research on decontamination since they can be replaced or removed.

Theme	(6) Environmental fate studies of radioactive materials generated during decommissioning
"Descriptions / Background issues" on the interim report	It is essential to clarify the behavior of radioactive materials such as adsorption, dispersion, moving along with groundwater flow in shallow underground in order to conduct environmental fate studies to ensure they will not affect the environment.
Basic direction	In order to properly evaluate and reduce the risk of future environmental impact caused by radioactive materials in the Fukushima Daiichi NPS site, it is necessary to provide proper evaluation and estimation of the environmental fate of radioactive materials around the site via the shallow underground water and the surface water, or the ports, the marine, and the air, and to provide appropriate environmental countermeasures. Targeted radioactive materials are (1) the radioactive materials that exist in the ground or on the surface of the ground through the contaminated water leaked just after the accident (^{137}Cs, ^{90}Sr, ^{3}H, etc.), (2) the radioactive materials that poured into the ports in past and accumulated on the bottom of the sea (^{137}Cs, ^{90}Sr, etc.), and (3) the radioactive materials that are contained in the contaminated water that will be generated as the result of retrieval of the fuel debris or decommissioning and dismantling of the buildings (including ion such as actinide and suspended solids) that can be the future source term impacting environment. In order to estimate the impact of radioactive materials on the surrounding environment, it is indispensable to understand the existence form and the transport behavior of the radioactive materials as the required basic knowledge. Specifically, the targets include the existence form of the radioactive materials in the underground water, the distribution in the soil, the advection and diffusion behavior in the underground water, the existence form and the advection and diffusion in the surface layer, the existence form and the molten and diffusion behavior of the radioactive materials in the seawater in the port and on the bottom of the sea, and the transportation behavior to the surrounding environment through marine or air. Although all of those depend on the characteristic of the intermedium such as the property of soil and the geological condition, since the measurement work on 1F is limited, it is necessary to aim at establishing the evaluation method in a similar environment. In addition, in order to provide the accurate future estimation of the environmental fate, it is also necessary to develop the monitoring technology to identify the accurate contamination condition and the analysis technology to simulate the transportation behavior of the radioactive materials. As for the monitoring technology, the technology for long term and continuous remote measurement and the mapping and behavior identification technology using the big data are expected. As for the simulation technology, the creation model that can be used to analyze the behavior (influence of unsaturated layer, kinetic evidence, etc.) specific to shallow underground and the estimation technology using the code are expected. It is also important to aim at reducing the risk of the radioactive materials as environmental countermeasure. While a number of technologies can be developed

	including control of the amount of underwater, soil improvement, stabilizing agent, adsorbent for purification of contaminated materials, and the permeable reaction wall, it is necessary to examine the factors that have priority since they may have critical influence on the decommissioning works. In order to provide reasonable environmental fate studies for the radioactive materials, it is important to proceed with considerations on the risk of environmental influence so the development of the evaluation method related to the risk of environmental influence has to be taken into account from this viewpoint.

Attachment 15 Recruitment brochure for manpower development training on the decommissioning of TEPCO Fukushima Daiichi NPS

東京電力・福島第一原子力発電所（1F）の廃炉に関する人材育成研修のご案内

第1回　2019年12月11日（水）～13日（金）
第2回　2020年2月5日（水）～7日（金）

現在、福島第一原子力発電所では、毎日3000人以上の方が廃炉作業に従事しており、今後も廃炉作業に従事する人材の確保・育成が急務です。

原子力損害賠償・廃炉等支援機構（NDF）と日本原子力研究開発機構（JAEA）は、**1Fの廃炉に携わる地元企業やメーカー等の技術者等（設計者、技術者、研究者）の方々を対象**に、「1F廃炉全般に関わる基礎知識の習得」、「1F廃炉に携わる技術者等が共通して有することが望ましい技術の習得」を目的とした「廃炉人材育成研修」を開催致します。

研修では、「現在の1F各号機の炉内状況」、「1F事故に伴い生成した燃料デブリの性状」、「燃料デブリ、破損燃料等α放射性物質の取扱い」などについて、専門家や担当者から最新の情報をお伝えするほか、1Fの現場の視察なども行う予定です。

主催者	：原子力損害賠償・廃炉等支援機構（NDF） 国立研究開発法人　日本原子力研究開発機構（JAEA）
会場	：ホテル蓬人館(ホウジンカン) 福島県双葉郡富岡町小浜44-2
参加費	：無料　（※宿泊費、会場までの交通費は参加者負担です）
対象者	：1Fの廃炉作業に従事する、または今後従事する予定の技術者、設計者、研究者（大学の教員、学生は除く）
募集人数	：第1回、第2回ともに50名程度
申し込み方法	：下記のJAEAのホームページから申し込みください。 **https://nutec.jaea.go.jp/index.php**

（注）
原則として先着順で参加者を決定しますが、より多くの企業の方に受講していただけるよう、**1社あたりの申し込み数は、2名までとします。**
また、1日単位での受講も受け付けております。
詳細は、JAEAのホームページをご覧ください。研修プログラムは、裏面をご参照ください。

申し込み開始日（第1回）：2019年10月16日
締切日（第1回）：2019年11月14日
（募集人数に達し次第締め切ります）

1F1号機側からの外観（東京電力ホールディングス提供）

第１回廃炉人材育成研修プログラム（案）

12月11日	【初日】　会場：蓬人館	講師所属
(10:00)	（富岡駅着）	
10:30～10:45	開講挨拶、オリエンテーション	
10:45～12:45	1F事故の内容と現在の1Fサイト状況	東京電力ホールディングス㈱
12:45～13:30	昼休憩	
13:30～14:30	各号機の炉内状況	東京電力ホールディングス㈱
14:35～15:05	1F廃止措置等に向けた中長期ロードマップ	経済産業省
15:10～15:40	1F廃炉のための技術戦略プラン	原子力損害賠償・廃炉等支援機構
15:45～16:45	廃炉研究開発の状況（廃炉・汚染水対策事業）	国際廃炉研究開発機構
16:50～17:35	廃炉研究開発の状況（英知事業他）	日本原子力研究開発機構
(18:00～19:45)	情報・名刺交換会（任意参加、自己負担）	
12月12日	【二日目】　会場：蓬人館	
9:00～10:00	海外における炉心溶融を伴う事故事例	原子力損害賠償・廃炉等支援機構
10:05～11:05	レガシーサイト（ー海外核汚染サイトのデコミッショニングー）	電力中央研究所
11:10～12:10	燃料デブリの性状	日本原子力研究開発機構
12:10～12:55	昼休憩	
12:55～13:55	燃料デブリ、破損燃料等α放射性物質の取扱い	日本原子力研究開発機構
14:00～15:00	遠隔操作技術ー高線量率下で動作可能なロボットの技術ー	国際廃炉研究開発機構
15:05～16:35	1F放射性廃棄物の特徴、取扱いとその分析技術	日本原子力研究開発機構
16:40～17:40	燃料デブリ取り出し時の臨界管理技術	国際廃炉研究開発機構
12月13日	【三日目】	
10:00～	施設見学（1F（バス車窓より）、JAEA楢葉センター）	

形状変化型ロボット
（国際廃炉研究開発機構提供）

※　講師都合等により、プログラムに変更が生じることがあります。

※　第２回のプログラムは、第１回のプログラムと同様です。

問い合わせ先：日本原子力研究開発機構　原子力人材育成センター

Tel：

Email：

Attachment 16 Major activities related to enhancing international collaboration

Table A16-1 Intergovernmental Framework between Japan and other countries

Framework	Descriptions
Annual Japan-UK Nuclear Dialogue	This dialogue is held based on the appendix to the joint statement of the Japan-UK top level meeting in April 2012, “Japan-UK Framework on Civil Nuclear Energy Cooperation” (Since February 2012).
Japan-France Nuclear Energy Committee	It was established under the joint statement of Japan–France top-level meeting in October 2012 (Since February 2012).
Japan-US Decommissioning and Environmental Management Working Group	After the Fukushima Daiichi NPS accident in March 2011, the establishment of the US-Japan Bilateral Commission on Civil Nuclear Cooperation (the Bilateral Commission) was announced in April 2012 based on the relationship between Japan and the US to further reinforce bilateral cooperation. Under this commission, “the Decommissioning and Environmental Management Working Group (DEMWG)” was established (Since December 2012).
Japan-Russia Nuclear Working Group	The Nuclear Working Group was established after confirming that Energy is one of the eight areas of cooperation plan approved at the Japan-Russia top-level meeting in September 2016, (Since September 2016).

Table A16-2 Inter-organizational Cooperation Agreement

Domestic	International	Descriptions
NDF	NDA	Exchange of information for various technical knowledge on decommissioning, etc. and personal exchange are provided. (Concluded in February 2015)
NDF	CEA	Exchange of information for various technical knowledge on decommissioning, etc. and personal exchange is provided. (Concluded in February 2015)
TEPCO	DOE	Umbrella Contract was made and information is exchanged as needed. (Concluded in September 2013)
TEPCO	Sellafield, Ltd.	Information Exchange Agreement for site’s operation, etc. was concluded. (September 2014)
TEPCO	CEA	Information Exchange Agreement on for decommissioning was concluded. (September 2015)
JAEA	NNL	Comprehensive Agreement for advanced technology on nuclear R&D, advanced fuel cycles, fast reactor, radioactive waste
JAEA	CEA	Cooperation Agreement for specific technical issues on molten core-concrete interaction, etc.
JAEA	Belgium Nuclear Research Center	Agreement of Cooperation for Nuclear R&D and Research on the accident of the Fukushima Daiichi
JAEA	Nuclear Safety Research Center (Ukraine)	Memorandum for decommissioning research, etc. of the Fukushima Daiichi NPS and Chernobyl was concluded.
JAEA	IAEA	Research Agreement on characterization of fuel debris

Table A16-3 Dissemination of information to the world (Holding or attending International Conference (from April 2019 to August 2020))

Conference Name	Period	Organization
ATOMEXPO2019	April, 2019	NDF METI TEPCO
INSIDER Project Meeting	May, 2019	NDF
International Meeting on Fukushima Decommissioning Research 2019 (FDR2019)	May, 2019	METI
The 27th International Conference on Nuclear Engineering (ICONE27)	May, 2019	IRID
WTO/SPS Committee, Briefing for EU countries	July, 2019	METI
The 60th Annual INMM Meeting (US)	July, 2019	NDF
The 4th International Forum on the Decommissioning of the Fukushima Daiichi NPS	August, 2019	NDF
The 63rd IAEA Conference Side event	September, 2019	NDF METI JAEA
10th International Conference on Isotopes	February, 2020	NDF
The 4th UK-Japan Nuclear Industrial Forum	February, 2020	NDF METI
ICONE International Conference, Fukushima Session	August, 2020	TEPCO
The 64th IAEA Conference Side event	September, 2020	NDF METI TEPCO
Fukushima Research Conference	Year round	JAEA

Table A16-4 Dissemination of information to the world (on web (in English)

Site	Organization
Mid-and-long-term Roadmap towards the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Station Units 1 to 4 （http://www.meti.go.jp/english/earthquake/nuclear/decommissioning/）	METI
Monthly report to the embassies concerning discharging and seawater monitoring from the Fukushima Daiichi NPS	METI, MOFA
Nuclear Damage Compensation and Decommissioning Facilitation Corporation's website （http://www.dd.ndf.go.jp/eindex.html）	NDF
Information Portal for the Research and Development for the Fukushima Daiichi Decommissioning (http://www.drd-portal.jp/en/)	NDF
Activities for Decommissioning（https://fukushima.jaea.go.jp/english/）	JAEA
IRID website (http://irid.or.jp/en/)	IRID
Fukushima Daiichi Decommissioning Project （http://www7.tepco.co.jp/responsibility/decommissioning/index-e.html）	TEPCO
Providing English version of Press release to foreign media	TEPCO
Management Office for the Government-led R&D program on Decommissioning and Contaminated Water Management(https://en.dccc-program.jp/)	MRI (Business consignee)

Table A16-5 Major collaborative projects with foreign organizations

Project	Contents/Period of project	Participating Organization
IAEA Project		
DAROD	・Knowledge and experience obtained from the efforts on challenges of decommissioning and recovery of damaged nuclear power facilities (regulations, technologies, systems, and strategies) are shared among the relevant countries. ・Project period : 2015 to 2017	NDF
OECD/NEA Project		
BSAF	・Researching institutions and governmental organizations from eleven countries joined to conduct benchmark study using severe accident analysis codes developed by these organizations to find out how the accident in the Fukushima Daiichi NPS progressed and how the fuel debris and FPs spread inside the reactors. Knowledge and findings related to the modeling of phenomenological issues obtained by member countries' organizations are being utilized. ・Data measured during the accident and information database regarding the post-accident radiation levels are shared. ・Project period : 2015 to 2018	IRID JAEA TEPCO
ARC-F	・In succession to the BSAF project, researching institutions and governmental organizations from twelve countries joined	NRA IR

	to investigate the situation of the accident in more detail and utilize it for further researches to improve safety of light-water reactor ・Project period : 2019 to 2021 (scheduled)	JAEA
PreADES	・Sharing characteristics information that helps to understand properties of fuel debris such as its phase state and composition. ・Enhancing "Fuel debris Analytical Chart" that summarizes needs and priority of fuel debris analysis. ・Maintenance of tasks after analysis and analysis facility information ・Project period : 2018 to 2020 (scheduled)	METI NRA IR JAEA IRID NDF TEPCO
TCOFF	・In reference to the accident progression of the Fukushima Daiichi NPS, (1F) advancing molten core and molten fuel models, FP migration behavior model and thermodynamic database as their basis. Based on the material scientific knowhow, evaluating details of molten core and fuel on condition of 1F accident, and characteristics of fuel debris and its producing mechanism. Then, providing material scientific knowhow and result of detail evaluations to international cooperation project including PreADES, ARC-F, TAF-ID, and domestic decommissioning project like IRID. ・Project budget was contributed from MEXT. ・Project period : 2017 to 2019	MEXT JAEA IR Tokyo Institute of Technology
EGCUL	・Discussing on characterization method for waste from unknown derivation	METI NDF JAEA TEPCO