# Technical Strategic Plan 2017
# for Decommissioning of the Fukushima Daiichi
# Nuclear Power Station of
# Tokyo Electric Power Company Holdings, Inc.

## Overview

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Nuclear Damage Compensation and Decommissioning

Facilitation Corporation

NDF

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# 1. Introduction

Since 2015, the Nuclear Damage Compensation and Decommissioning Facilitation Corporation (NDF) has annually developed the Technical Strategic Plan for Decommissioning of the Fukushima Daiichi Nuclear Power Station of Tokyo Electric Power Company Holdings, Inc. (hereinafter referred to as "the Strategic Plan"). This is the part of NDF’s statutory obligations to provide advice, guidance and recommendations for ensuring an appropriate and steady implementation of the decommissioning of the Fukushima Daiichi NPS and R&D projects for technologies required for decommissioning based on the Nuclear Damage Compensation Facilitation Corporation Act (hereinafter referred to as “the NDF Act”).

Six years have passed since the accident at the Fukushima Daiichi NPS. In this period, we have made some progress in various activities such as building land-side impermeable walls as a part of contaminated water management, removing spent fuel from the spent fuel pool and improving the outdoor work environment. We have gained some prospect for short-term measures. Moreover, from a mid-and long-term perspective, it has been revealed recently that the work environment inside the buildings for the future activities is very severe. On the other hand, steady progress has been made in the investigation inside the reactors and the R&D projects.

An amendment of the NDF Act was passed in May 2017. This amendment requires Tokyo Electric Power Company Holdings, Inc. (hereinafter referred to as "TEPCO"), the operator of the Fukushima Daiichi NPS, to deposit the necessary funds for decommissioning with the NDF, to ensure the implementation of decommissioning as the decommissioning project moves to the phase of addressing mid- and long-term issues. In addition, in the Revised Comprehensive Special Business Plan (The Third Plan), which was made public in the same month, it is stated that the decommissioning of the Fukushima Daiichi NPS is the major premise for the restoration of Fukushima and should be implemented in an appropriate and steady manner.

Based on the amendment, the NDF is responsible for managing and supervising the implementation of decommissioning by TEPCO. NDF will: 1) manage the funds for decommissioning; 2) manage the implementing structure of the decommissioning process; and 3) manage the decommissioning work under the decommissioning fund reserve system. The NDF will have more increased role and responsibility in such as project management.

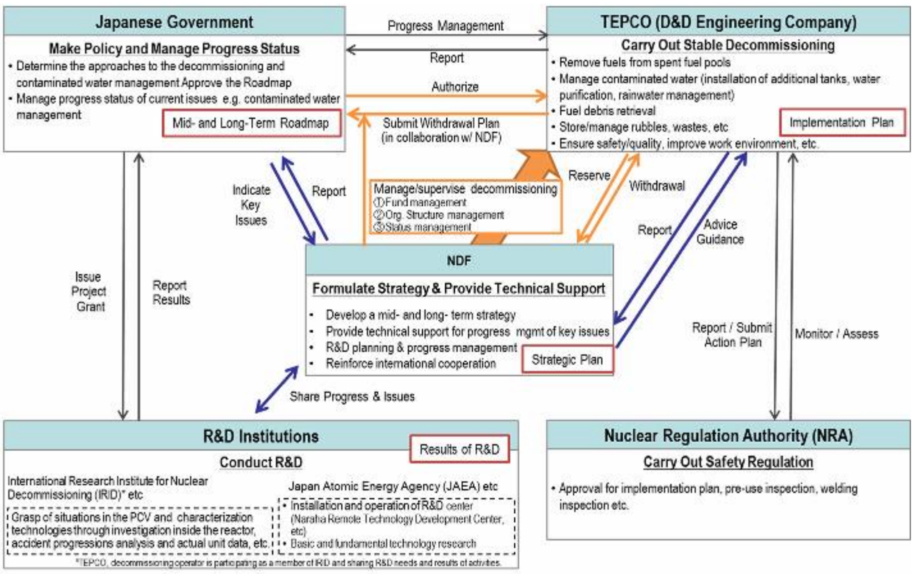



Fig.1 Roles and Responsibilities of Organizations Relevant to Fukushima Daiichi NPS Decommissioning

# 2. Strategic Plan

## 1) Purpose and positioning of the Strategic Plan

The purpose of the Strategic Plan is to provide a technical basis for contributing to the implementation and revision of the Government-developed Mid-and-Long-Term Roadmap towards the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Station (hereinafter referred to as "the Roadmap"). The Strategic Plan 2017 provides strategic proposals for determination of fuel debris retrieval policies for each unit and compilation of the basic concept of solid waste management, which are parts of the milestones mentioned in the revised version of Roadmap (as of June 12, 2015).

The decommissioning of Fukushima Daiichi NPS is a project in which considerable uncertainty inheres. As a result of the accident, the reactor interior and surroundings are in a radioactive environment and workers are unable to have access there easily. Accordingly, the properties of radioactive materials and the damages of on-site equipment and structures left there remain unknown, posing uncertainty.

It is desirable if all the information that is currently difficult to confirm could be collected to eliminate such uncertainty before starting decommissioning; however, many resources, especially a considerably long time, are required to do so.

To realize prompt decommissioning, it is necessary to assume the attitude of taking flexible and prompt approach, based on the directions determined with previously obtained experience and knowledge and with experiment- and analysis-based simulation, placing safety at the top priority, even though a certain extent of uncertainty remains.

To proceed with decommissioning flexibly and promptly, the attempt of optimizing the entire project from the long-term and comprehensive viewpoint, and the attitude of making preparations for unexpected cases, are also important.

The two Strategic Proposal herein has developed based on this basic attitude.

## 2) Basic concept of the Strategic Plan

i. **Fundamental policy**

The Fukushima Daiichi NPS has the necessary safety measures in place that are required by the NRA in “the matters for which measures should be taken” (hereinafter referred to as “Matters to be addressed”) and is maintained in a state with a certain level of stability. However, there may still be increase of risks posed by radioactive materials resulting from aging degradation of the facility. For this reason, "to continuously and promptly reduce the risks posed by the radioactive materials generated by the accidents" is the fundamental policy of decommissioning of the Fukushima Daiichi NPS.

ii. **Five guiding principles**

Five Guiding Principles important to achieve the fundamental policies above are described below.

- Principle 1: Safe- Reduction of risks* posed by radioactive materials and ensuring work safety *Environmental impacts and exposure to the workers
- Principle 2: Proven- Highly reliable and flexible technologies
- Principle 3: Efficient- Effective utilization of resources
  (e.g. human, physical, financial and space)
- Principle 4: Timely- Awareness of time axis
- Principle 5: Field-oriented- Thorough application of Three Actuals

(actual field, actual things and actual situation)

## 3. Strategy for reducing risks posed by radioactive materials

In the Strategic Plan, a mid- and long-term strategy for the reduction of the risks posed by the radioactive materials will be developed to achieve the fundamental policy of the decommissioning of the Fukushima Daiichi NPS. For this purpose, the major risk sources will be analyzed, evaluated, and risk reduction measures will be studied.

### 1) Progress in decommissioning of Fukushima Daiichi NPS

Over the last year, progress has been made in the following areas.

(1) Contaminated water management

Measures for managing contaminated water based on three principles (removing the contamination source; isolating groundwater from the contamination source; and preventing leakage of contaminated water) are in place.

In removing the contamination source, they are treated with the multi-nuclide removal equipment.

In isolating groundwater from the contamination source, freezing operation of the land-side impermeable walls started in March 2016. The operation on the sea side was completed in October 2016. The operation on the mountain side is yet to be completed only at one location. After the operation on the sea side was completed, the amount of groundwater pumped up from the area 4m above sea level was reduced to one-third (an average of about 118 $m^3$/day in March 2017). The stagnant water in the buildings was treated and the groundwater level around the buildings was reduced using the subdrain system. As a result, the amount of groundwater flowing into the buildings decreased to an average of about 120 $m^3$/day in March 2017.

In preventing leakage of contaminated water, the concentration of radioactive materials in the surrounding sea area is constantly low.

The stagnant water in the buildings has been treated in a steady manner with the goal of completing the treatment in 2020. The stagnant water level in the Unit 1 Turbine Building was reduced to the lowest floor level in March 2017.

(2) Removal of spent fuel from the spent fuel pool

Unit 1: The removal of the cover wall panels for the Reactor Building was completed. An investigation on the operating floor was started and information gathering on the rubble and the fuel handling machine that is required to develop a rubble removal plan is in progress.

Unit 2: For fuel removal, a yard around the Reactor Building was prepared and a working platform for access to the operating floor was constructed.

Unit 3: Measures to reduce the dose rates on the operating floor (decontamination and shielding) were completed. Installation of a cover for fuel removal was started in January 2017.

(3) Fuel debris retrieval

The following activities to investigate the conditions in the reactor for fuel debris retrieval have been performed.

Unit 1: In a robotic investigation of the conditions in the primary containment vessel (PCV), a dosimeter and a camera were hung down from the first floor of the PCV to investigate the current conditions in the basement outside the pedestal and in the vicinity of the access opening of the pedestal.

The dose rates were higher at locations closer to the bottom of the PCV. A deposit of unknown substances was found at the bottom.

Unit 2: A PCV internal survey using a robot has found fallen/deformed gratings inside the pedestal.

Unit 3: An investigation into internal PCV using a remotely operated underwater survey vehicle (hereinafter referred to as underwater ROV) revealed that there are some material which seems to be melted substance turned into solid, some fallen stuff including and grating and some other deposited materials inside the pedestal. Moreover, current evaluation of muon measurement data indicates any large-sized high density materials were not identified in RPV including both reactor area and the bottom, though there might be some fuel debris remaining there.

(4) Waste management

The waste reduction measures are continued to be in place. An operation to reduce waste protective clothing with an incinerator was started. The projected solid waste generation was revised and the Solid Waste Storage Management Plan was updated. Sampling and analysis is underway in order to characterize the solid waste.

(5) Other specific measures

Since the rubble removal and facing in the area 4m above sea level intended for improving site environment have resulted in the reduced risks of contamination, the classification for the protective equipment has been changed to “ordinary clothing area” where the workers are allowed to enter and work in general workwear or in on-site safety workwear with disposal dust-proof mask.

## 2) Basic thought in reducing risk of radioactive materials

The principle for risk reduction is the reduction of magnitude of the risk caused by the risk sources (herein after referred to as “the risk level”) and ensuring/retaining promptly the risk levels be adequately low. The risk reduction may properly be achieved by combining the activities/means for reducing the significance of negative impacts on human health and environment caused by the risk sources (hereinafter referred to as “the level of impact”) and activities/means for reducing the possibility of being affected by the negative impacts (hereinafter referred to as “the likelihood of impact). It is also important to develop optimal risk reduction measures based on the “Five Guiding Principles”.

i. **Major risk sources**

The major risk sources to be studied at the Fukushima Daiichi NPS are as follows;

- Fuel debris in Units 1-3, fuel assemblies stored in Units 1-3 SFP, fuel assemblies in the common pool and fuel assemblies in the dry casks.
- Contaminated stagnant water in Unit 1-4 buildings, in the Main Process Building and in the High-temperature Incinerator Building (hereinafter referred to as “the stagnant water in buildings”), and concentrated liquid waste accumulate in the tanks (including the water used for strontium removal)
- Solid Waste
  - Secondary waste generated from the water treatment system (waste adsorption columns, waste sludge and slurry stored in the high integrity container (hereinafter referred to as HIC slurry))
  - Rubble store in the solid waste storage facilities (hereinafter referred to as “rubble

(storage facility)" and rubble/felled trees covered with soil or stored in temporary storage facilities (hereinafter referred to as "rubble, etc.(outdoors)"

- Structures, pipes, equipment and other components in the R/B, PCV and the RPV which were contaminated by fission products released in the accident, and activated structures (hereinafter referred to as "the contaminated structures in building").

ii. **Risk estimation and evaluation**

The risk level is defined by the combination of the level of impact in case of the release of radioactive materials contained in the above mentioned risk sources and the likelihood of the impact.

In this section, risk estimation and evaluation is performed based on the SED (Safety and Environmental Detriment) score developed by the U.K. Nuclear Decommissioning Authority (NDA).

The Hazard Potential in the SED was used to indicate the level of impact. The Hazard Potential is defined as the amount of radioactive materials contained in the risk source, taking into account the form of risk sources such as gas, liquid and solid in terms of likelihood of spreading and getting into human body/environment and the available time for recovery in the event of a loss of safety function to control the inherent instability of the risk source.

The Safety Management in the SED was used as an index to indicate the likelihood of impact. The Safety Management consists of combination of the factors for ranking integrity of the facility and containment function of the risk sources, and the factor for ranking a possibility of change in the state of the risk sources. A score is given to each factor.

Fig. 2 shows the sample of the risk levels of the major risk sources based on information as of March 2017.

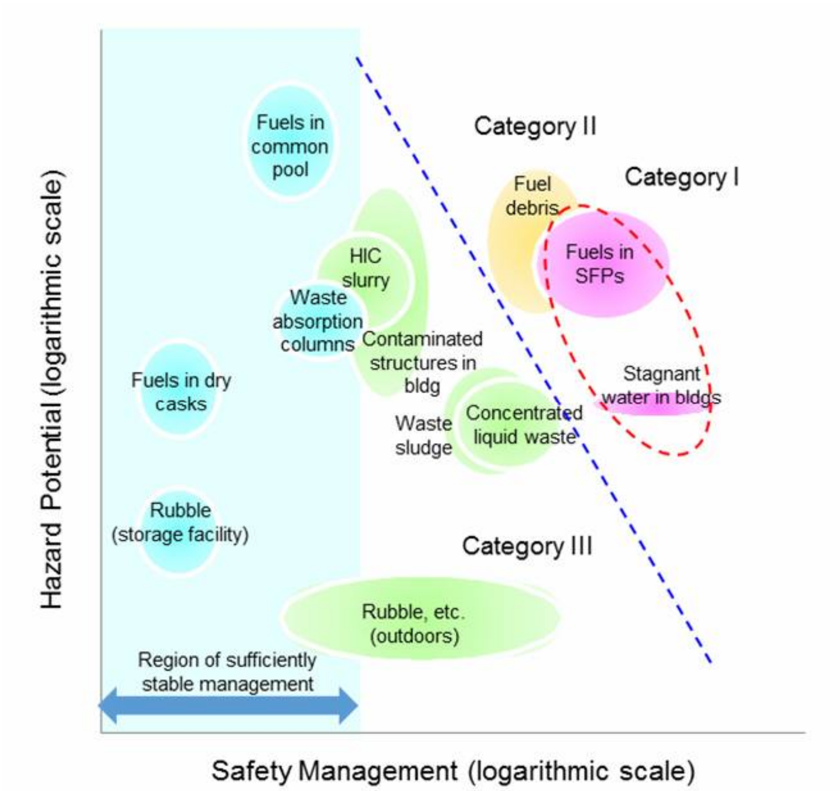



Fig. 2 Risk level of risk source at the Fukushima Daiichi NPS

In Fig. 2, the effect of uncertainty of data on scoring the Hazard Potential and the Safety Management is represented by the area. The uncertainties anticipated in the concentrations, amount and properties of radioactive materials and the time available for recovery are considered in the Hazard Potential. A higher degree of uncertainty in properties is considered for the contaminated structures in buildings and fuel debris.

The width of score band was considered as an uncertainty in the Safety Management, because the two factors are originally judged with qualitative information, and a quantitative score is assigned to each judgement result. Different storage conditions were considered for rubble, etc. (outdoors).

The risk level was evaluated by comparing different risk sources. It will be appropriate to classify the risk sources in three categories as shown in Fig. 2, and develop risk reduction measures based on the classification.

The fuels in common pool, the fuels in dry casks, rubble (storage facility) and the waste adsorption columns can remain stable enough by managing them in the same way continuously. They are evaluated to be stored and managed in the same level of stability as radioactive materials stored in the facilities of a nuclear power station that has not damaged by a severe accident. Therefore, the interim goal of risk reduction for the risk sources of categories I, II and III is to bring their risk levels into the range where the risk levels of the fuels in common pool, the fuels in dry casks, rubble (storage facility) and the waste absorption columns are residing.

iii. **Current status of risk reduction measures**

The major risk reduction measures taken or under consideration against the risk sources categorized in the previous section are as follows;

< Category Ⅰ > Risk source to be addressed as soon as practicable

The radioactive materials contained in the fuels in SFPs are assemblies of fuel pins covered with cladding, and are unlikely to spread out in terms of their form. However, the buildings of Units 1 and 3 have been damaged and the ceiling of the building has been partially lost, and fallen objects such as rubble and heavy structures have been found at the operation floor of the buildings. The fuels in SFPs are planned to be transferred to the common pool, where the Safety Management is sufficiently low. Preparation works for removal of rubble are underway toward fuels transfer to the common pool. In Unit 3, the removal operation of large rubble fallen into SFP was completed and therefore the Safety Management of fuels in SFP of Unit 3 was reduced.

Operations toward reduction of radioactive materials in the stagnant water in buildings are underway, by such means as drain of contaminated water in the condensers at Unit 1 turbine building, and removal of stagnant water in the lowest floor in Unit 1 turbine building. Moreover, the water level control has been improved by increasing subdrainage capability and closing land-side impermeable walls partly in order to keep the level of stagnant water in the building lower than that of groundwater. The efforts to reduce radioactive materials such as removing contaminated water in the condenser in the turbine building with high concentration of radioactive materials are still underway.

< Category II> Risk source to be addressed safely, effectively and carefully with thorough preparations and technologies to realize a more stable condition

The fuel debris is currently under a certain level of containment stability. However, as they have been spread in different locations and are in a variety of forms and their forms/characteristics may change over mid- and long-period of time. Technological studies/developments are underway toward prompt removal and appropriate safe storage of fuel debris.

< Category III > Risk source that requires actions to be taken for a more stable condition

Risk sources in Category III should be dealt with towards ensuring reduced risk levels and adequately stable storage condition. The risk sources of this category are; concentrated liquid waste, waste sludge, HIC slurry, rubble, etc. (outdoors) and contaminated structures in the buildings.

The risk levels of Category III risk sources are lower than those of risk sources of Categories I and II in general. And it is expected that certain risk levels could be sustained by implementing continuous maintenance and management. These risk sources, however, include surface contamination, sludge form waste and reactive materials which may generate hydrogen. Thus, it is necessary to make continuous effort toward reduction of risk levels and bring them into adequately safe and stable condition, by implementing appropriate measures in planned manner.

iv. **Challenges during risk reduction**

It is necessary to consider a temporary change in the risk level and the exposure of workers when implementing risk reduction measures.

Even if the risk source is currently in a certain stable condition, it will not be tolerated for a long period of time. In addition, the level of the risk may rise due to degradation of facilities and changes in the conditions of risk source unless any measures are taken. To avoid this, risk reduction measures should be implemented by an appropriate time.

If there is a possibility that the risk level may increase temporarily, it is important to minimize the increase in the risk level. However, if it takes a long time for preparation and work to minimize it, the existing risk may persist and the exposure of workers may increase. Therefore, a temporary increase in the risk level should be controlled by considering a prompt reduction in the existing risk and a reduction in the exposure of workers in a comprehensive manner.

Such changes in the risk level over time are different between the risk sources. It is therefore important to set the timing suitable for the features of the risk sources and thorough preparation should be given to it. Since the operations will have to be performed under the various kinds of uncertainties, the plan should be reviewed flexibly as they are clarified.

## 3) Implementing risk reduction strategies

The government and TEPCO have been working on the Category I risk sources such as spent fuel stored in the pools and stagnant water in the buildings among the major risk sources. The stagnant water has been reduced gradually and the efforts are supposed to complete in 2020. However, as water treatment is still required to continue after that, it is essential to discuss a mid- term strategy.

The risk reduction strategies for Category II, fuel debris, and Category III, secondary waste from water treatment and rubble, will be discussed in Sections 4 and 5 below respectively.

When implementing the risk reduction strategies, securing “Safe” is most important among the five guiding principles. The word “Safe” here means to protect people and the environment from the harmful effects caused by the facilities and a variety of activities performed there. It is required to define an appropriate concept for each category of the risk sources.

The scheduled risk reduction measures for the Category I risk sources have already been implemented or prepared, and the safety measures have been put in place according to the Matters to be addressed.

Risk reduction efforts for the Category II and III risk sources will also be conducted based on the Matters to be addressed basically. The details of the risk reduction measures are to be specified.

The basic concepts for ensuring safety for these categories should conform to the detailed efforts. It is useful to follow the safety principles developed by international organizations such as International Atomic Energy Agency (hereinafter referred to as "IAEA") and International Commission on Radiological Protection (hereinafter referred to as "ICRP"),, to factor in the actual situation of Fukushima Daiichi NPS, and then to develop the basic concepts for ensuring safety by sharing the issues with the stakeholders.

The basic concepts for ensuring safety for Category II regarding fuel debris retrieval requires understanding of fuel debris and retrieval operation, and will be further discussed in Section 4 below. It is necessary to ensure the safety for storing, management, treatment and disposal of solid waste in Category III, including waste resulting from the implementation of risk reduction measures for the risk sources in other categories since it has different characteristics from the waste generated at ordinary nuclear power stations. This will be discussed in detail in Section 5.

# 4. Strategic plan for fuel debris retrieval

## 1) Study plan for fuel debris retrieval

The radioactivity levels (Bq) and decay heat of the fuel debris of Units 1, 2, 3 have significantly decreased as time has passed since the accident. And the criticality/cooling system/containment parameters have been all stable.

However, the current stable state is just supported by the temporary measures for damaged reactor buildings and melted reactor cores and still having risk management issues such as “uncertainty”, actual reactor state has not been disclosed yet, “instability”, the damaged fuel/facilities are in unstable condition, and “inadequate management”, it is difficult to access the site to see the actual state under the extreme condition with high levels of radiation. The purpose of fuel debris retrieval is to fundamentally improve this situation and to bring the reactor and the fuel debris into safer and more stable condition. And it requires two different strategies: one for reducing mid-term risks and the other for long-term ones.

The risks from the mid-term perspective are those that adversely affects the outside when fuel debrisdeviation from the state with a certain level of stability occurs. It is expected that the reactors will be managed in a more stable manner by implementing appropriate measures at an appropriate time, including retrieving highly unstable fuel debris (fuel debris that is in an unstable form or physically or chemically unstable), managing it in stable condition and evaluating the state of the fuel debris and the structures in the reactors.

The risks from the long-term perspective are those of environmental contamination due to the leakage of highly toxic nuclear fuel materials that are included in the fuel debris into the environment, which may occur as a result of deterioration of the buildings. Japan’s basic principle is to ensure the ultra-long-term safety of spent fuel by reprocessing spent fuel and isolating high-level radioactive reprocessing waste from the human environment (geological disposal) and stabilizing it. The basic principle is to retrieve the fuel debris within a time period when containment in the reactor building can be ensured (in the range of several decades), to bring it into a well-managed and stable state, and ultimately to reduce the risk to a level comparable to the backend operation.

Considering this perspective, leaving nuclear fuel materials unattended for a long period of time, with no prospect for retrieval, - that maybe being effective in short-term containment but difficult to manage in a safe manner for a long period of time as the concerns raised during activities to maintain Chernobyl Nuclear Power Plant Unit 4 after the accident - must be called an act of passing due commitments onto the next generation.

Therefore, the same kinds of efforts/initiatives as those for Chernobyl will not be made for Fukushima Daiichi NPS. The followings will be implemented the fuel debris retrieval, instead.

Both the mid-term risk reduction and the long-term risk reduction are important in fuel debris retrieval. It is necessary to focus on the reduction of the mid-term risk and select a method that allows the fuel debris to be retrieved as efficiently as possible in the initial phase of fuel debris retrieval. The present goal is to retrieve a certain amount of fuel debris using this method, to reduce the mid-term risk and to achieve the risk level low enough that would be widely accepted by the public. The next goal is to remove the risk (remove and isolate the nuclear fuel materials) from the longer-term perspective based on activities such as subsequent further fuel debris retrieval and facility dismantling.

Fuel debris retrieval is the action of making a change to the current stable state - accessing the fuel debris and causing its state change - and could increase the risk (leakage of radioactive materials and exposure of workers due to possible malfunctions and/or accidents during the operation). There are limited human resources and time available for the decommissioning process. Therefore, it is necessary to use a safe, reliable and practical method that allows the risk associated with the retrieval operation to be reduced to a level within the allowable range. In other words, it is necessary to achieve, in a well-balanced manner, both the goal of reducing the risk as soon as possible and the goal of suppressing the risk associated with the retrieval operation based on the "Approach to risk reduction associated with implementation of mid- and-long-term efforts" stated in the Roadmap (revised in June 2015).

## 2) Basic concept for ensuring safety in the fuel debris retrieval operation

In order to achieve both the goal of reducing the risk as soon as possible by retrieving the fuel debris and the goal of reducing the risk associated with the retrieval operation, the concept of safety function and principles for realizing these functions have been developed, taking into account factors, such as the international safety fundamentals, the safety-related characteristics of the Fukushima Daiichi NPS and the risk associated with the fuel debris retrieval operation.

(1) Concept of safety function

- Features to ensure the containment function (release prevention and management) and measures to prevent loss of the features are necessary for limiting the release of radioactive materials.
- Decay heat removal and criticality control, as well as prevention of pulverization and spread of fuel debris to the extent possible, should be considered to prevent an increase in the concentration of radioactive materials or the dose rates in the PCV.
- Preparedness for normal operations as well as for anticipated external events, such as earthquakes and tsunamis, and internal events, such as failures and operator errors, is required.
- It is necessary to observe the dose limits for workers under normal operating conditions, to reduce the exposure of workers to the extent possible, and to observe the emergency dose limits for workers engaged in emergency response activities.

(2) Principles for realizing safety functions

- Considering that the reactors after the accident are decommissioned, it is important to effectively use existing equipment, to provide the necessary equipment and to consider the combination of equipment and work management.
- In order to reduce the exposure of workers engaged in preparatory work and maintenance work, it is important to ensure the containment function by maintaining the PCV at a negative pressure with the combination of static structures and active equipment and to consider agile action using both permanent and mobile equipment.
- In applying defense-in-depth, it is necessary to carefully consider the hierarchy of defense levels and the need for the independence of each level. Considering the speed of progress of each event and its scale and the limitations to work in the field, it can be effective in risk reduction to focus on measures to prevent spread of an unusual event, instead of preventing it.
- It is important to recognize the presence of uncertainty in the conditions in the PCV and to be able to change plans in a flexible manner if differences from the assumptions made in the planning stage are found.
- In safety assessment, it is important to set a realistic management goal and assessment conditions. For example, actual lifestyles and the environmental conditions in the surrounding area of the site should be considered when specifying typical individuals.

## 3) Current status of each unit

In order to perform fuel debris retrieval, it is necessary to comprehend, as well as possible, the following information on the conditions in the PCV and RPV.

- Distribution of fuel debris (rough information on the location and amount of fuel debris is required to discuss the approach to fuel debris retrieval)

- Information to ensure accessibility to fuel debris and to judge the feasibility of removing obstacles if it is required
- Information to judge safety during the retrieval operation with no possibility of surrounding structures and fuel debris falling down, and to judge the feasibility of preliminary construction if it is required to ensure safety

For the above mentioned, a comprehensive picture of fuel melting process has been performed via severe accident progression analysis, and fuel debris distribution, conditions of the buildings and the environment have been analyzed applying the assessment based on the heat balance using actual plant parameter and trends. And investigations into internal PCVs have been conducted to record images/movies and to collect the data on the actual temperature and radiation dose; a set of useful data has been collected over time. In addition, the investigations into fuel debris distribution to get a rough sketch using muon measurement have been conducted. The Table 1 provides the current assumptions about fuel debris distribution for each unit.

(1) Unit 1

- It is assumed that the most of the fuel debris is located on the bottom floor of PCV with a small amount at the RPV bottom. According to estimation by severe accident analysis code, some of the fuel debris is assumed to have spread out the pedestal through the entrance.
- For the access route, it’s been confirmed that the bottom of the dry well is accessible from the grating located outer pedestal through the access opening via an internal PCV investigation using a small robot.
- Concerning the condition of the surrounding structures, in a PCV internal investigation, no major damage was observed on the outer surface of the pedestal and the structures, as far as the obtained images indicate.

(2) Unit 2

- It is assumed that large amount of the fuel debris exists at the RPV bottom with a small amount at the bottom of the PCV.
- For the access route, it’s been confirmed that it is possible to access near the pedestal opening via an internal PCV investigation using a small robot.
- Concerning the condition of the surrounding structures, the pictures taken through inner PCV investigation show that some part of the grating has fallen down but there is no large fallen structures, such as the CRD housing, inside the pedestal. No abnormal conditions, such as cracks, were found on the inner surface of the pedestal on the pedestal platform.

(3) Unit 3

- Although certain amount of fuel debris is likely to be present at the bottom of the RPV, it is assumed that a larger amount of fuel debris than that of Unit 2 is distributed at the bottom of PCV. An investigation into internal PCV found something which seems to be melted material turned into solid inside the pedestal.
- For the access route, an inner PCV investigation using a small robot revealed that it is possible to access inside the pedestal via pedestal opening.
- For the surrounding structures condition, inner PCV investigation found some structural damages and CRD housing bracket fallen off in the pedestal. And there were no grating on the platform but some found at the bottom of inside the pedestal. There were also some fallen objects and deposited materials at the bottom of inside the pedestal.

It is critical to continue field investigations into inner PCVs and perform sampling in a timely manner to collect the information about inner reactors states and fuel debris properties in order to make a substantial contribution to fuel debris retrieval.

And it is crucial to discuss the timing of field investigations into inner RPVs and develop a plan based on the results of the PCV investigations.

Furthermore, it is very important to collect and provide detailed information about fuel debris distribution/properties such as three dimensional distribution and the forms (granules or blocks, etc.) of the debris, and condition of inner reactors including temperatures, dose rates and neutron flux distribution through inner PCVRPV investigations so as to rationalize device designing and retrieval planning.

### 4) Potential risk of fuel debris

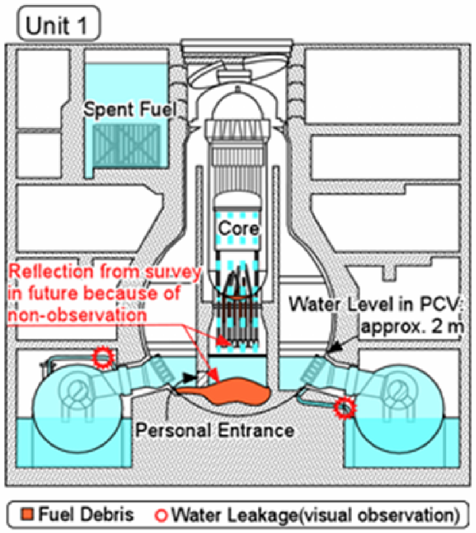
It is estimated that the fuel debris is located diverse locations and has different characteristics. Therefore, the risk level of fuel debris in each form and location might be different. In addition, "instability" of fuel debris and reliability of containment functions might change by aging. As the aging impact might cause changes of fuel debris form into diffusible one, change in controllability in cooling and change of containment function, it is necessary to consider the potential changes in risk levels of fuel debris.

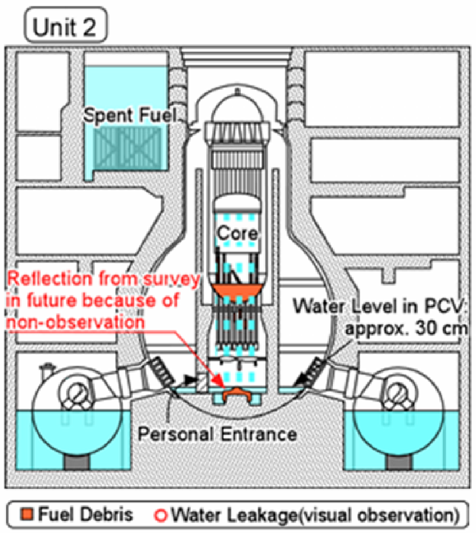
Risk levels of fuel debris have a huge impact on the percentage of presence of the types of fuel debris in high diffusible form and easily taken into human body. Due to the specific characteristics of fuel debris, a part of fuel debris might become particle and/or might leach into the cooling water, and then the risk of leakage of fuel debris may increases. Moreover, particle form ones or leached ones can easily flow with the coolant into a circulating cooling water system, and risk of leakage with gas or the coolant in the event of a significant loss of containment function may increase. For this reason, the risk levels can be reduced effectively and relatively earlier by giving priority to retrieve fuel debris in form of particles and fragments, which have greater mobility, during the fuel debris retrieval operation, and managing them in a stable condition.

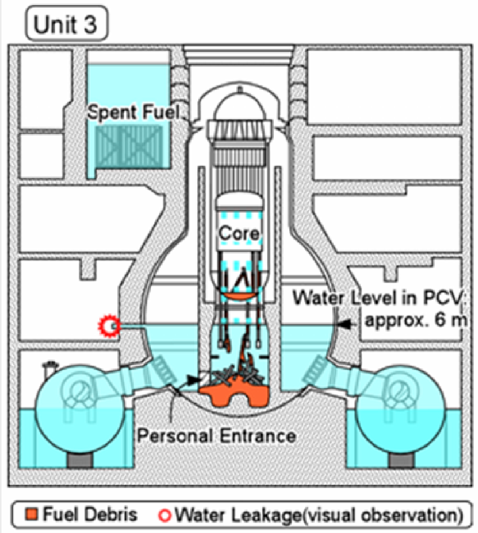
The products of molten core-concrete interaction (MCCI) has a high uncertainty in its properties and instability. The containment function of the fuel debris at the bottom of the PCV is not highly redundant. There is a high uncertainty in the controllability of the decay heat (coolability) and in the change over time in the containment function. Therefore, the risk level of the fuel debris at the bottom of the PCV (particularly the MCCI products) is likely to be higher than that of the fuel debris in the RPV. Therefore, it is beneficial to investigate the fuel debris at the bottom of the PCV and to evaluate the properties, instability, controllability and containment function of the debris residing at the PCV bottom.

In the fuel debris retrieval operation, it is necessary to consider the possibility that when external operations, such as suction, cutting and crushing of fuel debris, are performed, fuel debris with high fluidity may move or the fuel debris may break into molecules or fragments or break and fall and the risk level of the fuel debris may change. Therefore, in order to prevent the excessively large change in risk level, it is important to conduct the necessary investigation and to perform the retrieval operation in a planned manner and appropriately according to the state of the fuel debris.

Table 1　Fuel Debris Distribution Estimated in Units 1-3*




| | Unit 1 | Unit 2 | Unit 3 |
|---|---|---|---|
| Core Region | • Little fuel remains. | • Little fuel remains.<br>• (Stub-shaped fuels might exist in peripheral region.) | • Little fuel remains. |
| RPV Lower Head | • A small amount of fuel debris is present.<br>• A small amount of fuel debris is present in the inside and on the outer surface of the CRD housing. | • Large amount of fuel debris is present.<br>• A small amount of fuel debris is present in the inside and on the outer surface of the CRD housing. | • Fuel debris remains on the RPV lower head partly.<br>• A small amount of fuel debris is present in the inside and on the outer surface of the CRD housing. |
| Pedestal Inside | • Most of fuel debris is present. | • A small amount of fuel debris is present. | • Amount of fuel debris in Unit 3 is more than that in Unit 2. |
| Pedestal Outside | • Fuel debris may have spread on the pedestal outside through the personal entrance. | • The possibility of fuel debris spreading on the pedestal outside through the personal entrance is low. | • Fuel debris may have spread on the pedestal outside through the personal entrance. |

* Based on the document provided by IRID and internal survey performed in 2017.

## 5) Feasibility of the fuel debris retrieval method

First of all, what is important in developing a method of fuel debris retrieval is to select which of the two methods: in water or air. Generally, there are two methods for handling highly radioactive contaminated materials such as fuel debris: in-water method and in-air method. In the in-water method, as in a nuclear power plant, water is used to provide a radiation shield and prevent spread of dust. In the in-air method, as in a reprocessing plant, an iron cell provides a radiation shield and dust is prevented from spreading by maintaining it in a negative pressure. For the Fukushima Daiichi NPS, it is not a matter of choice between the two options. Rather, it is a matter of how much we expect water to act as a shield and prevent spread of dust while keeping the cooling capability with a minimum required amount of water in the PCV, or a matter of deciding the water level.

Also, the fuel debris needs to be accessed for retrieval. An opening must be provided in the reactor containment vessel, which was damaged in the accident but still keeps its original structural robustness, to establish an access route. There are two access routes for routine periodic inspection: a route for accessing from above that can be established by opening the PCV head or RPV head from the operating floor when changing the fuels or performing work inside the reactor, and a route for accessing from side by opening the CRD hatch or equipment hatch located on the first floor of the reactor building when changing control rods at the bottom of the reactor or performing work inside the PCV. It is realistic to use either of these two access routes for fuel debris retrieval, depending on its location.

As discussed above, the important points in the method for fuel debris retrieval are the water level and the access route. In order to evaluate the feasibility of the fuel debris retrieval methods, which are based on combinations of water levels and access routes, three priority methods have been selected: (1) a Submersion Top-access method, (2) a Partial submersion Top-access method, and (3) a Partial submersion Side-access method. These are the methods that were evaluated with priority in the Strategic Plan 2015 and 2016 in terms of feasibility for combinations of three directions of access to the fuel debris and four PCV water levels: Full-submersion, Submersion, Partial submersion, and Dry. Technical requirements for these methods were presented. In the R&D activities, a concept design was developed and a feasibility study was conducted.

In the Submersion Top-access method, the PCV will be completely filled with water or filled with water to a level at which the fuel debris is present, in expectation that the water will provide a radiation shield and prevent spread of radioactive dust. This method was successfully used at Three Mile Island Nuclear Power Plant Unit 2 (TMI-2), although there are difference in the reactor type, the scale of accident and the submersion water level between Fukushima Daiichi and TMI-2.

Partial submersion-Top access & Partial submersion-Side access methods: methods in which a part of the fuel debris will be dealt with in the air. It is called Top access if fuel debris is accessed from the operating floor, and Side Access if accessed from the side of the PCV.

i. **Technical requirements for the fuel debris retrieval methods**

The following are the technical requirements to make the fuel debris retrieval methods feasible.

(1)Establishment of containment function
(2)Maintaining cooling function
(3)Criticality control
(4)Ensuring the structural integrity of the PCV and R/B against earthquakes
(5)Reducing occupational radiation exposure
(6)Ensuring occupational safety
(7)Establishment of access routes to fuel debris
(8)Development of equipment and devices for fuel debris retrieval
(9)Establishment of system equipment and working areas

Described below are the R&D activities that have been performed to meet the technical requirements.

(1) Establishment of containment function

Since it is very likely that the containment functions such as the leak tightness of PCVs of Fukushima Daiichi NPS Units 1 to 3 have been damaged and lost the containment capabilities to large extent which are compared to an operating reactor building and other nuclear facility buildings, it is necessary to develop a method of containment combined with maintaining the PCVs at negative pressures.

Specifically, we are considering a method of containment by establishing a primary containment boundary formed by the PCV and the retrieval cell and a secondary containment boundary formed by the reactor building and a container. This containment function consists of a liquid-phase portion to collect water containing fuel debris in fine particle form and a gas-phase portion to collect fine dust and maintain the inside of the PCV at a negative pressure.

A. Establishing a containment function for the liquid phase portion

The upper parts of the PCVs (the first floor of reactor buildings and above) are not easily accessible due to high radiation dose rates. There is not much progress in investigating locations requiring repair. There are many penetrations that require repair, making it technically difficult to completely stop water and maintain water leak blockage for a long period of time.

To repair the bottom part of the PCVs (below the first floor), techniques for water leak blockage of vent tubes, strainers and downcomer; it is possible to ensure containment capabilities for Partial submersion methods via combination of PCVs repair, appropriate water levels and water recovery system.

The water level in the PCVs need to be determined to prevent the level of the stagnant water in the torus rooms from being higher than the ground water level outside the building in the event of an abnormal condition, such as contaminated water in the PCV flowing out rapidly into the torus room, and thus to prevent release of radioactive materials into the environment.

B. Establishing a containment function for the gas phase portion

Assuming the current inner PCV pressure and nitrogen supply, containment of alpha-emitting radionuclides and other radioactive materials is expected to be achieved with general system configuration and normal equipment scale of the systems (gas circulation systems and filtered vent systems, etc.) to maintain the PCVs at negative pressure levels. Techniques (repair welding, sealant application, etc.) to prevent leakage into the PCVs are also being developed to increase the air-tightness of the PCVs. A system is being developed that collects and treats leakage from the primary containment boundary by covering the reactor building or placing a container in the reactor building to establish a secondary containment boundary and by maintaining the building at a slightly negative pressure.

(2) Maintaining cooling function

Since the fuel debris generates decay heat, the cooling function needs to be maintained during the fuel debris retrieval. As the decay heat, however, decreases over time, the need for the cooling function decreases over time. Monitoring of temperature at the bottom of the RPV indicates that the temperature is constant and the cooling function required for the fuel debris retrieval can be ensured.

We seek to develop a circulating water cooling system to prepare to start the fuel debris retrieval operation.

(3) Criticality control

Criticality of the fuel debris produced by the core melt accident seems unlikely so far. The possibility, however, may change due to raised PCV water levels and altered form of retrieved fuel debris and there is considerable uncertainty about information on inner PCV condition and the fuel debris. So we are now discussing the measures to detect and stop the criticality of fuel debris in addition to the measures to prevent the criticality in order to prevent impact of recriticality on human health and the environment. For this purpose, efforts to clarify the conditions of recriticality of fuel debris and development of technologies for increasing reliability of criticality prevention capability and for detecting criticality are underway. The feasibility of management approaches will be increased by reflecting the information about actual condition of inner PCVs and fuel debris to be obtained.

(4) Ensuring the structural integrity of the PCV and R/B against earthquakes

The major structures such as R/B PCV and RPV of each unit have been evaluated such that they have relatively large seismic safety margin against a design basis seismic ground motion Ss (600Gal) for all the three methods of fuel debris retrieval to be focused on, taking into account the damage caused by the accident, degradation over 40 years, increased weight of new facilities and cooling water for inner PCV required for fuel debris retrieval.

Seismic structural safety assessment using detailed analytical models for S/C supports which have relatively small seismic safety margin is underway considering that it may be affected significantly by the way of lower PCV repair . The past assessment shows that they may have a certain level of safety margin in the case of water leak blockage at the vent tubes/strainer parts.

The pedestal was evaluated by experiments and analyses to determine to what extent its strength and stiffness decreased due to high temperature history during the accident and the subsequent coolant injection, and has been evaluated to have a margin of safety against the design basis seismic ground motion Ss, even if it has decreased the strength and stiffness.

It is necessary to evaluate the seismic safety margin of R/Bs, PCVs and RPVs in more detail as the investigation and design processes proceed.

(5) Reducing occupational radiation exposure

It is essential to reduce occupational radiation exposure for the workers as almost works will be performing in the areas of high radiation levels. Accordingly, assessment of radiation exposure due to PCV repair and preliminary work such as decontamination of retrieval work area and removing of existing facilities, and the spread of contamination/radiation exposure due to retrieval activities is necessary.

Regarding the occupational radiation exposure during PCV repairing in the case of upper PCV sealing for Submersion method, it is assumed that the occupational exposure will be several times of the past annual total occupational exposure since there are so many potentially damaged penetrations in the first to fourth floor of the reactor building even though the dose rate in the work area can be reduced to 3mSv/h.

Meanwhile, it is possible that the occupational exposure during water sealing for lower PCV repair for Partial submersion method will be the same as or smaller than the past annual total occupational exposure since there are just a few locations to be repaired. It is required to further discuss the reduction of dose rates and retrieval methods based on the assessment above.

As for the occupational exposure during fuel debris retrieval operation, there will not be much difference depending on the retrieval method and access route as the retrieval works must be remotely handled anyway. However, it is required to establish the secured technology for installing radiation shielding containment cells.

(6) Ensuring occupational safety

The fuel debris retrieval at Fukushima Daiichi NPS is an unprecedented and unique challenge in the whole world and the workers are forced to work under extremely severe conditions. To eliminate industrial accident is one of the top priority goal for accomplishing the task safely under workplace environment. For this purpose, it is critical to consider worker training and using mockups preventive action countermeasures against unexpected events in advance. It is also important to study carefully how to improve the workplace environment and working conditions during the preparation of the implementation plan.

(7) Establishment of access routes to fuel debris

According to the description in 3) Current Status of Each Unit, it is possible that the fuel debris exists both in RPV and at the bottom of PCV. We have been evaluating different access routes (Top-Access and Side-Access methods) to the fuel debris.

Top-Access method seems mostly suitable for the fuel debris located in RPV. But, establishing the access route for the method requires a large scale of work, including removing the well shield plugs and various structures in RPV and opening PCV and RPV tops, and long time to complete these tasks. Meanwhile, for now, establishing the route for the debris located in RPV by Side-Access method seems technically difficult.

For the fuel debris at the bottom of PCV, the result of the investigation into the internal PCV indicates that it will take a relatively short time to achieve the accessibility to the fuel debris. However, it is still required to take the findings of future internal investigations into the consideration. Meanwhile, establishing an access route for Top-Access method seems hard technically, as it requires removing of equipment installed at RPV bottom after retrieving the fuel debris located in RPV and there is uncertainty about from how far the operation should be controlled remotely and actual status of RPV bottom. And for the fuel debris located outside of the pedestal, it seems more difficult technically to achieve the accessibility to the fuel debris as the pedestal itself becomes an obstacle. Regarding Unit 3, the current water level of inner PCV is about 6 m and it needs to be decreased to an appropriate level when retrieving fuel debris via a side access method.

Because of the possibility that the fuel debris exists both in the RPV and at the bottom of PCV, it is also necessary to consider access method from both sides such as a combination of Top-Access method and Side-Access method.

(8) Development of equipment and devices for fuel debris retrieval

The development of the elemental technologies (remotely controlled seal welding for the cells through a Side-Access method, etc.), selected during considering the needed steps for each method to be used as primary equipment for retrieving fuel debris at PCV bottom and in RPV, is underway. It is necessary to continue the development toward practical use. Assuming extreme working conditions such as high radiation doses, moisture and high dust concentration, the equipment must be extremely robust and easy-to-maintain. It also requires a reliable rescue system for emergencies. It is also necessary to intensively consider the topics (treatment of alpha-emitting radionuclides for Partial submersion method and cutting of solid debris masses, etc.) selected during discussions on the retrieval methods as priority issues.

(9) Establishment of system equipment and working areas

It is necessary to build an environment that will support safe operation by controlling negative pressure in the containment areas and water levels at PCV, and cooling/purifying circulation water before starting the retrieval. For this purpose, we have considered the concepts of the systems and spaces for the systems to establish the functions for “containment of Air-Phase and Liquid-Phase parts”, “cooling” and “criticality control” required for safety. The systems for the containment of the gas and liquid phases were roughly evaluated for the environmental impacts of radiation during the fuel debris retrieval and under unusual conditions.

A rough assessment of radiation exposure of the environment when using containment system shows that each method is feasible; though we still have some issues regarding management of massive water leaks upon emergencies in the case of Submersion methods, it is assumed that radiation exposure of the environment will not be extreme. However, it is still essential to discuss the measures to reduce radiation exposure by further prevention of spread of dust, considering potential hazard of internal radiation exposure by alpha nuclide. We have calculated the required space for the areas of installing system equipment. For actual installation area planning, we need to consider establishing the area both inside and outside of the R/B factoring in handling of the high dose rates areas inside of the R/B and interfering activities. Once fuel debris retrieval policies are fixed, the applicability should be evaluated based on the actual condition of the site.

As it is vital for fuel debris retrieval to monitor the condition in PCVs, various types of measurements are being considered in the discussions on the required systems, etc. Development of measurement systems (visualization, pressure, temperature, radiation, criticality (noble gas concentration, etc.) hydrogen concentration) is an important future issue to be addressed.

ii. **Technical requirements for storage of fuel debris in safe and stable condition**

It is necessary to store the retrieved fuel debris safely in stable condition regardless of retrieval methods. The following are required:

- Fuel Debris Management: Containment, Transfer and Storing
  Building a comprehensive system to design and manufacture the fuel debris containers and to transfer and store them on site. Planning safe on-site storing of the fuel debris in stable condition. Building/repairing required facilities.
- Waste Management
  Planning appropriate management, including classification and storing, of a variety of waste such as structures removed from the reactors and components of the devices that will be produced through preparation, retrieval and clean-up based on regular safety checks. Building/repairing required facilities.
- Safeguards
  It is important to work closely together with relevant players to develop transparent safeguard policies responding to fuel debris management in order to implement them prior to the initiation of the retrieval.

iii. **Evaluation of feasibility of the methods**

Summarized below are the results of evaluation of the feasibility of the three methods to ensure a safe and reliable fuel debris retrieval operation (See Table 2)

- In order to make the Submersion method feasible, it is essential to repair the PCV. There are many portions at the upper part of PCV that are likely to be damaged. It is difficult to develop a remote technique suitable for each portion. The total occupational exposure of workers during investigation and repair work will be excessive. For these reasons, the feasibility of the method is low in terms of developing a containment mechanism.
- In the Partial submersion method, containment may be possible by maintaining the PCV at a negative pressure. Therefore, we should continue to develop a technique to maintain the PCV at a negative pressure to contain alpha-emitting radionuclides.
- Based on an estimated fuel debris distribution, it will be necessary to combine the top-access method and the side-access method in order to complete the fuel debris retrieval operation. As the investigation and the technology development continue, we should search for suitable methods in a flexible manner.

## 6) Comprehensive evaluation based on five guiding principles

Based on the five guiding principles for continuous risk reduction to proceed with the decommissioning process at the Fukushima Daiichi NPS, a comprehensive evaluation of the fuel debris retrieval methods was performed, including the evaluation of technical feasibility in the previous chapter.

The principle for fuel debris retrieval provides the basis for starting full access to the fuel debris in each unit, taking into account the entire process, from the beginning to the end of the fuel debris retrieval operation, and forms a basic concept for fuel debris retrieval methods that are considered to be feasible. In terms of risk reduction in the entire process of fuel debris retrieval, this basic concept includes components to form the basis of the retrieval methods, such as the locations of the fuel debris to be retrieved, the order of access, the combinations of methods, and the water level in the PCV during the retrieval operation.

The results of evaluation are described below.

(1) Evaluation of the water level during the fuel debris retrieval operation

The Submersion method that fills the PCV with water to a level at which the fuel debris is present is advantageous in terms of prevention of spread of radioactive dust and shielding against radiation and is expected to be used if possible.

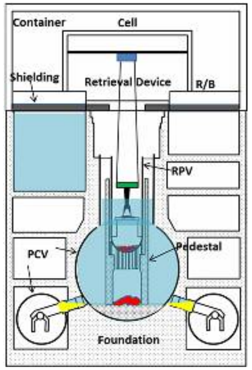
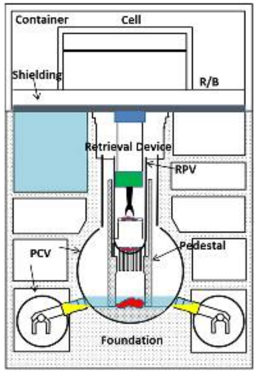
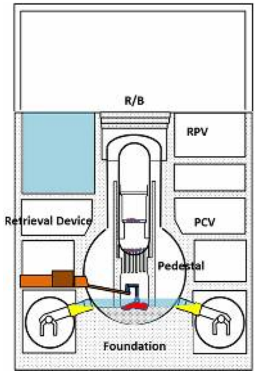
However, in all three units, there are many through-holes in the top of the PCV that are different in accessibility and structure. In order to prevent leakage of water through the holes, it is necessary to resolve very challenging issues both in making repairs and in guaranteeing performance.

Particularly, when the extent of decontamination inside the buildings is taken into account, the exposure of workers during repair work will be enormous. In terms of ensuring safety by reducing the exposure of workers, it will be very difficult to adopt the Submersion method based on currently available technology.

On the other hand, in the Partial submersion method, it is necessary to develop a gas-control system and contain radioactive materials in the gas-phase portion using the system. Considering the current R&D process and the conditions inside and outside the reactor, we should further accelerate the R&D process and evaluate the applicability of the method to work in the field toward materialization of the Partial submersion method, in order to retrieve the fuel debris in the air in all Units 1 to 3.

Incidentally, we should continue the effort to reduce the dose rates in the buildings. With discussing the feasibility of the Submersion method in the future scope, we should also store the knowledge obtained in the R&D process and remaining issues in an appropriate manner to prepare for the possible use of them.

# Table-2: Feasibility Study Results: Fuel Debris Retrieval Methods

| Methods | | Submersion-Top access | Partial submersion-Top access | Partial submersion-Side access |
|---|---|---|---|---|
| Concept Diagram (Image)<br><br>*Red: potential location of fuel debris<br><br>*Blue: potential water level<br><br>*Yellow: Case of bent tube water leak blockage | |  |  |  |
| Major Technical Requirements | | | | |
| Ensuring Containment Capability | Liquid Phase | ・Hard to ensure water leak blockage capability of resisting hydrostatic pressure when being submerged<br>・Hard to ensure containment capability to remotely fix penetration holes for upper PCV with lots of holes<br>・Emergency water leak prevention measure is required as a large amount of water is supposed to be kept. | ・Technical difficulty is slightly lower as hydrostatic pressure is lower than that of submersion case.<br>・Penetration holes on upper PCV to be fixed are limited.<br>・It is possible to prevent water leakage even on emergencies depending on water level settings. | ・Technical difficulty is slightly lower as hydrostatic pressure is lower than that of submersion case.<br>・Penetration holes on upper PCV to be fixed are limited.<br>・It is possible to prevent water leakage even on emergencies depending on water level settings. |
| | Gas Phase | ・Although air conditioning system with capability of maintaining negative pressure is required, small scale equipment may be good enough. | ・Air conditioning system with capability of maintaining negative pressure for containing alpha-emitting nuclides is necessary. The scale of the equipment will be large, but it can be feasible. | ・Air conditioning system with capability of maintaining negative pressure for containing alpha-emitting nuclides is necessary. The scale of the equipment will be large, but it can be feasible. |
| Maintaining Cooling Capability | | ・Feasible | ・Feasible | ・Feasible |
| Criticality Management | | ・Preventing criticality when reactor core is covered with water is an issue. | ・There is a low probability of re-criticality as reactor core will not be covered with water. | ・There is a low probability of re-criticality as reactor core will not be covered with water. |
| Structural Soundness / Seismic Resistant Features of PCV and R/B | | ・Although the total weight of coolant in PCV and fuel debris retrieval equipment to be installed at upper R/B increases, seismic margin will be ensured for major components. | ・Although the total weight of fuel debris retrieval equipment to be installed at upper R/B increases, seismic margin will be ensured for major components. | ・Better seismic margin will be ensured as fuel debris retrieval equipment will be installed on the first floor. |
| Reducing Occupational Radiation Exposure | | ・Occupational radiation exposure would be of several times of the past annual total exposure when sealing upper PCV as there are lots of penetration holes on the upper PCV. | ・Occupational radiation exposure would be less than the past annual total exposure when sealing lower PCV. | ・Occupational radiation exposure would be less than the past annual total exposure when sealing lower PCV. |
| Establishing Access Route | Inner RPV | ・Scale of work concerning retrieval of fuel debris located in RPV could be significant as inner structures of reactor must be removed. | ・Scale of work concerning retrieval of fuel debris located in RPV could be significant as inner structures of reactor must be removed. | ・Building an access route to fuel debris located in RPV is difficult at present. |
| | PCV Bottom | ・Scale of work concerning retrieval of fuel debris located at the bottom of PCV could be more significant than that of side-access method as it is required to bore the bottom of RPV. | ・Scale of work concerning retrieval of fuel debris located at the bottom of PCV could be more significant than that of side-access method as it is required to bore the bottom of RPV. | ・Scale of work concerning retrieval of fuel debris located at the bottom of PCV could be less significant than that of top-access method. |
| Conclusions | | ・Development of technologies for remotely fixing penetration holes for water sealing is difficult.<br>・Total occupational exposure concerning repair work could be enormous. | ・It is necessary to continue development of technology for maintaining negative pressure in order to contain alpha-emitting nuclides.<br>・Both top-access and side-access would be required. | ・It is necessary to continue development of technology for maintaining negative pressure in order to contain alpha-emitting nuclides.<br>・Both side-access and top-access would be required. |

(2) Access routes

At the moment, it is considered difficult to access the fuel debris inside the RPV from the side for retrieval. It is necessary to access it from the operating floor (from the top).

It takes a long time to access the fuel debris at the bottom of the PCV from the operating floor (from the top) and reach it. In addition, the remote control distance is long. For these reasons, the level of technical difficulty will be high. The pedestal is a physical obstacle in retrieving the fuel debris outside the pedestal from above. Based on the experience in investigating the bottom of the PCV, the debris will be accessible to relatively small equipment and devices if the side-access route is used. It is more realistic to access the fuel debris at the bottom of the PCV and retrieve it from the side of the PCV (on the first floor level of reactor buildings). In terms of reducing the exposure of workers and performing maintenance work, it is reasonable to access it from the side of the PCV. It is necessary to develop a basic design and ensure the feasibility of the method.

(3) Locations in the reactor from which fuel debris should be retrieved first

In all three units at the Fukushima Daiichi NPS, fuel debris is likely to be present more or less inside the RPV and at the bottom of the PCV. In order to reduce the risk of the fuel debris as soon as possible while minimizing the increase in the risk associated with the retrieval, it is realistic to retrieve the fuel debris from the bottom of the PCV first by accessing from the side.

The reasons are:

- The bottom of the PCV in Units 1 to 3 has been investigated and, as a result, a certain amount of knowledge on the routes for accessing the bottom from the side has been accumulated, which can be used for realistic engineering.
- The actual time to reach the fuel debris after starting preparations will be longer when accessing the inside of the RPV from the top than when accessing the bottom of the PCV from the side.
- In order to streamline the decommissioning process as a whole, preparations for side access to the bottom of the PCV can be made concurrently with the removal of the fuel from the pool, while some cautions, such as ensuring safety when working from the top and the bottom simultaneously, exist. In addition, a certain amount of extra time will be available before the retrieval of the fuel debris from the RPV, and, as a result, the dose originated from Co-60 in the core internals can be expected to decrease.

It was thought that fuel debris might be present in large amounts at the bottom of the PCV in Unit 1 and 3, and in small amounts at the bottom of the PCV in Unit 2. The latest investigation of the inside of the PCV in Unit 2, however, showed that a certain amount of fuel debris is present at the bottom of the pedestal in Unit 2 as well.

From the above, with regard to the locations in the reactor from which fuel debris should be retrieved first, it is considered reasonable to work on the bottom of the PCV first.

## 7) Proposal for deciding fuel debris retrieval policies and efforts after decision (Strategic proposal)

### i. **Proposal for deciding fuel debris retrieval policies**

While it is important to reduce the potential risks as soon as possible, it is also critical to assume considerable uncertainty about fuel debris characteristics/locations and retrieval technique as the information is very limited and development of technologies are still underway. Considering of fuel debris retrieval under such circumstances requires to develop short-term plans carefully and precisely, and prepare long-term plans comprehensively in a flexible manner in order to deal with the uncertainty.

Thus, through the discussions on fuel debris retrieval, the basic concept which seems most reliable should be adopted first, and engineering for judging the feasibility of the construction work should be conducted based on the concept next. Then the results of the internal investigation obtained through the retrieval should be used for the following access to/retrieval of the fuel debris promptly and continually in order to improve the accuracy of retrieval ahead. Since fuel debris retrieval includes investigations into the surrounding condition and the next target, it is important to analyze small but important successful experiences, expand the scope and accumulate useful information gradually, and then further proceed in a flexible manner to deal with actual circumstances.

Based on the discussion above, the following recommendation is provided for deciding on the fuel debris retrieval policies:

(1) Develop a comprehensive fuel debris retrieval plan aimed to optimize the entire retrieval process, from preparation work and transfer from the site to treatment, storage and cleanup, including coordination with other works in the field.

(2) Move forward in a flexible manner according to the information gained little by little via a step by step approach after deciding the retrieval method to be focused on.

(3) Assume that combination of a variety of methods will be required to complete the fuel debris retrieval.

(4) Promote preliminary engineering and R&D focusing on the Partial submersion methods.

(5) Firstly, focus on retrieving the fuel debris located at the bottom of the PCV and keep reviewing the methods based on the newly gained expertise/experience through the retrieval.

(6) At first, focus on the route from the side of the PCV (the side-access method) for the first access to the fuel debris located at the bottom of the PCV. The following are the points to be stressed about the method.

- Reducing dose rates in the field
- Developing a technique for water-level control
- Developing a technique for cell connection and ensuring the work area

ii. **Efforts after deciding fuel debris retrieval policies**

Once the fuel debris retrieval policies have been decided, the following priority issues should be dealt with towards “determination of fuel debris retrieval method for the first implementing unit” and accelerating the development of the actual construction plan

(1) Preliminary engineering

In the preliminary engineering phase, based on the fuel debris retrieval policies, the applicability of the results of R&D and system concept to the actual field will be evaluated and the processes involved in the retrieval will be specified.

As needed, the fuel debris retrieval methods may be revised based on the results of the preliminary engineering.

(2) Acceleration of technology development based on the selection and prioritization of R&D projects and practical application of technology

- Extra investigations into internal PCV
- Investigations into internal RPV
- Judging feasibility of alpha-emitting radionuclides management system required for Partial submersion methods

- Promoting the necessary R&D projects to materialize the side-access method into practical use and discussing the significance of mockup facility
- Conducting R&D on a system for containing, transferring and storing fuel debris, on the preparation of a storage facility, and on the waste to be generated by fuel debris retrieval.

(3) Path to commencement of fuel debris retrieval

In addition to preparing the devices/equipment for retrieving fuel debris, it is also required to conduct further internal investigations to see the actual condition, establish appropriate work environments, prepare the storage facilities for the retrieved fuel debris, obtain approval for them and develop a feasible plan for safeguards implementation according to the actual state of Fukushima Daiichi NPS in order to start retrieval.

Hence, it is essential to well communicate with national regulation authorities and international institutes such as IAEA considering the fuel debris retrieval policies.

There are a lot of issues to be discussed before starting fuel debris retrieval including the above mentioned. It is important to remember the following when promoting the fuel debris project.

- Considerations to the continuity of the project

  Fuel debris retrieval is a project that spans over a long period of time, from preparation work and retrieval operations to containment/transport/storage of the retrieved debris. It is important to develop an environment that makes it possible to continue the fuel retrieval operation in a steady manner and to continue the management of the project to transform the fuel debris into a more stable, managed state as soon as possible.

- Optimization of the entire retrieval process

  In order to retrieve the fuel debris in a safe, reliable, reasonable, prompt and field-oriented manner, it is necessary to consider the unit-wise optimization, implementation of unified facilities for all the units, and the entire decommissioning operations across the Fukushima Daiichi NPS site.

  In addition, the entire project needs to be further optimized based on the reasonableness of the activities and past experiences; the next target reactor (and target location of the fuel debris in the reactor) following retrieval of the fuel debris of the first target reactor should be carefully considered from a point of view of reasonableness.

- Close communication with the local government and community

  In developing and implementing a plan for the fuel debris retrieval operation, it is crucial to give top priority to safety and to gain a full understanding of the local government and community to gain a sense of security.

# 5. Strategic plan for waste management

## 1) Study policy on the Strategic Plan for waste management

The Roadmap defines that the basic concept of solid waste management is to be compiled in FY2017.

It is considered that the solid waste(*) generated due to Fukushima Daiichi NPS accident has different characteristics from the waste generated by normal operation of nuclear power stations. Hence, characterization of solid waste has been conducted, on the basis of which the study towards processing/disposal has progressed. The management such as storage of solid waste also has been implemented in accordance with risk reduction approach.

In this section, the international safety principles on radioactive waste management are compiled and the policies on solid waste management to be applied are shown, in light of the current state that solid waste characteristics data has been accumulated. These policies will be the proposals for establishment of the basic concepts.

(*) In the Strategic Plan, the words “Solid Waste” and “Solid Waste Management” mean the following, respectively:

Solid Waste:

Following to the definition in the Roadmap, “Solid Waste” is the rubble (although some of them may be reused on the site and may not be considered as waste or radioactive waste) and solid radioactive waste that had been stored in the Fukushima Daiichi NPS before the accident. The secondary waste from water treatment to be managed based on the same policies is added to Solid Waste. Fuel debris, however, is not included.

Solid Waste Management:

IAEA defines radioactive waste management as “All administrative and operational activities involved in the handling, pretreatment, treatment, conditioning, transport, storage and disposal of radioactive waste”, and radioactive waste generated by accident is included in the radioactive waste to be managed. Hence, Solid Waste Management here is to include all activities from generation to disposal as well.

## 2) International safety principles on radioactive waste management

The safety principles on radioactive waste management compiled by ICRP and IAEA are for all radioactive waste, and reflecting experiences on waste generated by other accidents occurred prior to Fukushima Daiichi NPS accident. They should be worth to refer for study on ensuring safety of solid waste management, and described below are some principles in this regard.

- The preferred strategy for the management of all radioactive waste is to contain it and to isolate it from the accessible biosphere. This strategy does not preclude the discharge of effluents, arising from waste management activities, that contain residual amounts of radionuclides, or the clearance of materials that meet the relevant criteria.
- Radioactive waste may be generated in various form. During the management activity of radioactive waste, the radioactive waste will generally be processed to have stable solid form, and reduced volume to the extent possible and immobilized to facilitate for storage, transport and disposal.
- At various steps in the predisposal management of radioactive waste prior to disposal, the radioactive waste shall be characterized and classified.
- During the predisposal management, storage is important as a measure to give the management with flexibility. Proper storage should be provided at all stage in predisposal management.

- Waste shall be stored in such a manner that it can be inspected, monitored, retrieved and preserved in a condition suitable for its subsequent management.
- The anticipated needs for any future steps in radioactive waste management have to be taken into account as far as possible in making decisions on the processing of the waste.

## 3) Current status of solid waste management

i. **Storage**

The solid waste that has been generated up to now consists of “rubble, etc.” and secondary waste from water treatment. The radioactive contamination of “Rubble, etc.” attributed to scattering and diffusion of nuclides which originated from core fuel. Secondary waste from water treatment system is generated by adsorption treatment of nuclides originating from core fuel in water. Waste due to fuel debris removal work will be generated in the future (Fig 3). Solid waste is safely stored continuously according to its type and surface dose rate (Table 3). Construction of facilities has been progressing steadily, and volume reduction of solid waste such as used protective clothing is being carried out by operation of miscellaneous solid waste incineration facility.

In the Solid Waste Storage Management Plan, the amount of solid waste generated in the next ten years is estimated, and a plan is shown to reduce volume of waste stored outdoors as much as possible and transfer to indoor storage in order to achieve further reduction of the risk on storing solid waste.

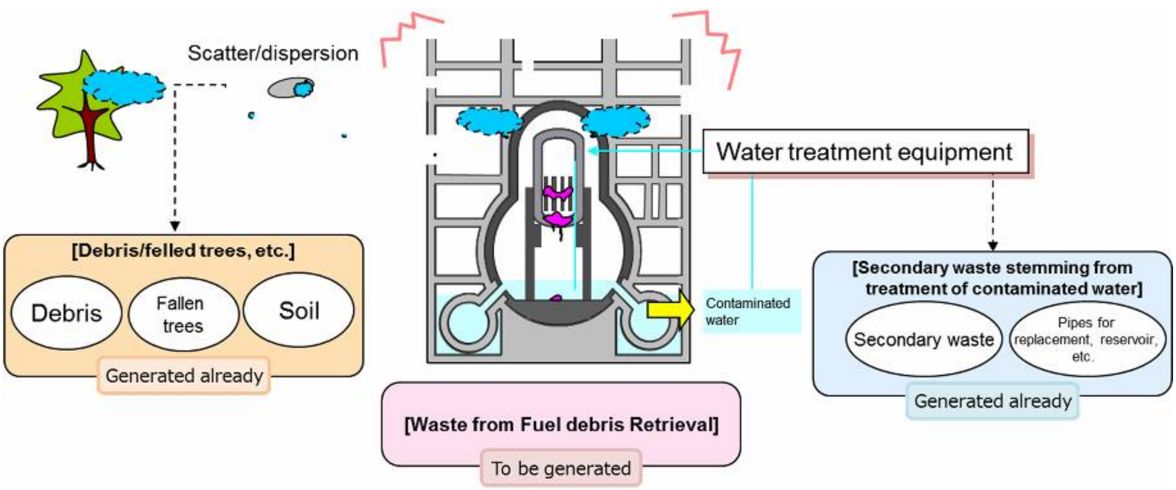



Fig 3 Outline of solid waste contamination source and nuclide migration pathway[1]

1 IRID supplementary budget for 2014 “Management Water Contaminated and Decommissioning of Project (R&D for processing and disposal of solid waste) Final report, August, 2017

Table 3 Solid Waste Storage Status[2]

(a)Management status of rubble, felled tree, used protective clothings etc. (As of April 30, 2017)

Rubble

| Surface dose rate (mSv/h) | Storage Method | Storage Volume ($m^3$) / Capacity ($m^3$) (%) |
|---|---|---|
| ≦0.1 | Outdoor storage | 147,900 / 214,300 (69%) |
| ≦1 | Outdoor Sheet covered storage | 30,900 / 71,000 (44%) |
| 1～30 | Soil covered temporary storage facility, Temporary storage tent, Outdoor container storage | 20,800 / 27,700 (75%) |
| ＞30 | Container(in Solid waste storage building) | 8,300 / 12,000 (69%) |
| Total | ---- | 207,900 / 325,000 (64%) |

Felled tree

| Category | Storage Method | Storage Volume ($m^3$) / Capacity ($m^3$) (%) |
|---|---|---|
| Root | Outdoor storage | 79,500 / 144,500 (55%) |
| Branch/leaves | Temporary storage pool | 19,600 / 24,900 (79%) |
| Total | ---- | 99,100 / 169,400 (59%) |

Used protective clothing

| Storage Method | Storage Volume ($m^3$) / Capacity ($m^3$) (%) |
|---|---|
| Container | 67,500 / 71,200 (95%) |

(b) Management status of Secondary Waste generated from Water Treatment (As of May 18, 2017)

Used Vessel

| Storage place | Type of Used Vessel | Storage Number | Storage Number/Capacity (%) |
|---|---|---|---|
| Outdoor temporary storage area of used vessels | Cesium Absorption apparatus | 758 | 3,628 / 6,239 (58%) |
| | 2nd Cesium absorption apparatus | 188 | |
| | HICs from multiple radio-nuclides removal system | 1,365 | |
| | HICs from improved multiple radio-nuclides removal system | 1,044 | |
| | Used vessels from high-performance multiple radio-nuclides removal system | 73 | |
| | Used column from multiple radio-nuclides removal system | 9 | |
| | Used vessels and filters from mobile-type strontium system | 191 | |

Sludge and concentrated waste liquid

| Category | Storage Method | Storage Volume ($m^3$) | Storage Volume ($m^3$) / Capacity ($m^3$) (%) |
|---|---|---|---|
| Sludge | Sludge storage facility (Indoor) | 597 | 597 / 700 (85%) |
| Concentrated waste liquid | Concentrated waste liquid storage tanks (Outdoor) | 9,379 | 9,379 / 10,700 (88%) |

2 Decommissioning and contaminated water management team meeting (42th), Attachment 3-4,Radioactive waste processing and disposal, May 25, 2017

ii. **Waste characterization**

In order to study processing and disposal of solid waste, it is necessary to understand nuclide composition, radioactivity concentration and other characteristics of solid waste. Sampling and analysis were carried out mainly on “rubble, etc.” and secondary waste from water treatment generated after the accident. Analysis results of about 300 samples have been accumulated over the past 6 years. Fig 4 shows examples of the sampling location.

Although some contamination characteristics of solid waste are being estimated based on accumulation of analysis results, further analysis is still required. In addition, in order to promote characterization, a method of understanding the characteristics by using analysis data and nuclide migration model evaluation data is being developed.

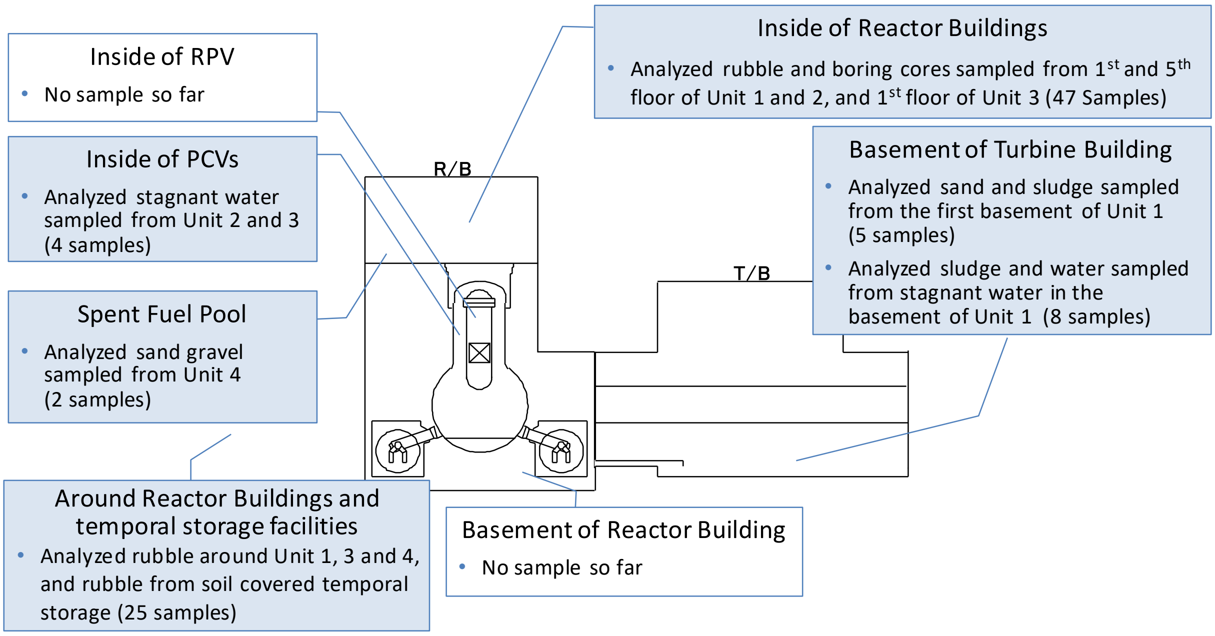



Fig 4 Examples of sampling location[3]

iii. **Processing and disposal**

Some of secondary waste from water treatment system has high fluidity, includes materials and components that have no experience in processing or disposal of in Japan, and is relatively in high dose rate. Therefore, the technologies for stabilization and immobilization have been developed with priority. In order to narrow down the applicable candidates of conditioning technology, fundamental tests for solidification have been conducted with simulated non- radioactive waste using proven technologies. Through these tests, data was obtained on the possibility of solidification and the soundness of the solidified products such as the requirements for solidification, and mechanical strength.

As for disposal, waste classification methodology has been studied on a trial basis with use of the information of nuclide composition tentatively set for existing disposal concepts as an example, from the point of view of disposability. In addition, the case-based study of overseas disposal

3 IRID/JAEA, Fukushima Daiichi Nuclear Power Station Solid Waste Sample Analysis (Achievement to Date), May 25, 2017, p.4.

facilities has been conducted in order to contribute to the study on disposal concepts which is based on the characteristics of solid waste.

## 4) Proposal for compilation of the basic concept of solid waste management (Strategic proposal)

i. **Characteristics of solid waste**

Described below are the characteristics of solid waste that have been presumed based on the results of the past activities for solid waste management and of R&D.

- The amount of solid waste is greater than that of solid radioactive waste generated by normal operation of nuclear power stations, and proportion of solid waste with relatively high dose rate is high. As the major source of contamination is fuel debris, radioactive concentration of nuclides in solid waste does not exceed that of spent fuel.
- Composition and radioactive concentration of nuclides in solid waste have a lot more varieties, compared with those of solid radioactive waste generated by normal operation of nuclear power stations.
- Secondary waste generated from water treatment has high fluidity, high dose rate that can causes the generation of hydrogen, and the materials/substances which have never been dealt with in Japan.
- Solid waste generated immediately after the accident include materials/substances whose chemical characteristics might impact on the safety of the predisposal and disposal and/or whose chemical hazard might affect the environment.
- Information about the total amount of solid waste and their characteristics, which are essential for discussions on disposal, will be revealed sequentially as decommissioning activities proceeds.

ii. **Solid waste management policies**

Characterization, storage and preceding processes in predisposal management are mainly focused on until a prospect of disposal is obtained, considering the international safety principles for radioactive waste management and radiological protection, as well as the characteristics of solid waste which have been presumed based on the results of the activities for decommissioning and of the waste characterization after the accident. The following solid waste management policies are proposed:

- Thorough containment and isolation;

  In order to prevent harmful exposure to radiation, implementing thoroughly containment of radioactive materials not to be dispersed and leaked, and isolation of them not to be accessed by people
- Reduction of the amount of solid waste;

  Reducing the amount of solid waste generated by decommissioning as much as possible in order to ease the burden of solid waste management
- Promotion of waste characterization;

  In order to deal with future increase in analytical samples, increasing analytical capability systematically by constructing required facilities/equipment, keeping on analytical talented staff and bringing up analytical staff, and improving characterization by R&D from the perspective of efficiency.
- Thorough storage;

  Implementing the Solid Waste Storage Management Plan steadily in order to improve the safety of solid waste storage.

Information on the total amount of solid waste and their characteristics, which is necessary for studying disposal, will be revealed sequentially as decommissioning work proceeds and its plan becomes clear. Solid waste which will be generated sequentially in the future will be stored in safer and more reasonable manner in light of their characteristics. And the storage capacity will be secured in order to ensure storage in the site of Fukushima Daiichi NPS.

- Establishment of a selection system of preceding processing methods in consideration of disposal;

Establishment of a selection system of preceding processing methods for stabilization and immobilization of solid waste before technical requirements are set in order to implement safer and more reasonable storage of solid waste.

iii. **Present efforts and R&D based on solid waste management policies**

- Thorough containment and isolation;

For thorough containment and isolation of solid waste, the measure such as store in containers or immobilization is performed as needed. Solid waste is isolated by storing in the storage place which is set up appropriately, and suitable management such as monitoring is performed.

- Reduction of the amount of solid waste (quantity reduction, volume reduction);

For reduction of the amount of solid waste, continue such efforts as carry-in control, re-use/recycling and volume reduction.

- Promotion of waste characterization;

As for increasing analytical capability, construct new facilities/equipment and use existing ones systematically from a mid- and long-term perspective, and establish a system for human resource development (HRD) and technology transfer. And as for R&D for improving characterization from the perspective of efficiency, develop a characterization method with complimentarily combining analytical data and evaluation data based on nuclide migration model, and facilitate R&D for optimizing the number of analytical samples and for simplifying analytical methods to speed up analysis.

- Thorough storage;

Reduce the amount of solid waste that have been stored temporarily outside of storage facilities by moving them to storage facilities after volume reduction as much as possible in order to improve the safety of solid waste storage.

Discuss the methods of evaluating the amount of hydrogen gas generated from the secondary waste from water treatment during the period of storage, estimate the timing of implementing additional safety measures and consider what kind of the measures will be required, considering the characteristics of the solid waste to be generated sequentially in the future.

Study storage methods for solid waste to be generated by fuel debris retrieval parallel to the study on fuel debris retrieval/storage methods.

- Establishment of a selection system of preceding processing methods in consideration of disposal

Establish a selection system of preceding processing methods. In this system, safety assessment of specifications of a provisional waste package is performed relatively in each developed disposal concept. The provisional waste package is made by treatment method which is narrowed down, the selection of preceding processing methods depends on the result of safety assessment.

- Efficient implementation of R&D projects from the perspective of overall solid waste management

  Share the issues and discussions progress among the all players and proceed with R&D, reviewing required R&D themes with a bird's-eye-view of overall solid waste management.

- Development of a system for continuous operations

  Develop a continuous operational system including development of adequate facilities and human resources, which are concerned with solid waste management, in order to continue safe and steady solid waste management.

- Measures to reduce the exposure of workers to radiation

  Implement thorough and sound radiation exposure control, safety management and healthcare program based on the relevant laws/regulations.

# 6. R&D initiatives

## 1) Basic policy for R&D

### i. **Basic policy**

NDF has determined the R&D duties implementation policy based on the NDF Act. According to this policy, NDF gathered national/international expertise and managed a variety of R&D that support steady implements of measures based on the Roadmap. As fuel debris retrieval policies for each unit will be fixed, such R&D methodology shall enter a new phase. And as detailed processes towards the decommissioning will be clarified, the roles of each R&D player should be more clarified. In this case, it is necessary to arrange the division of roles and responsibilities between the government and the operator in an appropriate manner in order to steadily implement R&D results on the decommissioning site. And it is considered to be further expected that the government and the relevant research institutes should establish a center of basic research/research infrastructure based on a mid- and long-term perspective. Research institutes are expected to enhance the technologies required for decommissioning through considerations on the status of the project and the fundamental R&D activities according to scientific and technological issues (needs) regarding the decommissioning.

### ii. **Entire perspective of R&D**

There are variety of institutions engaged with the Fukushima Daiichi NPS decommissioning R&D projects through the areas of basic/fundamental research, application R&D research/utilization. (Fig-5) NDF has been undertaking optimization of R&D activities carried out by each institution for a better effectiveness and efficiency as a whole.

Regarding gathering national and even international expertise, METI's Project of Decommissioning and Contaminated Water Management includes foreign companies as its players, and international joint-research projects in the Nuclear Energy Agency of the Organization for Economic Co-operation and Development (hereinafter referred to as "OECD/NEA") such as BSAF, a research project of severe accident progression analysis, are ongoing. Moreover, joint-research projects with overseas institutes are underway as a part of MEXT's World Intelligence Project for Nuclear S&T and Human Resource Development.

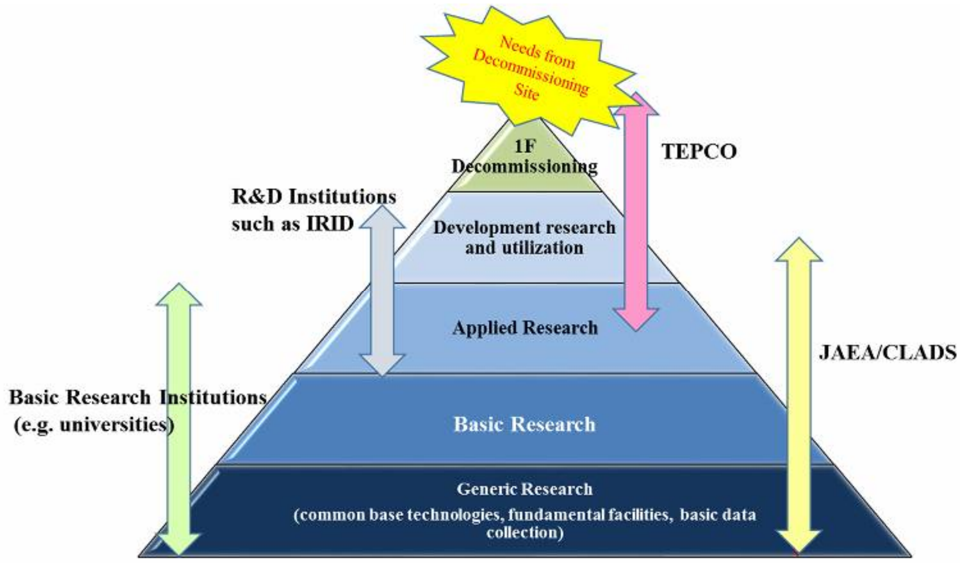



Fig-5 A conceptual picture of the division of roles among main R&D Institutions for 1F decommissioning

## 2) Promotion of R&D aimed at utilization for the decommissioning process

### i. **R&D activities performed by TEPCO**

It is required for TEPCO, as a responsive operator of the Fukushima Daiichi NPS decommissioning, to implement R&D activities, and also to promote introduction and demonstration of necessary excellent technologies with economic feasibility, with consideration for the site conditions. TEPCO is expected to continue actively implementing highly feasible R&D projects necessary for decommissioning, and to promote engineering projects for applying component technologies developed in the Project of Decommissioning and Contaminated Water Management as well. Especially, TEPCO is expected to develop practical equipment as the progress of the engineering necessary for fuel debris retrieval.

### ii. **Project of decommissioning and contaminated water management**

METI's Project of Decommissioning and Contaminated Water Management has achieved certain results. It is important to flexibly reorganize this kind of R&D projects, depending on the accurate grasp of the "needs" in the decommissioning operations, latest conditions in the reactor, the decommissioning process or the actual progress status of each R&D project, to make the entire project realistic and effective.

Once the fuel debris retrieval policies for each unit are determined, engineering activities, such as application designing for actual units, shall commence. As these processes progress, it is needed to continuously revise R&D projects in a manner of proper division of the roles between the government and the operator in order to make it work more closely with engineering processes.

## 3) Reinforcing cooperation in R&D

Since the R&D projects for the Fukushima Daiichi NPS decommissioning involves a lot of institutions/organizations, it is important to understand the R&D efforts of one another institution/organization, to share the information of such activities, and to build and retain closer cooperation/connection between the decommissioning site and R&D sites. For this purpose, NDF has been hosting the Decommissioning R&D Partnership Council meetings. NDF also has launched a website "Information Portal for the Research and Development for the Fukushima Daiichi Decommissioning" in order to offer national and international researchers opportunities of cooperation and to encourage them to join the R&D activities.

The closer links among academia have been facilitated and collaborative efforts such as establishing "Platform of Basic Research for Decommissioning" and "Academic Network Contributing to Fukushima Reconstruction and Reactor Decommissioning."

To add attractive incentives in order to make the research institutes keep motivated and participate in R&D continuously is one of the next issues as well.

### i. **R&D priority agenda based on needs and its strategic promotion**

To facilitate the Fukushima Daiichi NSP decommissioning project that may continue for over three to four decades in a safely steady and effective manner, it is essential to develop mid- and long-term R&D strategies including scientific and technological investigation based on understandings of the principles and the theories. For this purpose, NDF has built a task force on research collaboration and specified the Essential R&D Themes that should be preferentially and strategically targeted. Now, sectional meetings have been established in the Platform of Basic Research for Decommissioning and discussions to compile R&D strategies for the themes are underway.

These Essential R&D Themes are fundamental R&D issues to be dealt with based on scientific and technological investigation on the issues (needs) regarding the decommissioning project and the status of the project. To implement the themes, it should be required to establish a sustainable framework of COE with outstanding staff or core researches. It is expected the government will start to conduct or sponsor the R&D activities associated with the themes and consider developing a scheme to have those R&D projects run more effectively in accordance with the status of the progress of the R&D strategy of the Essential R&D Themes.

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

It is essential to work on developing R&D infrastructure and accumulating technological knowledge, such as previously mentioned Essential R&D Themes, developing generic technologies and collecting basic data, building up research centers, facilities and equipment, and human resource development.

The building for international research collaboration of JAEA/CLADS has opened in April 2017 in Tomioka-machi, Fukushima prefecture as a place where domestic and overseas universities, research institutions and industry form a network to promote R&D activities and human resource development in an integrated manner. The government and the organizations involved should implement measures to further utilize JAEA/CLADS.

It is also important to develop research infrastructure of hardware. JAEA put the Naraha Remote Technology Development Center in service in April 2016, and the Okuma Analysis and Research Center (radioactive material analysis and research facility), and other facilities are under construction. Research facilities for the decommissioning, contaminated water management and environmental decontamination measures have been set up mainly in Fukushima Prefecture, and those facilities are forming global centers for decommissioning R&D on the mid- and long-term vision of R&D.

iii. **Developing and securing human resource**

It is important for long-term sustainable R&D activities to facilitate programs of human resource, such as for developing and providing human resources of the researchers and engineers. MEXT's the Center of World Intelligence Project for Nuclear S&T and Human Resource Development has been proactively facilitating HRD via research activities among universities/colleges.

In long-term and large-scale projects, such as the decommissioning project at the Fukushima Daiichi NPS, it is important to develop core personnel for R&D who can perform scientific and engineering investigation from the academic perspective and personnel with a panoramic perspective (system integrators) who can integrate individual technology seeds into a system with practical functionality. This activity is being implemented by working on the previously mentioned Essential R&D Themes.

Meanwhile, it is also important to train and develop the engineers of private companies who are working in job sites. It is expected that companies will continue to make effort to expand the employees' capabilities by encouraging them to acquire related qualifications such as Professional Engineer or Chief Engineer of Reactors.

## 7. Enhancement of international cooperation

Decommissioning of Fukushima Daiichi NPS is an extremely complicated and difficult project that we have never experienced in Japan. On the other hand, there are some experiences and expertise in the world on decommissioning of nuclear facilities and sites that experienced accidents or contamination. To actively learn and make use of these learnings will help to facilitate safer and more efficient decommissioning of Fukushima Daiichi NPS, and it is important for the relevant organizations in Japan to proactively enhance international cooperation.

### 1) Integrating and utilizing wisdom

To utilize the knowledge and experiences of overseas organizations, NDF has been engaged in various international collaboration activities, including participation in the activities of the international organizations such as IAEA and OECD/NEA, signing the co-operation agreement with NDA, U.K. and memorandum of understanding with Alternative Energies and Atomic Energy Commission (CEA), for information exchange, etc., and also participation in the discussions under the governmental framework among U.K., U.S., France, Russia and Japan. NDF also invites distinguished experts from the U.K., France, Spain, and the U.S. as International Special Advisers to receive advice from them. NDF holds the Decommissioning R&D Partnership Council, in order to promote effectively and efficiently the R&D projects of individual organizations to realize overall optimization.

The necessity to learn from overseas knowledge and experiences is increasing as the technically challenging works progress. Therefore, it is vital to carry out decommissioning of Fukushima Daiichi NPS by integrating wisdom from around the world such as continuing to collect and utilize knowledge and experiences on decommissioning activities of other countries and to be evaluated against the international standards.

### 2) Active information dissemination to international communities

In order to introduce our efforts on decommissioning of the Fukushima Daiichi NPS, NDF has been participating in a variety of events in close collaboration with the government such as holding The International Forum on the Decommissioning of the Fukushima Daiichi NPS, and a side event at IAEA General Conference and presenting at Waste Management Symposia. . Also, NDF has been participating in the activities of OECD/NEA for providing the information on Fukushima Daiichi NPS.

It is important to carry out decommissioning in a manner open to the international communities in order to fulfill our responsibilities to the international communities as a nation that had the accident. Additionally, in order to attract people who may lead decommissioning activities in the future and contribute to collecting global intelligence, it is also essential to disseminate information about the issues, progress and achievements to international communities to receive their advice and assessments as decommissioning proceeds.

Furthermore, since it is necessary to prevent reputational damage, efforts need to be made to help the international community better understand. Further, it is necessary to reinforce dissemination of information that is easy for them to understand.

### 3) Close cooperation between relevant organizations

The relevant domestic organizations such as the government, NDF, IRID, JAEA and TEPCO have been engaging in each of their international collaboration activities according to their own roles and responsibilities. It is vital to share the information obtained through those activities and facilitate closer cooperation among these organizations.

## 8. Future actions

In the Strategic Plan 2017, we presented two strategic proposals. The importance of project management will increase as the decommissioning activities at the Fukushima Daiichi NPS progress to an advanced phase and technically difficult activities, such as fuel debris retrieval, are fully performed. As described in Section 1, NDF as the organization responsible for managing and supervising the implementation of the decommissioning project will be more involved in project management.

In ensuring the steady implementation of the project, it is important to gain the confidence of local residents.

### 1) Enhancing project management capabilities

At the Fukushima Daiichi NPS, a variety of decommissioning projects such as contaminated water treatment and retrieval of fuel from the spent fuel pool are being implemented concurrently and interactively with each other. The fuel debris retrieval operation, which is technically difficult and needs to be performed, taking into account the relationship with and the continuity of the activities that have been performed, will be fully performed.

This decommissioning project is an effort to complete a technically difficult task that is unprecedented in the world. Furthermore, successful completion of the project is the basis for the restoration of the regional society. Thus, the implementation of the project is of great significance. Considering the difficulty and complexity of the project, managing the project in an effective and integrated manner is key to the success of the decommissioning project.

Project risk management that identifies the risks which may impact on the implementation of the project, analyzes the significance of the risks and take required actions is essential for thorough decommissioning project especially at Fukushima Daiichi NPS with a high level of uncertainty.

In such a case as Fukushima Daiichi NPS with a high level of uncertainty, if there is a significant gap between the information/assumptions obtained/made at the time of planning and the data gained through actual work, the scheduled activities may not be feasible; it is important to consider always this kind of risks. Moreover, for Fukushima Daiichi NPS decommissioning in which so many different programs run in parallel, it is very critical to implement the programs in a well-organized manner. It is necessary to take more suitable measures against such project risks as to affect continuous progress of the entire decommissioning project.

In the US/UK decommissioning cases, various measures against such risks as impact on the progress of the project have been discussed and implemented. And detailed assessments of the impact of those risks on the entire schedule and cost have been performed. It is vital to deal with project risks in an effective manner while learning from such past cases.

Moreover, restoring confidence of people is a very important basis for implementing the decommissioning project. In order to continue to gain the confidence of people and appropriately manage the reserve funds, TEPCO, as the organization responsible for the implementation of decommission, and NDF, as the organization responsible for the management and supervision of decommission, need to clearly define their roles and accountability, and strengthen project governance to increase transparency in decommissioning activities and fund management in order to facilitate sound progress of the project, respectively.

### 2) Stakeholder engagement

The domestic/overseas professionals and organization that have experiences in decommissioning insist on the importance of good communications with local communities towards successful and steady decommissioning. Even a minor safety trouble may cause the fear/concern of the local residents, lead to decreased motivation for restoring/returning to home, increase reputational risks and affect the local economy.

It is indisputable that efforts should be made to prevent troubles with due care. If any troubles occur, it is vital to provide sincere and detailed explanations. Providing plain and accurate information is crucial to achieve this. Needless to say, at the time of a problem, Information should be positively provided on the implementation status of safety measures and the improvements in safety management in the field after a trouble.

Furthermore, it is required to share the concepts of the risk reduction strategy with the local residents in each and every phase of decommissioning. It is also important to have common understanding among relevant parties that the risks must be prioritized and classified as "risks to be removed as soon as practicable" and "risks to be dealt with in a careful manner" based on the risk reduction strategy.

Just sharing information between the providers and receivers is not enough to establish good communications. It is also necessary to have good conversation, make continuous effort mutually in order to reduce the gap between them and repeat these processes. The government has been hosting "Fukushima Advisory Board on Decommissioning and Contaminated Water Management", NDF has been hosting "The International Forum on the Decommissioning of the Fukushima Daiichi Nuclear Power Station", and TEPCO has been providing explanation to and having conversation with local residents at "Prefectural Safety Assurance Conference".

Just anxiety about potential risks may cause serious harm to the reputation. Even worse, it is often pointed out that only the significance of the image just after the accident will be highlighted even if around six years have already passed and it remains to be regarded as risk with the frequency ignored, typically.

The delay in taking appropriate actions and increase of the occupational exposure of the workers and cost through the approaches to existing reputational damages and reducing the risks posed by radioactive materials may harm public image/reputation of the decommissioning. And the consequences may cause further delay in implementing measures and trigger a downward spiral.

To avoid further reputational damages, it is more significant, than anything else, to manage radioactive materials in an appropriate manner in order not to let them leak and reduce the existing risks promptly. It is also crucial to provide appropriate information based on accuracy and transparency in a timely manner not only to the local residents, the press, market players and distributors but to domestic/overseas consumers, as well. To continue careful, polite and respectful communication is also important.

### 3) Consideration for the project sustainability

It is the lifeline for Fukushima Daiichi decommissioning to ensure the project sustainability for long-term period, so it is important to succeed the technical knowledge/information and maintain the human capability/motivation. Therefore, it is necessary to ensure the mechanism that enables continuous project management, R&D, engineering, and site management, etc. and to secure a large variety of human resources taking the roles in these works. In particular, it is desirable to manage the knowledge and experiences, establish the database, archive the data, and build the system to utilize and succeed them, as well as to build an environment which enables people involved in the project to develop their careers with pride, motivation, and the sense of reassurance.