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MISSION REPORT

IAEA INTERNATIONAL PEER REVIEW MISSION ON MID-AND-LONG-TERM ROADMAP TOWARDS THE DECOMMISSIONING OF TEPCO'S FUKUSHIMA DAIICHI NUCLEAR POWER STATION UNITS 1-4

Tokyo and Fukushima Prefecture, Japan
15–22 April 2013

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REPORT TO
THE GOVERNMENT OF JAPAN

Tokyo and Fukushima Prefecture, Japan

15–22 April 2013

MISSION REPORT

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MISSION REPORT

CONTENTS

SUMMARY 1
1. BACKGROUND, OBJECTIVES AND SCOPE OF THE MISSION 9
1.1. Background 9
1.2. Objective 9
1.3. Scope of the mission 10
2. CONDUCT OF THE MISSION 11
3. MAIN CONCLUSIONS AND ADVICES 12
3.1. Initial review of the Roadmap 12
3.1.1 Strategy and planning 12
3.1.2 Stakeholder involvement & communication 13
3.1.3 Organizational structure 16
3.1.4 Preparation for licensing 16
3.2 Specific short-term issues and recent challenges 18
3.2.1 Assessment of current condition of reactors and PCVs 18
3.2.2 Management of waste, spent fuel and fuel debris 23
3.2.3 Management of radioactive releases and assessment of associated doses 32
3.2.4 Decontamination within the site for improvement of working environment 33
3.2.5 Structural integrity of reactor buildings and other constructions 35
3.2.6 Reduction of radioactive exposure of the employees 39
4. TENTATIVE TOPICS FOR THE SECOND MISSION 43
APPENDIX I - MISSION PROGRAMME 44
APPENDIX II - LIST OF PARTICIPANTS 49

SUMMARY

Following the accident at TEPCO's Fukushima Daiichi Nuclear Power Station (NPS) on 11 March 2011, the "*Mid-and-Long-Term Roadmap towards the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Station Units 1-4*" was adopted by the Government of Japan and TEPCO Council on Mid-to-Long-Term Response for Decommissioning in December 2011 and revised in July 2012. The *Roadmap*, which is scheduled for an additional update in June 2013, describes the main steps and activities to be implemented for the decommissioning of the Fukushima Daiichi NPS through the combined efforts of the Government of Japan and TEPCO.

Within the framework of the IAEA Action Plan on Nuclear Safety, the Government of Japan invited the IAEA to conduct an independent peer review of the *Roadmap* with two main objectives:

- To improve the decommissioning planning and the implementation of pre-decommissioning activities at TEPCO's Fukushima Daiichi NPS; and
- To share with the international community the good practices and lessons learned by the review.

The review has been organized in two steps, and the IAEA conducted the first part in Japan from 15 to 22 April 2013. The objective of the first mission was to undertake an initial review of the *Roadmap*, including assessments of decommissioning strategy, planning and timing of decommissioning phases and a review of several specific short-term issues and recent challenges. Specifically, it covered the assessment of current reactor conditions, assessment of management of radioactive releases and associated doses, control of radioactive exposure of employees and decontamination within the site for improvement of working environment, structural integrity of reactor buildings and other constructions. The incidents recently experienced at the site, related with failures of the power supply and leakages of water from the underground reservoirs, were also included in the review of the specific short-term issues.

The Government of Japan and TEPCO have provided comprehensive information on the decommissioning plan. The mission was conducted through the assessment of the information provided to the team, professional and open discussions with the relevant institutions in Japan, and a visit to TEPCO's Fukushima Daiichi NPS, which provided an opportunity to observe how the *Roadmap* items were progressing and to discuss the generic and specific site issues with the plant operator.

This report presents an overview of the main findings, observations and advices of the mission, as of 22 April 2013.

Although a relatively stable cooling of the fuel (and fuel debris) in the reactors and spent fuel pools has been established and is adequately removing decay heat, there are several challenges to achieve a sustainable situation. The accumulation of enormous amounts of liquids due to the continuous intrusion of underground water into the reactor and turbine buildings is influencing the stability of the situation and requires additional countermeasures at the short term. For ensuring the long term stability of the fuel (and fuel debris) cooling, it will be necessary to continue the efforts to improve the reliability of essential systems, to assess the structural integrity of the site facilities and to enhance the protection against external hazards.

Regarding the incidents recently experienced at the site, related with failures of the power supply and leakages of water from the underground reservoirs, the IAEA team reviewed the internal assessment performed by TEPCO for identifying their causes and the related corrective and preventive countermeasures, including technical and communication aspects. The IAEA team identified some additional measures to further enhance the monitoring processes and instruments, for ensuring a prompt identification and mitigation of events at the site, as well as to improve the communication of events to the authorities and the public.

This report highlights 9 areas of important progress (Acknowledgments) to date and offers Advices on 17 points where the team felt that current practices could be improved. The Advices cover improvements in strategy and planning for decommissioning, stabilization of the reactors and spent fuel pools cooling, management of radioactive releases and assessment of associated doses, management of radioactive liquids on the site, radiological protection of workers on-site and site decontamination, taking into account both international standards and experience from decommissioning programmes in other countries. Japan is encouraged to continue its current efforts and to take into consideration the mission's Advices for the planned update of the "*Mid-and-Long-Term Roadmap towards the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Station Units 1-4*".

Acknowledgments and Advices

The highlights of the work of the review mission are presented below in the form of acknowledgments and advices.

STRATEGY AND PLANNING

Acknowledgment 1

The IAEA team acknowledges that the *Roadmap* was developed early after the accident. It indicates that solid engineering studies of alternatives have been performed to provide a basis for further implementation of activities towards the decommissioning of Fukushima Daiichi NPS. It serves as a framework, elaborating on major strategic issues and key decisions for the pre-decommissioning and decommissioning process, introducing the main phases of the process, main activities to be implemented and their interrelations. It is a high level document which indicates base line technical activities and identifies holding points where decisions for changes have to be eventually considered. It is a good tool to ensure which activities need to be further elaborated in the implementation plans specific to the individual phases.

Advice 1

The IAEA team encourages the Government of Japan and TEPCO to prepare to discuss the end-state of the Fukushima Daiichi NPS decommissioning strategy in close cooperation with other stakeholders. The preparatory work for such discussions would require elaboration of technical options, effects on local communities, the general public, the environment, occupational doses of workers and cost effectiveness.

As pointed out during the October 2011 mission on remediation, the IAEA team encourages all stakeholders to continue discussions on appropriate end-points for the radioactive waste. A lack of availability of such end-points would unduly limit and hamper successful accident recovery activities and the decommissioning of Fukushima Daiichi NPS as well as off-site remediation activities, thereby potentially jeopardizing public health and safety.

STAKEHOLDER INVOLVEMENT & COMMUNICATION

Acknowledgement 2

The team acknowledges that the Government of Japan and TEPCO have recognized the importance of appropriate stakeholder involvement and communication in dealing with decommissioning programmes and have been committed to implementing the relevant activities to ensure that all levels of Japanese society, communities and citizens are properly informed and communicated with in an open and transparent manner. The team appreciates that the Government of Japan has an intention to ensure transparency in the *Roadmap* revision process for better understanding of both local and national citizens through providing appropriate information.

Advice 2

TEPCO and the Government of Japan are encouraged to cooperate and collaborate to promote stakeholder involvement and communication in a more transparent and systematic manner. This effort could be helped by setting up clear and transparent rules and procedures necessary for communicating with the Nuclear Regulation Authority (NRA), the municipal authorities, the media and the public, for all situations of potential interest.

Advice 3

The team considers that reporting and communication activities are essential to gain confidence with the public, especially under difficult circumstances, as those derived from operational events. Therefore, the IAEA team encourages TEPCO to conduct a comprehensive assessment of its current procedures for reporting to concerned parties and for communicating with the public, both in normal and abnormal situations. The conclusions of this assessment should be shared with relevant parties (including the NRA and local authorities) and stakeholders, with the dual purpose of enhancing coordination among the different institutions and of helping to meet the expectations of the public.

PREPARATION FOR LICENSING

Advice 4

The review team encourages TEPCO to take more proactive approach for licensing for decommissioning of the Fukushima Daiichi NPS in order to ensure the decommissioning process to be prepared and implemented in a timely way.

SPECIFIC SHORT-TERM ISSUES AND RECENT CHALLENGES

ASSESSMENT OF CURRENT CONDITION OF REACTORS AND PCVS

Acknowledgment 3

The IAEA team views the efforts to provide redundancy and diversity as important progress towards reliability. Furthermore, updated maintenance procedures and practices based on the experience gained are also factors in continuous improvement of reliability. It is also acknowledged that establishment of an organization dedicated to rapidly identify and resolve problems is a positive step towards preventing and mitigating incidents.

Advice 5

The IAEA team encourages, emphasized by two recent events, TEPCO to continue and expedite its efforts towards enhancing reliability of the essential structures, systems and components (SSCs) as follows:

- Single-point vulnerabilities should be systematically and continuously evaluated, especially for the essential SSCs; and
- TEPCO should consider inclusion of transition plans from mobile and temporary SSCs, including monitoring equipment, to reasonably permanent ones in a timely manner to increase reliability against ageing, external hazards, and human induced failures.

Advice 6

TEPCO should consider ensuring the separation of the reactive (rapid fix of problems) scope and responsibility of Emergency (Immediate) Response Headquarters from the proactive scope and responsibilities, i.e. to anticipate, identify, and prevent 'potential' issues. This scope should be covered by an on-site group who would be continuously monitoring and evaluating the functionality and health of the SSCs and be isolated from incident response and daily operations activities.

MANAGEMENT OF WASTE, SPENT FUEL AND FUEL DEBRIS

Spent fuel removal from the storage pools

Acknowledgement 4

The IAEA team acknowledges TEPCO's efforts to quickly move forward the spent fuel removal project. The plan seems solid, considers alternatives and is well aligned with research and development (R&D) needs and time lines in the *Roadmap*.

Fuel debris removal from reactor pressure vessel

Acknowledgement 5

The IAEA team recognizes TEPCO's efforts in formulating a logical and rational plan for removing fuel debris, a crucial and complex task in decommissioning Fukushima Daiichi NPS. The efforts done so far, based on sound engineering approaches to base line and alternatives, are remarkable and have utilized best practices and available international experience.

Acknowledgment 6

The IAEA team acknowledges TEPCO's efforts to identify early in the process an R&D programme to study options for management of fuel debris after its removal.

Advice 7

Considering the complexity of the implementation of fuel debris removal, the IAEA team encourages TEPCO to ensure that adequate contingencies are in place to address the huge uncertainties that are likely to be faced during project execution. It would be fairly important to ensure good communication with the NRA so that project can effectively move forward.

Generic waste management issues

Advice 8

The IAEA team encourages TEPCO to start preparing its strategy and long-term waste management plan by estimating volumes, types and characteristics of different waste streams and by identifying optimized waste management scenarios for all phases identified by the *Roadmap* for decommissioning Fukushima Daiichi NPS, even though end-points for waste are not yet defined.

Additional reference to Advice 1.

Management of accumulated radioactive water and associated secondary waste

Acknowledgement 7

The IAEA team recognizes TEPCO's efforts to deploy large-scale treatment technologies for decontaminating and desalinating highly radioactive water accumulated at site. The treated water is being used to successfully cool the damaged reactor cores. Considering the challenges in the mobilization of industry support, the design and fabrication in relatively short time frame as well as the installation and operation under difficult conditions, this is a commendable achievement. The international community can also benefit from this valuable experience.

Advice 9

The IAEA team encourages TEPCO to review its strategy for accumulated water management and to work out a comprehensive plan taking into account the constraints and associated risks in the current approach in consultation with all relevant stakeholders, including the NRA and the public. Continuous attention should be paid to improving the safety and reliability of water treatment and storage facilities.

Additionally, considering the high total inventory of radioactivity currently stored in the numerous tanks located upstream of the pumping wells of the groundwater bypass system, it is of utmost importance to have adequate measures in place for detecting leaks promptly and mitigating their consequences.

MANAGEMENT OF RADIOACTIVE RELEASES AND ASSESSMENT OF ASSOCIATED DOSES

Advice 10

The IAEA team encourages the Government of Japan and TEPCO to establish a frank and informed discussion with the relevant authorities and stakeholders, including the NRA and local authorities, to assess the balance of risks and benefits of the dose limit to the public and its practical implementation, particularly from the direct exposures at the site-boundary arising from contaminated solids and accumulated liquids on the site and for the possibility of controlled discharges of liquid from the site. The discussions should include an assessment of the balance of off-site and on-site exposure risks, as well as the consideration of the parallel progress of the off-site remediation programme and the *Roadmap* for on-site decommissioning and their mutual interaction. The discussion should also include the definition of the representative member of the public to be considered in the assessments of individual doses in different areas, taking into consideration the real and evolving off-site situation.

DECONTAMINATION WITHIN THE SITE FOR IMPROVEMENT OF WORKING ENVIRONMENT

Advice 11

The IAEA team suggests that TEPCO defines an adequate end state of debris removal and then considers a simplification of the floor decontamination techniques as advised in Section 3.2.4. The IAEA team also suggests that TEPCO should reassess the operational dose-rates objectives for defining the different working areas, especially referring to controlled areas, taking into consideration the best international practices in this field as well as the possibility for using extra localized decontamination or shielding, in order to further optimise the management of radiation protection for workers. It is also suggested to make the mentioned reassessments on a periodical basis taken into consideration the evolution of the radiological conditions in the relevant areas.

STRUCTURAL INTEGRITY OF REACTOR BUILDINGS AND OTHER CONSTRUCTIONS

Acknowledgement 8

The work presented by TEPCO was well organized, executed in a logical manner and examined the different areas of concern in a conscientious way. The task of evaluating the structural integrity is very complex, in general, and even more so under the specific circumstances of the conditions at the plant. The analysis presented by TEPCO shows that the reactor buildings have margin against design seismic events.

Advice 12

Seismic and structural integrity analysis could be enhanced by the items as identified in Section 3.2.5.

Advice 13

Additional peer review and/or independent confirmatory analyses by experts in the areas of dynamic seismic analysis, finite element modelling, progressive collapse, thermal effects on structures, and reinforced concrete inelastic behaviour are advised to improve the confidence of the results and conclusions.

Ageing management

Advice 14

The ageing management programme could be enhanced by the following items:

- Develop or expand upon current structural and materials aging management programmes for the reactor buildings and other critical structures to provide for the long-term decommissioning efforts;

- Consult with experts in the international community in the areas of materials degradation including corrosion and corrosive environments, steel embrittlement due to the high radiation levels, and reinforced concrete degradation; and

- Prepare methods and procedures to mitigate and repair additional damage that may occur due to future aging-related degradation to the critical structures required to function for the long term decommissioning.

Re-evaluation of External Hazards

Advice 15

The Re-evaluation of External Hazards programme could be enhanced by the following items:

- To complete the external hazard re-evaluations for the Fukushima-Daiichi NPS site as early as possible with broad involvement from the scientific community and to share the results with the public; and

- To continue assessing the tsunami protection to ensure consistency with the hazard.

Seismic monitoring and collection of data to assist in building realistic modelling

Advice 16

To install accelerometers with recording capability on the building structures (e.g. reactor buildings) at characteristic locations to allow for the proper establishment of the level of shaking being experienced during possible future earthquakes. Data recorded during such events will be a valuable input in validating and calibrating the models used for predicting the seismic response for the reactor buildings.

REDUCTION OF RADIOACTIVE EXPOSURE OF THE EMPLOYEES

Acknowledgment 9

The IAEA team acknowledges that TEPCO is highly committed to enhance radiation protection and implementation of individual radiation management, examination and implementation of measures for reduction of dose optimized for individual work activities, and rationalization of protective measures. Several measures were applied in order to reduce the dose to the workers during individual work operations to the lowest reasonably achievable level. By taking such dose reduction measures, exposure dose is gradually decreasing. In the future, additional dose reduction measures will be implemented for further reduction of individual and collective doses. The applied dose limits are in accordance with international good practice.

Advice 17

The IAEA team suggests further improvement and enhancement of the operational radiation protection system for reducing radioactive exposure of the workers. It may include following measures: application of passive dosimeters; increasing the number of online monitoring stations; clarification of high radiation dose areas; application of ventilated masks in special situations; application of dose optimization software when possible and increasing the whole body counting possibilities by gamma spectrometry.

1. BACKGROUND, OBJECTIVES AND SCOPE OF THE MISSION

1.1. BACKGROUND

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

The Government of Japan (Ministry of Economy, Trade and Industry - METI) requested the IAEA to organize an International Peer Review of the *Roadmap* including a review of the relevant individual topics. The intention to host the review was expressed during the Fukushima Ministerial Conference on Nuclear Safety in December 2012.

Through the review, which was performed in the framework of the IAEA Action Plan on Nuclear Safety, the Government of Japan contributed to the enhancement of international cooperation and underlined Japan's intention to share with the international community information and knowledge concerning the accident to be acquired in the future decommissioning process. This International Peer Review has been organized in two steps (two missions) to implement the required review, first of which was performed by this mission.

This review also reflected the relevant conclusions of the IAEA International Experts' Meeting on Decommissioning and Remediation after a Nuclear Accident held under the IAEA Action Plan on Nuclear Safety in Vienna from 28 January to 1 February 2013 (i.e., "*The IAEA should assist Member States with the development of end states and decommissioning strategies for decommissioning of accident damaged facilities.*").

1.2. OBJECTIVE

The objective of the mission was to provide an independent review of the activities associated with the planning and implementation of Fukushima Daiichi NPS decommissioning. It was based on the IAEA Safety Standards and other relevant safety and technical recommendations and aimed at assisting the Government of Japan in the revision of the "*Mid-and-Long-Term Roadmap towards the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Station Units 1-4*". In particular, it was intended to:

- Improve the decommissioning planning and the implementation of pre-decommissioning activities at Fukushima Daiichi NPS; and
- Facilitate sharing of good practices and lessons learned for decommissioning operations after the accident, identified during the review, with international community.

The main purpose of the first mission to Japan was to undertake an initial review of the *Roadmap* including assessments of decommissioning strategy, planning and timing of decommissioning phases and a review of several specific short-term issues and recent challenges.

1.3. SCOPE OF THE MISSION

The scope covered the following main areas:

- Initial review of the *Roadmap*:
    - Decommissioning strategy, planning and timing of decommissioning phases (including pre-decommissioning activities, proposed solutions and challenges, communication and stakeholders involvement, R&D to support decommissioning and radioactive waste management);
    - Organizational structure for decommissioning;
    - Preparation for the decommissioning licensing.
- Specific short-term issues and recent challenges:
    - Assessment of the current condition of the reactors (e.g. cooling of reactors, monitoring parameters, improving the reliability of cooling and monitoring, investigation of PCVs);
    - Management of radioactive releases and assessment of associated doses (e.g. strategy, influence of gaseous, liquid and solid radioactive materials in the site on doses, prevention of contaminated water leaks to external environment, measures to prevent groundwater intrusion to the reactor buildings);
    - Decontamination within the site for improvement of working environment (e.g. decontamination plan outside and inside the reactor buildings);
    - Structural integrity of reactor buildings and other constructions (e.g. investigation and evaluation of the seismic safety of Unit 1-4 reactor buildings and spent fuel pool building, periodical inspections of Unit 4 building);
    - Reduction of radioactive exposure of the employees (e.g. implementation of individual radiation management, examination and implementation of measures for reduction of dose optimized for individual work activities, rationalization of protective measures).
- The scope and a tentative date of the second mission. The mission will be focused on more detailed and holistic review of the *Roadmap* and on mid-term challenges and related specific topics.

Off-site management of radioactive waste was not within the scope of this review, however it was considered during the review as it has an impact on the decommissioning process.

2. CONDUCT OF THE MISSION

The mission was conducted by a team composed of eight IAEA and four international experts well recognized in this domain with support from the IAEA public information staff.

The mission was conducted from 15 April through 22 April 2013. The mission consisted of meetings with METI and TEPCO in Tokyo, a visit to the Fukushima Daiichi NPS, and further meetings at the Fukushima Daini NPS. The visit to Fukushima Daiichi NPS site provided an opportunity to observe how the *Roadmap* activities are progressing and the discussion of generic and specific site issues by the plant operator. A brief meeting with the NRA was also conducted.

The first and second days were devoted to presentations by METI, TEPCO and the NRA of the issues covered by the *Roadmap* including radioactive waste management and preparations for decommissioning of Fukushima Daiichi NPS. The second day included the travel to Fukushima Prefecture. The third day was dedicated to the Fukushima Daiichi NPS site visit to observe and discuss general and specific issues included detailed discussions of plant conditions and recent challenge. The IAEA team specific groups met with TEPCO officials and experts at the Fukushima Daini NPS facilities on corresponding issues on the fourth day and the fifth days. Upon travelling back to Tokyo at the end of the fifth day, the remainder of the mission was devoted to clarifying the issues and preparing the report. On the final day of the mission, the draft report was provided to METI and TEPCO, and a press conference was held on the results of the mission.

The mission team was divided into three groups:

- Management of Radioactive Waste and Releases;
- Decontamination of Site and Reduction of Employee Exposure;
- Structural Integrity.

Also the entire team grouped together to review the presentations provided by METI and TEPCO staff on:

- Current Conditions of the Reactors;
- Roadmap Strategy, Planning, and Organization.

3. MAIN CONCLUSIONS AND ADVICES

3.1. Initial review of the Roadmap

3.1.1. Strategy and planning

The issues related to strategy and planning for decommissioning of the Fukushima Daiichi NPS units 1-4 are elaborated in the basic document "*Mid-and-Long-Term Roadmap towards Decommissioning of the Fukushima Daiichi NPS Units 1-4*", which was provided to the review team by METI and TEPCO prior to the mission, together with several supporting documents. In addition, during the mission there were presentations related to the *Roadmap*, to the radioactive waste management and decommissioning challenges and to the "Implementation Plan of Measures to be Taken for the Specified Reactor Facilities at Fukushima Daiichi Nuclear Power Station".

The *Roadmap* provides information on the current strategic approach to the management of the consequences of the accident and to the decommissioning of Units 1-4.

The *Roadmap* describes a phased approach for planning and implementation of the post-accident (pre-decommissioning) and decommissioning activities. Three main phases are identified together with the main activities to be implemented in each of the phases, but only a very rough time schedule of the phases is provided. Revision of the *Roadmap* with more detailed description of phase 1 and phase 2 concepts is planned to be done in June 2013.

A high degree of uncertainties is influencing some of the key aspects which form the basis for implementation path forward. The most important one is the unknown detailed radiological and physical situation inside the reactor pressure vessels and the integrity of primary containment vessels of the units. Actual status and the location of the fuel debris, extent of the structural damages and the loss of integrity of the structures and components, as well as the magnitude of the contamination are not well known yet. The conditions and the location of the fuel debris have to be determined in order to plan for its removal and to develop adequate technologies since the removal of the debris is a prerequisite for the decommissioning activities.

These and some other unknowns do not allow more detailed planning and determination of more precise timeline, especially for the last decommissioning phase defined in the *Roadmap*, commencement of which is subject to a successful completion of the first two phases. TEPCO has informed the IAEA team about on-going efforts to obtain accurate information based on physical and radiological characterization of the mentioned zones, which are currently not accessible or very difficult to access.

There are also large uncertainties related to the management of the huge amount of radioactive waste coming from the accident and expected during decommissioning that are very much dependent on definition of decommissioning end state of Fukushima Daiichi site. According to TEPCO, the current intention is to clean out completely the entire site and to remove all the facilities, structures and the waste from the site to another location, which is not formally identified at the moment.

Considering the magnitude of the accident consequences on the site, achievement of such an end state will present a challenging task for several decades, will require deployment of very large human and financial resources and will involve generation and management of huge amounts of waste, including retrieval of the waste from the existing temporary waste storages and its proper disposal. Adequate waste disposal facilities or long term storage sites with adequate capacities will have to be made available in time to support a programme of such magnitude.

In any case it is advisable to perform adequate studies and analysis to better understand consequences of any desired path forward. In order to achieve the ultimate end state of the Fukushima Daiichi site adequate forecast of waste inventories and selection of waste management options would be essential for plans, schedules and cost estimates for all the activities on site and for the supporting activities off site, such as construction of disposal facilities, that should be developed.

Inviting international organizations and bilateral decommissioning partners for peer reviews would help provide constructive evaluation of the planned programme and its implementation. Such organizations may be also invited to attend the R&D management organization meetings to support the efforts of METI and TEPCO in R&D area.

Acknowledgment 1

The IAEA team acknowledges that the Roadmap was developed early after the accident. It indicates that solid engineering studies of alternatives have been performed to provide a basis for further implementation of activities towards the decommissioning of Fukushima Daiichi NPS. It serves as a framework, elaborating on major strategic issues and key decisions for the pre-decommissioning and decommissioning process, introducing the main phases of the process, main activities to be implemented and their interrelations. It is a high level document which indicates base line technical activities and identifies holding points where decisions for changes have to be eventually considered. It is a good tool to ensure which activities need to be further elaborated in the implementation plans specific to the individual phases.

Advice 1

The IAEA team encourages the Government of Japan and TEPCO to prepare to discuss the end-state of the Fukushima Daiichi NPS decommissioning strategy in close cooperation with other stakeholders. The preparatory work for such discussions would require elaboration of technical options, effects on local communities, the general public, the environment, occupational doses of workers and cost effectiveness.

As pointed out during the October 2011 mission on remediation, the IAEA team encourages all stakeholders to continue discussions on appropriate end-points for the radioactive waste. A lack of availability of such end-points would unduly limit and hamper successful accident recovery activities and the decommissioning of Fukushima Daiichi NPS as well as off-site remediation activities, thereby potentially jeopardizing public health and safety.

3.1.2. Stakeholder involvement & communication

The issues surrounding stakeholder involvement and communication in the course of implementation of the decommissioning programme have become one of the challenges that the Government of Japan and TEPCO need to deal with, as there are understandable anxieties and concerns among local communities and the nation as a whole.

It is important to know that stakeholder involvement and communication is a tool to bridge the gap of difference of thinking and perspectives in a process of mutual understanding. It may also be emphasized that two-way dialogue dealing with people's anxieties and concerns contributes to increasing mutual trust.

When stakeholder involvement and communication are conducted in a way that people's anxieties and concerns are properly addressed, the reliability of the Government of Japan and TEPCO will improve and the credibility of the whole decommissioning programme will increase.

The approaches of the Government

The Government of Japan recognizes that it is indispensable to ensure appropriate understanding of local residents on the decommissioning programme. The IAEA team noted that the Government of Japan implements stakeholder communication particularly focusing on the local communities by issuing status reports of the decommissioning on a monthly basis, having video conferences with local municipals surrounding the site on a monthly basis, visiting local municipals to explain the status reports on a monthly basis, and issuing brochures with less technical jargons to the local residents on an occasional basis.

The IAEA team observed that the Government of Japan further considers seriously enhancing stakeholder involvement and communication with all levels of Japanese society through ensuring clear explanation, securing transparent processes to revise the *Roadmap* and promoting confidence-building measures. The IAEA team appreciated that the Government of Japan is ready to reflect upon the public opinions of the revision of the *Roadmap*.

The measures and challenges of TEPCO

The IAEA team recognized that TEPCO includes several measures in its Implementation Plan submitted to the NRA which will be taken to promote people's understanding on the decommissioning programme.

Building trust

The IAEA team observed that the Government of Japan and TEPCO have faced difficulty in building or re-building public trust, although they have made efforts to conduct active stakeholder involvement and communication. Public trust issues can be overcome by constructive dialogue and the use of consistent and credible messages.

Reporting and Communication during the recent incidents

Recent events at the site related to electrical supply failures and the contaminate water leakages have created some anxiety in the public. The IAEA team has reviewed the reporting and communication processes associated to these events.

TEPCO presented its conclusions on the "investigation of the cause of delayed report and announcement and countermeasures" related to the events of electrical supply failures at Fukushima Daiichi NPS. These events were reported to the concerned parties in accordance with Article 25 of the Act on Special Measures concerning Nuclear Emergency Preparedness. Analysis of the sequence of the reporting activities to the relevant parties and of the associated announcements to communicate with the public were included in TEPCO's presentation, as well as the problems and failures detected in the two processes and the assessment of causes and countermeasures.

An excessive time in finding the cause of the power supply failure on the spent fuel pool cooling was identified as the main cause of the delays in reporting to the concerned parties and communicating with the public, as TEPCO's officials wanted to provide accurate information. Additional problems in the reporting and communication processes were identified related to internal processes to prepare the information to be provided to both concerned parties and public, with special focus on failures of coordination between the site and TEPCO's headquarters, as well as problems of coordination with the concerned parties regarding public communication.

Further, TEPCO decided to establish the "Social Communication Office" to properly handle and to accurately disseminate important information to the public under the direct supervision of TEPCO's President. TEPCO explained that the Social Communication Office will be composed of risk management experts.

Acknowledgement 2

The team acknowledges that the Government of Japan and TEPCO have recognized the importance of appropriate stakeholder involvement and communication in dealing with decommissioning programmes and have been committed to implementing the relevant activities to ensure that all levels of Japanese society, communities and citizens are properly informed and communicated with in an open and transparent manner. The team appreciates that the Government of Japan has an intention to ensure transparency in the Roadmap revision process for better understanding of both local and national citizens through providing appropriate information.

Advice 2

TEPCO and the Government of Japan are encouraged to cooperate and collaborate to promote stakeholder involvement and communication in a more transparent and systematic manner. This effort could be helped by setting up clear and transparent rules and procedures necessary for communicating with the NRA, the municipal authorities, the media and the public, for all situations of potential interest.

Advice 3

The team considers that reporting and communication activities are essential to gain confidence with the public, especially under difficult circumstances, as those derived from operational events. Therefore, the IAEA team encourages TEPCO to conduct a comprehensive assessment of its current procedures for reporting to concerned parties and for communicating with the public, both in normal and abnormal situations. The conclusions of this assessment should be shared with relevant parties (including the NRA and local authorities) and stakeholders, with the dual purpose of enhancing coordination among the different institutions and of helping to meet the expectations of the public.

3.1.3. Organizational structure

The organizational structure for managing the "*Mid-and-Long-Term Roadmap Towards Decommissioning of the Fukushima Daiichi NPS Units 1-4*" and deliberating important matters concerning the Fukushima Daiichi decommissioning was reinforced in February 2013.

The Nuclear Emergency Response Headquarters established "the Council for the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Plant (chaired by the Minister of METI)" to reinforce the R&D management towards fuel debris removal and to enhance the further collaboration between on-site work and R&D, considering current needs such as to address further technically-difficult challenges towards fuel debris removal from RPVs. Simultaneously, the Government and TEPCO Council was abolished. In addition, it is planned to establish a new organization for R&D management through public-private partnership around June. The organization is anticipated to ensure efficient R&D management for a long term.

Also, Fukushima Daiichi Stabilization Centre and Fukushima Daiichi NPS were merged into the one organization, which is responsible for the construction, operation of stabilization/decommissioning related facilities.

In response to recent emergency events (see Section 3.1.2), the "Emergency (Immediate) Response Headquarters for Reliability Improvement at Fukushima Daiichi Nuclear Power Station" was established on 7 April 2013. All TEPCO resources are available for further improvement of reliability on site and to deal with issues that may happen. TEPCO might keep certain level of flexibility regarding the organizational structure for decommissioning, especially for later stages. It will allow TEPCO to reflect actual decommissioning needs on site.

3.1.4. Preparation for licensing

The issue of preparation for licensing of decommissioning of the Fukushima Daiichi NPS Units 1-4 is not explicitly addressed in the current version of the "*Mid-and-Long-Term Roadmap Towards Decommissioning of the Fukushima Daiichi NPS Units 1-4*". It was only briefly discussed during the IAEA mission. Basic information was provided to the IAEA team prior to the mission in the material "Implementation Plan of the Measures to be Taken at Fukushima Daiichi Nuclear Power Station Designated as a Specified Reactor Facility". This material was used by TEPCO for a presentation during the mission. In addition, a brief meeting with representatives of the NRA was organized during the first day of the mission, when the licensing of the Fukushima Daiichi NPS prior to the accident, during the emergency period and at present was discussed. Plans for a new licensing regime in the near future were announced, but licensing of the later phases defined in the *Roadmap* were not discussed.

Discussions of the planning and safety issues, held during the week, partly addressed the licensing approach as well.

Decommissioning of Fukushima Daiichi NPS Units 1-4 will be licensed and regulated by the NRA, which was established in September 2012 by merging the Nuclear and Industrial Safety Agency (NISA) with the Nuclear Safety Commission (NSC).

Prior to the accident, the operation of the Fukushima Daiichi NPS was regulated under the Electricity Business Act and Nuclear Reactor Regulation Act. A basis for licensing of the operation was the Facility Management Plan, together with a number of supporting documents.

Licensing of the on-going activities at the Fukushima Daiichi NPS is still based on the Facility Management Plan. There are many operating facilities or facilities under construction on site (for example water treatment facilities), which have their own licensing process.

The licensing regime for the Fukushima Daiichi NPS is currently in transition. Based on the understanding that special control of the plant will continuously be needed, and that ensuring safety by application of emergency measures over a prolonged period of time is not an appropriate solution, a new regulatory framework was introduced. In November 2012, Units 1-6 were designated as Specified Reactor Facilities. This designation was done to control damaged nuclear facilities in an appropriate manner, responding to the situations where nuclear emergencies occurred and consequences exist for which special regulations commensurate with condition of the plants are stipulated.

The NRA prescribes set of safety requirements to be fulfilled by the operator of a Specified Reactor Facility. This set consists of 18 general requirements that follow the principles for protection of workers, public and the environment in a post-accident situation.

Together with designating the Fukushima Daiichi NPS Units 1-6 as Specified Reactor Facilities, the NRA directed TEPCO to implement the "items required for measures", based on the set of safety requirements provided.

TEPCO prepared an Implementation Plan, based on the *Roadmap* and consistent with it, and submitted it to the NRA in December 2012. The Implementation Plan includes information on the following:

- Overall Schedule and risk assessment of the specified nuclear facility;
- Design and equipment of the specified nuclear facility;
- Security of specified nuclear facility;
- Physical protection of specified nuclear fuel material;
- Fuel debris removal and decommissioning;
- Promotion of understanding of implementation of implementation plan; and
- Undergoing inspections pertaining to implementation plan.

This Implementation Plan is now under review by the NRA. Once the plan is approved, the NRA will conduct inspections to verify its implementation.

In addition to this special designation, the NRA amended the Nuclear Reactor Regulation Act and related regulations by April 2013. Although this Act is mainly focused on nuclear reactors under normal operation, the amendments provide a framework for reactors under special circumstances. Very specific conditions at the Fukushima Daiichi NPS site require special regulations and non-standard licensing process. Activities are on-going to re-define the regulatory and licensing framework for the Fukushima Daiichi NPS Units 1-4 and for the activities defined in the *Roadmap*. Flexible licensing regime is needed to accommodate activities associated with high uncertainties and with high potential for changes. The intention to apply non-prescriptive regime based on a set of more general safety requirements seems to be appropriate for the situation on site.

Advice 4

The review team encourages TEPCO to take more proactive approach for licensing for decommissioning of the Fukushima Daiichi NPS in order to ensure the decommissioning process to be prepared and implemented in a timely way.

3.2. Specific short-term issues and recent challenges

3.2.1. Assessment of current condition of reactors and PCVs

To review the activities associated with the planning and implementation of Fukushima Daiichi NPS decommissioning and to review several specific short-term issues and recent challenges, the IAEA team was tasked with assessing the current condition of the reactors because the road towards decommissioning might take more than 25-30 years, and current conditions of reactors including the sustained reliability to maintain and to enhance stable conditions throughout that period is essential. Furthermore, the current conditions and programme and processes also establish an initial state that will sequentially reflect on the extent and timing of actions considered and planned in the *Roadmap*. Hence, the IAEA team concentrated on the current cooling schemes of the reactors and associated physical and programmatic structures in order to provide an independent input on anticipated challenges and potential risks as well as advice on assisting on-going process improvements. This section of the report describes the IAEA team's observations and results of this review based on the material provided by METI and TEPCO staff on current conditions of the reactors, reliability improvement plans and activities, explanations of the most recent events, and overall *Roadmap* strategy and planning.

Current State of Cooling of Reactors and Spent Fuel Pools

The Reactor Pressure Vessels (RPV) of Fukushima Daiichi NPS Units 1-3 are currently being cooled by injecting circulated water through core spray and feedwater lines. The cooling water drains from the RPV to the Primary Containment Vessel (PCV) and combines with penetrating underground water in the reactor building. Via penetrations between the buildings, this 'contaminated water' leaks to the turbine building, where additional penetrating underground water collects. This 'contaminated water' in the turbine buildings is extracted and purified via the water processing equipment and then circulated back to the reactors. This cooling scheme has kept the reactor temperatures well below the upper temperature limit of 80°C (temperatures at the vessel bottom are currently approximately at 22°C, 35°C, and 33°C for the Units 1, 2, and 3, respectively).

The spent fuel pools (SFP) of Units 1-4 are cooled by a separate loop from the RPV cooling scheme. In this closed loop, the water extracted from the SFP is cooled by a heat exchanger. Initially, the cooler water then went through purification processes to remove chloride (existed from earlier seawater injection) and to deoxygenize as anti-corrosive measure and was injected back to the SFP. To be noted, TEPCO stated that the water in the Unit 1-4 SFPs has already been desalinated, and the purification system is no longer needed. However, the SFP water is continuously cooled and sampled to ensure water quality against corrosion. This cooling loop has kept the SFP temperatures well below the upper temperature limit of 65°C (temperatures at the SFPs are currently below 20°C in the Units 1, 2, and 3, and approximately 25°C in Unit 4).

Although relatively stable cooling of the fuel (and/or fuel debris) in the reactors and the spent fuel has been established and is adequately removing heat, there are several challenges. Foremost, the IAEA team noted that the road towards decommissioning, which will eventually result in the removal of spent and damaged fuel from spent fuel pools and the reactors, might take more than 25-30 years. Hence, as acknowledged by TEPCO experts, reliable cooling must be provided until the fuel (and fuel debris) is safely stored and forced heat removal is no longer needed. Therefore, the equipment necessary for this essential cooling must perform its functions for at least the next couple of decades. To address this point, TEPCO described its on-going activities to improve the reliability of both essential and non-essential structures, systems and components (SSCs) by several manners as follows:

- Improving Reliability by Redundancy, Diversity, and Independency:

  The cooling systems for the reactors are already equipped with redundant and diverse components, such as three redundant pumps, diverse and stand-by water and power sources, and back-up provisions such as fire trucks, etc. On the other hand, the work towards providing similar reasonable redundancy and diversity for other essential SSCs, including the spent fuel pool cooling system, is continuing. Completion of those activities will increase the reliability and availability of such SSCs. The IAEA team views these efforts to provide redundancy and diversity as important progress towards reliability. However, the IAEA team observed, and TEPCO staff confirmed, that various single-point vulnerabilities (SPVs) exist in the plant's essential and/or non-essential systems. The IAEA team also observed that the plant operator is aware of such issues and is continuously working towards elimination of those SPVs. One example of such SPVs was demonstrated in the recent event of power loss to the spent fuel pool cooling due to a short circuit of the Units 3-4 temporary M/C inside the container on the trailer by an intruding small animal. Although this event did not result in serious consequences due to relatively rapid (considering the site conditions and availability of dedicated resources) identification and resolution of the condition by the plant staff within the time permitted for mitigation and recovery. Similar events, that have continued to occur due to equipment failure and/or degraded performance, could potentially result in more serious consequences. As the enhanced diversity and redundancy efforts continue, the reliability of the SSCs needs to be further ensured by rigorously identifying those SPVs and eliminating them in timely manner.

  Additionally, considering the length of time (25-30 years) during which the SSCs will continue to be needed for 'essential' cooling, such issues as ageing, vulnerability to external hazards, and susceptibility to the human induced failures have to be taken into the consideration. As later indicated, the preventive maintenance and replacement of temporary SSCs by TEPCO is necessary to maintain the degree of reliability against ageing and material durability, such as conversion to polyethylene hoses as a counter-measure to long and treacherous cooling lines being prone to leaks (additionally, TEPCO is considering implementing measures to reduce risks against the seismic hazard for such lines). However, the IAEA team observed that the *Roadmap* does not include explicit plans for transition to permanent SSCs, especially for the essential ones. Again, the recent power loss to the spent fuel pool cooling event demonstrates the temporary equipment's vulnerability of intrusion.

- Improving Reliability by Maintenance and Surveillance Programmes and Procedures:

  Currently, a maintenance programme has been structured and preventive maintenance has been implemented to maintain the functionality of the equipment. Although the IAEA team did not review the details of station's maintenance and surveillance programmes and procedures, the team was briefed by the responsible staff with an overview of preventive and predictive maintenance procedures on some essential SSCs. Station personnel described that preventive maintenance schedules have been determined by the equipment specifications and failure data. Based on these brief descriptions, these procedures intend to address the periodic surveillance, repair, and replacement of equipment and components and have similar format and content of the traditional maintenance programme and procedures of an operating nuclear power plant with an adaption to the specific and non-traditional/non-standard SSCs of the Fukushima Daiichi NPS. The IAEA team views these practices as an important factor for reliability. The limited amount of time that the team reserved for discussing maintenance programme and procedures was naturally not sufficient to make any comments on their contents, however, it would be an area to include in the future review missions to identify the weaknesses and strengths, and if necessary, to provide assistance with maintenance and surveillance practices as well as facilitating good practices and lessons learned from the Fukushima Daiichi NPS experience.

- Improving Reliability by Timely Implementation of Countermeasures:

Although the preventive maintenance and periodic surveillance provide assurance for the equipment functionality, the IAEA team noted that a well-structured, well-thought, and rigorous system-health monitoring programme at Fukushima Daiichi NPS is essential to ensure not only the functionality of the equipment but also the availability, performance and effectiveness of heat removal towards the decommissioning process.

As mentioned above, the plant staff is continuously working on establishing diversity and redundancy as well as following a structured preventive maintenance programme, progress of these efforts are affected by the adverse conditions including the environmental conditions in work areas and a limitation of resources. More importantly, occupation of the plant staff with continuous response and reaction to daily issues, which are very dynamic, is inevitable. As a result, the IAEA team observed that TEPCO's site and headquarter organizations are mostly involved with problem solving (reactive) rather than potential risk/problem identification (proactive). It must be noted that, during the IAEA mission, TEPCO has informed the IAEA team of recently established organization, namely Emergency (Immediate) Response Headquarters, "for the purpose of swift implementation of reliability improvement measures to maintain and enhance stabilization." This organization is intended "to implement further reliability improvement measures as well as to deal with problems that have already occurred." The IAEA team views this action as important progress towards reliability improvement by problem identification and resolution. The reactive, "Fix-it-Now", scope and responsibility of Emergency (Immediate) Response Headquarters should be separated from the proactive scope and responsibility of the organization in charge for operation.

Current State of PCVs

Based on the explanations from TEPCO and METI experts, currently there are leaks from the Units 1-3 PCVs. TEPCO has been working to locate these leaks and has already surveyed by robots the lower part of PCVs, specifically around the vent pipes, in Unit 2, and will survey lower part of Unit 3 PCV when the radiological conditions are suitable for conducting such activities. The survey results in Unit 2 so far have not detected any visual indication of leakage from the suspected vent pipe locations, e.g. the vent pipe sleeves, sand cushion drain pipe ends, and bellow covers. However, TEPCO experts will continue to survey other potential locations, such as pipes and valves of RCIC and HPCI and associated systems, to locate the leaks. Besides the visual search, surveys on the secondary parameters such as water levels and temperatures in the suppression chamber (S/C) have been conducted to determine potential locations of the leaks. Locating the leaks is a critical stage in the *Roadmap* because to conduct operations to remove damaged fuel and dispersed fuel debris, the PCV will be filled with water and those leaks must be repaired to establish and sustain a filled PCV. The IAEA team has recognized that adverse environmental conditions and physical limitations due to scattered debris at and around lower part of PCV create a great challenge to the *Roadmap* actions that are prerequisite to the commencement of fuel debris removal, and locating and repairing of those leaks are part of the critical path towards decommissioning. The IAEA team's review of environmental conditions and associated improvement strategies are addressed elsewhere in this report.

TEPCO experts presented to the IAEA team a current baseline plan and step-up (alternative) plans for leak repairs in a staged manner. Although the staged approach of the repair strategies provides controlled use of resources in general, the sequential planning based on the results of each strategy to conduct the next one may result in lengthening the schedule and consuming more resources. Similar approaches have also been observed by the IAEA team for other *Roadmap* items such as prevention of groundwater intrusion to the buildings, building structures for spent fuel and fuel debris removal etc. Utilizing commonly available decision making models, tools, and techniques could be beneficial to conduct the best solution for the repair (or other *Roadmap*) strategies to effectively implement schedules and activities towards the decommissioning.

Monitoring and Surveillance of Current Plant Conditions

The current health of the monitoring and surveillance of plant parameters is accomplished by using instrumentation that survived the accident and the subsequent environmental degradation in addition to newly installed portable and permanent monitoring equipment both for the existing SSCs and new SSCs as well as the replacement of degraded instrumentation for more reliable indications. The IAEA team's review of monitoring and surveillance of the current plant conditions for both essential and less-essential plant parameters was conducted in three areas: Reliability and adequacy of indication, availability of indications, and timeliness of indications.

It is critical to have reliable indications of plant conditions, especially the essential parameters related to cooling reactors and spent fuel, as well as the radiological conditions to confirm the relatively stable thermal-hydraulics state and off-site and on-site radiological releases.

The IAEA team recognized that there have been efforts to confirm and/or improve the reliability of indications. For example, alternate measurements of temperature and radiation levels in the Unit 1 and 2 PCVs were conducted by remote sensors that confirmed the reliability of existing instrumentation inside the PCV that survived the accident and subsequent environmental conditions and utilized to monitor the PCV conditions as well as the derivation of status of fuel debris and PCV integrity. However, the IAEA team has also seen evidence of unreliability of monitoring and surveillance.

The following recent events illustrates some of the IAEA team's findings on the issues associated with the method of surveillance and vulnerability of monitoring equipment to single point failures, respectively:

- Monitoring the Underground Water Pond Leaks: Highly contaminated water (10^4 – 10^5 Bq/cm^3, beta nuclides) is currently being stored in the underground ponds (seven in total with nearly 60 thousand tons capacity). Integrity of these ponds (for example, detecting any leaks), is verified by both level surveillance and radiochemical analysis. Routine radiochemical analysis for Pond #2 on 3 April 2013 indicated an increase in activity, suggesting leakage from the pond into the sealant layers which was not evident in routine pond water-level measurements. Prior to the identification of this leak, the level surveillance had been conducted daily while radiochemical analysis was performed weekly for all seven underground storage ponds. Following the discovery, Pond #3 was also checked, and it was also discovered that despite no indication of leak by the daily level surveillance, a leak was detected due to the determination of high salt concentration and activity. Similar circumstances were repeated for Pond #1 subsequently. Currently, radiochemical analysis is conducted daily.

  From this example, the IAEA team observed that adequacy of monitoring method, e.g. level measurement, was not sufficient to verify the surveillance scope of detecting a leak. The team did not further investigate the corrective action with respect to transportability of level measurements or the adequacy of test methods in general since it was not the scope of this review.

  The IAEA team also notes that similar issues have occurred to question reliability and/or adequacy of instrumentation readings. In the case of concluded malfunctions of RPV thermometers, the reliability of reactor cooling related monitoring is ensured in accordance with the requirements reflected in plant Technical Specifications, and TEPCO has periodically evaluated, confirmed, and provided reports to the regulatory body on the adequacy and reliability of instrumentation utilized to confirm reactor cooling. In this event of leak from the underground ponds, the IAEA team would expect that TEPCO would conduct a thorough transportability evaluation to the other monitoring that is based on similar level measurements. It is also the IAEA team's advice to scope confirmation applicability and adequacy of surveillance methods, in general.

- Monitoring the Spent Fuel Pool cooling: On 18 March 2013, power to the SFP alternative cooling, the common pool cooling, as well as the cesium absorption system, was lost due to a short circuit in the Units 3-4 temporary M/C inside the container on the trailer by an intruding small animal. As a result of the common cause, parts of the remote monitoring system were also lost resulting in loss of monitoring of parts of the facilities.

  The IAEA team recognized the issues in this event from two perspectives: Firstly, the reliability of monitoring equipment that is vulnerable to single failures as well as to the external disturbances and hazards needs to be continuously and systematically evaluated and improved proactively, as discussed elsewhere earlier in this section. Secondly, which is more applicable to this area of the review, is the reliability of monitoring via temporary and portable equipment such as the web cameras and make-shift instrumentation. It was already advised by the IAEA team above to consider transition to the permanent equipment, but by further review of this event, the IAEA team would like to highlight the delay in identification and mitigation of the event due to being partially unable to monitor the plant parameters requiring sending teams out to the field to obtain information.

Acknowledgment 3

The IAEA team views the efforts to provide redundancy and diversity as important progress towards reliability. Furthermore, updated maintenance procedures and practices based on the experience gained are also factors in continuous improvement of reliability. It is also acknowledged that establishment of an organization dedicated to rapidly identify and resolve problems is a positive step towards preventing and mitigating incidents.

Advice 5

The IAEA team encourages, emphasized by two recent events, TEPCO to continue and expedite its efforts towards enhancing reliability of the essential structures, systems and components (SSCs) as follows:

- *Single point vulnerabilities should be systematically continuously evaluated, especially for the essential SSCs; and*
- *TEPCO should consider inclusion of transition plans from mobile and temporary SSCs, including monitoring equipment, to reasonably permanent ones in a timely manner to increase reliability against ageing, external hazards, and human induced failures.*

Advice 6

TEPCO should consider ensuring the separation of the reactive (rapid fix of problems) scope and responsibility of Emergency (Immediate) Response Headquarters from the proactive scope and responsibilities, i.e. to anticipate, identify, and prevent 'potential' issues. This scope should be covered by an on-site group who would be continuously monitoring and evaluating the functionality and health of the SSCs and be isolated from incident response and daily operations activities.

3.2.2. Management of waste, spent fuel and fuel debris

3.2.2.1. Spent fuel removal from the storage pools

According to the *Roadmap*, fuel removal from spent fuel pools is planned for all units affected by accident. Unit 4 is scheduled to be the first to start in November 2013 and should be finished at the end of 2014. Prior to fuel removal, the debris on top of the reactor buildings should be removed and removal cover constructions with fuel handling equipment on operating floor should be installed. Removed fuel is planned to be packaged into wet casks, transported and stored in the common pool. Some of already stored spent fuel will be moved from the common pool to ensure sufficient room for the fuel removed from all units. That spent fuel is planned to be put into the dry casks and placed in the newly constructed temporary cask custody area. Also, nine existing dry storage casks located in the old custody area beside the sea will be inspected in the common pool and moved to temporary cask custody area.

Due to relatively low dose rates at Unit 4, its fuel removal will not require remote equipment.

For other units, however, remotely operated equipment and serious decontamination efforts would be required. Detailed plans for spent fuel removal from Unit 1 and 2 will be proposed in the mid-term, based on surveys of pools and assemblies and experience gained from fuel retrieval projects for Unit 3 and Unit 4.

The Research and Development (R&D) Roadmap for fuel removal from spent fuel pools in the mid-term includes evaluation of the long-term integrity of fuel assemblies exposed to seawater.

Currently, crews completed the removal of rubble from the top of Unit 4 reactor building, and efforts have been made to locate all debris that has fallen onto the fuel assemblies in the spent fuel pool. A removal cover frame is under construction along the south side of the reactor building of Unit 4.

Visual inspection of the pool has not revealed any damaged fuel assemblies. An investigation of two fresh fuel assemblies unloaded from Unit 4 pool showed that there was neither visible mechanical damage nor corrosion of the fuel pins. However, foreign objects were detected between the pins inside the fuel bundle.

For Unit 3, removal of debris surrounding the spent fuel storage pool has been underway, and an underwater camera survey of a limited area of the pool was carried out. The survey did not reveal any damage to the fuel assemblies, but the presence of heavy construction elements such as steel beams and the fuel charger was confirmed, so integrity of some fuel assemblies cannot be assured.

Visual inspection and dose rate measurement have also been conducted on the operating floors of Units 1 and 2 as an initial effort for future fuel removing deliberations. No information is available yet on the integrity of spent fuel in these pools.

Restoration of the common spent fuel pool primary facilities was completed in 2012, so common pool is ready for fuel acceptance. Dry casks from the old custody area have been inspected and absence of problem with sub-criticality function and spent fuel integrity was confirmed.

Acknowledgement 4

The IAEA team acknowledges TEPCO's efforts to quickly move forward the spent fuel removal project. The plan seems solid, considers alternatives and is well aligned with research and development (R&D) needs and time lines in the Roadmap.

3.2.2.2. Fuel debris removal from reactor pressure vessel

According to the *Roadmap*, TEPCO plans to start fuel debris removal in first unit of four within 10 years after completion of Step 2 (cold shutdown condition achieved). The fuel debris removal base line plan consists of the following steps:

1. Reactor building decontamination;

2. PCV leakage point inspection;

3. PCV lower parts repair;

4. Filling the lower part with water;
5. Internal PCV inspection and sampling;
6. PCV upper parts repair;
7. Filling PCV and RPV with water and open upper cover on RPV;
8. Internal RPV inspection and sampling;
9. Fuel debris removal; and
10. Storage, processing and disposal of the removed fuel.

Holding points are defined to assess the achievements of progress in accordance with baseline and to address eventual alternatives to the baseline that are already indicated in the *Roadmap*.

The first four steps are in the scope of mid-term plan and their implementation has begun or has been prepared. The fuel debris removal plan is tightly linked to R&D activity support dedicated to development of new technologies and equipment. It is important to note that R&D is envisaged not as a sequential effort, but rather as moving in parallel so that eventual changes to the baseline plan can be effectively addressed.

Dose level, radiation source and sampling analysis surveys of the first floors of reactor buildings for Units 1-3 were done for decontamination plan development, and hot spots and dose rate distribution data were defined. Tools and equipment for debris removal in this area prior to decontamination have been proposed.

Due to high radiation doses for PCV leakage point inspection, it is necessary to develop robots which have "self-location", "long cable processing", and "shape/flow detection" technologies. The requirements for robots, including resistance to high radiation fields, have already been formulated by TEPCO.

Quadruped robot survey results of eight vent pipes in the torus room of Unit 2 in December 2012 and March 2013 did not reveal any leakages in potential weak places of suppression chamber (e.g. bellows, sleeves). Four methods for PCV bottom part repairing are under consideration: stopping leaks in the jet deflector, at the vent pipes, at the downcomers of suppression chamber, or at the torus room. Different methods for PCV upper part repairs have also been proposed.

A successful large water tank test was conducted to check out possibility of sealing the double pipe water leak area between reactor and turbine buildings with plastic grout in a flowing water environment. Further R&D activity to improve this method for stopping inter-building water leakage is underway.

Internal PCV inspection results of Units 1 and 2 in 2012 provided data on the water level in PCV's lower part, temperature and dose rate distribution under the bottom of the PCV for the assessment of overall condition and future work planning.

Acknowledgement 5

The IAEA team recognizes TEPCO's efforts in formulating a logical and rational plan for removing fuel debris, a crucial and complex task in decommissioning Fukushima Daiichi NPS. The efforts done so far, based on sound engineering approaches to base line and alternatives, are remarkable and have utilized best practices and available international experience.

Acknowledgment 6

The IAEA team acknowledges TEPCO's efforts to identify early in the process an R&D programme to study options for management of fuel debris after its removal.

Advice 7

Considering the complexity of the implementation of fuel debris removal, the IAEA team encourages TEPCO to ensure that adequate contingencies are in place to address the huge uncertainties that are likely to be faced during project execution. It would be fairly important to ensure good communication with the NRA so that project can effectively move forward.

3.2.2.3. Generic waste management issues

The *Roadmap* rightly recognizes waste management as one of the important issues in decommissioning the Fukushima Daiichi NPS. The major challenge is associated with managing very large volumes of liquid and solid waste, some having unique characteristics. The *Roadmap* mainly addresses the management of waste generated as direct result of the accident and subsequent recovery efforts as defined in phase 1. The current path forward is to collect, segregate and temporarily store all generated and treated waste at the site. Details of waste streams that would be generated during phase 2 until spent fuel is removed from the reactors and beyond in phase 3, during removal of fuel debris and further decommissioning, are not assessed. As a result, waste management needs related to technologies and timing of facilities for processing to stable waste forms and preparation of waste packages for longer-term storage or disposal are not yet defined. The path forward for waste management at Fukushima Daiichi NPS is even more complex because end-points – either interim longer-term storage facilities for waste packages or disposal facilities – are not yet defined by the Government of Japan. The current *Roadmap* plans to establish the disposal concept of radioactive waste during 2015 and 2018 considering the result of R&D on processing and disposal of radioactive waste.

The forecast of waste arising and the strategy for waste management by and large depends on a final agreement between TEPCO, government authorities and local communities about the end-state of the Fukushima Daiichi NPS decommissioning project. Definition of the end-state of Fukushima Daiichi NPS as a green field (meaning that all contaminated material will have to be removed) or as a brown field (some structures, including waste facilities, may be left at site) or as nuclear site which will be used for power generation in future has a crucial impact on waste volumes, size and complexity of the waste management strategy and details of long-term plan.

The international experience with end-state of sites for NPPs that had severe accidents is very much limited but also different in each particular case. For example:

A1 plant in Slovakia, in which an accident happened in 1977, is still under decommissioning to a brown field. However the entire Bohunice site where A1 plant is located is continuously used as a licensed nuclear site. Two VVER type reactor units are operating and two older units are in decommissioning state. There are more or less confirmed plans to construct two more operating units at the site. Decision to continue to use it as the nuclear site had a crucial impact on how nuclear waste is managed at the Bohunice site. It is to be noted that disposal route in Slovakia is defined, as well as waste acceptance criteria for disposal which also contributes to selection of options for waste management.

Three units of Chernobyl NPP were shut down 11 to14 years after the accident in Unit 4 that happened in 1986. These three units are under decommissioning and the Safe Confinement is under construction for Unit 4. Decommissioning of three units is planned to be executed as phased approach till 2065. There are no plans to decommission the Safe Confinement which is designed for 100 years, but with provisions to extend its design life. The end-state for the entire site is planned as the brown field, which has impact on forecast of the volumes of the nuclear waste that needs to be removed from the site. The disposal route for very low and low level nuclear waste is already determined which contributes to overall waste management strategy.

The definition of the end-state for Three Mile Island site is still under considerations. The site is used as the licensed nuclear site since TMI-1 plant design life is extended for additional 20 years (60 years in total) and it will be operable to 2034. The final decision of the end-state of the entire site will be reached only after shutdown of TMI-1. It is expected that considerations of end-state of the site will take into account decommissioning of both units TMI-1 and TMI-2.

The end-state of the Fukushima Daiichi NPS site is an essential attribute of the decommissioning strategy, and it should be defined. The management of waste from Fukushima Daiichi NPS cannot be looked at in isolation. It has to be connected and coordinated with remediation efforts of other areas affected by nuclear accident especially in regard to identification of end-points (disposal facilities) for radioactive waste (see Advice 1 in Section 3.1.1).

Identification of waste types and generation rates that can be attributed to baseline technical options and alternatives that might be pursued during decommissioning is prerequisite for having TEPCO's strategy and long term plan for the waste management. Taking into consideration that effectiveness and associated costs of waste management are major contributors to the success of decommissioning, the long-term waste plan could be used as a tool to optimize baseline technical options and alternatives identified by the *Roadmap*. Engineering estimates of alternatives and associated costs would also allow identification of different waste management scenarios that should be considered during the decommissioning project and eventually optimized with timely deployment of cost effective technologies, processing and storage facilities on and off the Fukushima Daiichi NPS site. Work on long-term planning should start with rough estimates of volumes, types and characteristics of different waste streams for all phases identified by the *Roadmap* for decommissioning Fukushima Daiichi NPS, even though end-points for waste have not yet been defined.

The execution of efficient waste management means full understanding of the task or more detailed knowledge of waste inventory tracking, forecasting and planning. The regular updates of inventory are required for all of current and future radioactive waste and spent fuel and fuel debris management options. Such updates are used to estimate and confirm the adequacy of funds required to pay for these future liabilities as well as to plan for future waste management needs. The overall methodology that could be used is illustrated with Fig.1.

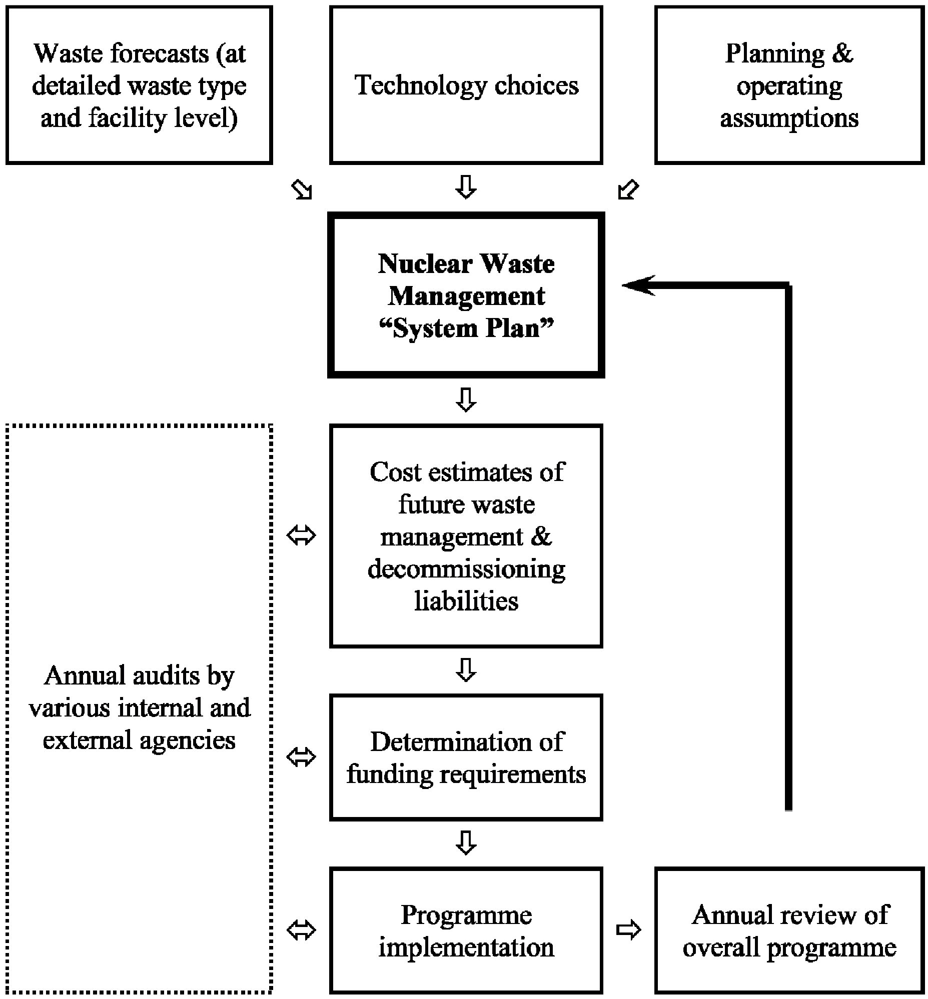

Fig. 1. Waste management planning methodology

The assessment should take into account all waste types and include lifecycle management needs from generation (clean-up) through transportation, treatment, storage and disposal. Waste forecasts should be done on the basis of individual waste type and/or facility. Various scenarios should be analysed, for example of alternatives to be pursued during different phases of the *Roadmap*. The stage-wise reference plan for waste management could be developed based on the results of these scenarios.

A comprehensive waste tracking system which tracks waste from clean-up to storage is essential. In addition to quantities, the system should also track waste characteristics and should be used for forecasting of future arisings and inventories. The database from tracking system could be used to compile a comprehensive low and intermediate level waste inventory report for use in the design and safety assessment for a repository.

It is to be noted that, as with long-term forecasts of waste arisings, there will be some uncertainty with selecting waste management technologies, especially for waste which is not foreseen to arise until the distant future. Waste management technologies and economics will evolve over time. A reference choice made today may not, in fact, be implemented 50 years from now when it is actually needed. A totally different technology may be in common use at that time. However, for planning purposes, it is generally considered to be conservative to assume that future waste arisings will be handled as they would be today without any technological advances.

Another aspect to consider while making long-term waste management plan is that a new waste management infrastructure should be developed on an "as needed" (modular) basis. If storage or disposal capacity is constructed in a modular sequence, it is generally easier to adapt to changes in needs rather than if a single large-sized facility is constructed all at once. However, due consideration needs to be given to the ultimate capacity in order to secure a license for the entire facility up front. These aspects are particularly important when engaging with local communities in discussions about siting of a repository.

Advice 8

The IAEA team encourages TEPCO to start preparing its strategy and long-term waste management plan by estimating volumes, types and characteristics of different waste streams and by identifying optimized waste management scenarios for all phases identified by the Roadmap for decommissioning Fukushima Daiichi NPS, even though end-points for waste are not yet defined.

Additional reference to Advice 1.

3.2.2.4. Management of accumulated radioactive water and associated secondary waste

Extensive efforts are currently devoted to the treatment of huge quantities of accumulated water for removing the major radionuclide cesium and desalination of this treated water. A range of water treatment facilities that utilize state of the art technologies in an unprecedented scale have been deployed. More than half a million cubic metres of contaminated water have been treated so far. Treated water is being successfully used to cool the damaged reactor cores. Temporary storage of huge volumes of accumulated (contaminated and treated) water has also been provided in the shortest possible time.

However, management of accumulated water is also associated with some other challenges, such as the continuing increase in the quantity of water requiring storage due to the ingress of ground water, the difficulty in getting approval of government and other stakeholders for discharge of treated water, and the management of secondary waste from water treatment.

TEPCO is actively pursuing implementation of a ground water bypass system to prevent or at least reduce its ingress into the reactor and turbine buildings. If successful, this countermeasure will limit the continuing need to increase water storage capacity. In addition, it is expected to eventually result in the removal of all accumulated water from the reactor and turbine buildings. This will also pave the way for repairs to the damaged structures and make it possible to fill the reactor and primary containment vessels with water in preparation for defueling operations.

Nevertheless, the quantity of water requiring storage is enormous. The treated water still has substantial residual radioactivity due to the presence of strontium and other radionuclides, and therefore its storage contributes to worker dose and presents the risk of leakage and potential spread of contamination. The situation can be alleviated if the treated water is discharged to the sea after removing all radionuclides down to levels below the stipulated discharge limits after getting approval of relevant ministries and stakeholders. The *Roadmap* prescribes that discharges to the sea must not be performed without the approval of the relevant ministries. A new advanced liquid-waste processing system for removing other radionuclides from cesium treated water has been commissioned and is currently undergoing hot tests. However, this facility does not remove tritium. In addition, it has not yet accomplished the expected result of removing some radionuclides in the hot tests. The possibility of dilution to attain the discharge limit also does not help because in the current situation treated water cannot be readily discharged to the ocean without approval of relevant ministries and stakeholders even if its radioactivity is within the stipulated discharge limits. It is indispensable to foster relevant stakeholders understanding for the discharge to the sea in conjunction with the on-going efforts to remove radionuclides from cesium treated water.

Spent sorbent columns and chemical sludge from the precipitation process are the two major secondary waste streams resulting from water treatment. The total volume of these secondary wastes is expected to be in the range of several thousand cubic metres, loaded with very high levels of radioactivity. While adequate facilities have been constructed to temporarily store these secondary wastes, the need for their processing and eventual disposal has been recognized in the *Roadmap* and relevant R&D activities in this regard are being pursued.

The recent leaks of radioactive water from some of the underground storage tanks illustrate the continuing challenge faced by TEPCO in accumulated water management. Originally constructed to provide high storage capacity for water treated by the new advanced liquid waste processing system, these underground tanks were used to store saline water containing relatively high levels of radioactivity due to the presence of strontium and other radionuclides that remained after removal of cesium. This situation arose because there has been significant delay in starting the operation of the new treatment system and TEPCO was unable to keep pace with the resulting need to build numerous new above-ground storage tanks. Currently, measures are being taken to transfer water stored in these underground tanks to some of the existing above ground tanks. While preliminary monitoring and assessment do not indicate extensive spread of the leaked radioactivity, the situation is being continuously monitored under close watch of the NRA to ensure that this is indeed the case. Construction of new above-ground tanks is also being accelerated.

Acknowledgement 7

The IAEA team recognizes TEPCO's efforts to deploy large-scale treatment technologies for decontaminating and desalinating highly radioactive water accumulated at site. The treated water is being used to successfully cool the damaged reactor cores. Considering the challenges in the mobilization of industry support, the design and fabrication in relatively short time frame as well as the installation and operation under difficult conditions, this is a commendable achievement. The international community can also benefit from this valuable experience.

Advice 9

The IAEA team encourages TEPCO to review its strategy for accumulated water management and to work out a comprehensive plan taking into account the constraints and associated risks in the current approach in consultation with all relevant stakeholders, including the NRA and the public. Continuous attention should be paid to improving the safety and reliability of water treatment and storage facilities.

Additionally, considering the high total inventory of radioactivity currently stored in the numerous tanks located upstream of the pumping wells of the groundwater bypass system, it is of utmost importance to have adequate measures in place for detecting leaks promptly and mitigating their consequences.

3.2.2.5. Management of solid waste (rubble, trees and etc.)

Current efforts at Fukushima Daiichi NPS related to solid waste are focused on collection, segregation based on dose, and temporary storage of the solid waste. The solid waste includes collected concrete debris (rubble), metal, contaminated trees and soil from various areas. The current inventory of collected, segregated and temporary stored solid waste at the site is around 100,000 cubic metres, which indicates TEPCO's effectiveness and commitment to handle the accident recovery situation in the shortest possible time. It should be understood that a typical nuclear power plant with a 1,000-megawatt reactor generates 250-400 cubic metres per year of operational waste, which results in total of 15,000-25,000 cubic metres of raw low- and intermediate-level waste for 60 years of operation. The decommissioning of normal operating plant with 1,000-megawatt reactor adds approximately 5,000-10,000 cubic metres of generated low-level waste. In other words, solid low-level waste already collected at the site is comparable by volume with low-level waste that would be generated by four units of Fukushima Daiichi NPS during their life time if accident had not happened. TEPCO's level of efforts so far should be fully understood and acknowledged.

It should also be understood that the generation of solid waste very much depends on the definition of the decommissioning end-state for Units 1-4 as already pointed out in Section 3.2.2.3. These units contain approximately 800,000 cubic metres of material, most of which will turn into very low level or low-level waste due to contamination that occurred during the nuclear accident if the entire site is to be decommissioned to a green field. It is important to note that management of solid waste will continue to be a challenge that would require pursuing of effective volume reduction technologies especially for combustible and compactable solid waste to decrease such enormous volumes.

Earth trenches are constructed as temporary storage for rubble. The design of temporary storage is adequately addressing safety of workers and general public. Trees are collected in designated areas. An incinerator is under construction to provide for treatment of combustible waste. The IAEA team noted that current activities are well planned and implemented. However, the major issue for solid-waste management is very much connected with generic-waste management issues pointed out in Advices 1, 7 and 8.

It is to be noted that not having path forward for solid waste to either long-term storage or disposal facilities results in site congestion with temporary storage facilities of solid waste in addition to temporary storages for liquids (tanks). Furthermore, this approach adds complexity in management of radioactive releases and doses at the site boundaries that are attributed to these numerous temporary storage facilities as pointed in Advices 9 and 10.

3.2.3. Management of radioactive releases and assessment of associated doses

The current limit for exposures arising from the sum of gaseous and liquid discharges and the solid radioactive materials generated and accumulated at the site of Fukushima Daiichi NPS, as a consequence of the on-site activities, is 1 mSv effective dose per year for a member of the public at the boundary of the site.

This limit is applicable to the additional exposures of the public that could arise from the current activities at the site towards the decommissioning of the plant, considering all the exposure pathways, and it is independent of the “legacy doses” caused by the accident itself. These “legacy doses” constitute the new post-accident “radiological background” off-site and are the cause of the different restrictions still in place for the living conditions in the affected areas (such as interim and long-term relocation of population, food restrictions, etc.). The remediation programme conducted by the relevant authorities at the off-site areas affected by the accident is intended to reduce the radiation exposure in these areas and to lift the restrictions in the short, mid and long terms as radiological conditions improve in each area.

The limit of 1 mSv per year is applicable to the boundary of the site, despite the fact that the offsite areas closer to the site are currently subject to a total restriction of use. While the limit applied to the gaseous and liquid discharges from the site could prevent exposures to individuals of the public living in zones beyond the restricted areas, it seems that this limit does not have any apparent benefit to prevent external exposures to any individual of the public in the border of the site from the storage of solids and tanks of liquids at the site, as the radiological impact of this solids and liquids would be limited to the areas surrounding the site, where people are not currently allowed to live.

A stricter imposition/interpretation of this limit at the border of the site is imposing significant constraints to the practical development of the decommissioning *Roadmap*, with special consideration to the mentioned storage of radioactive solids and liquids on site. In addition, the constraints are especially significant for liquids, as liquid discharges are not actually allowed, despite to the theoretical limit defined for all exposure pathways. This situation increases the dangers derived from the accumulation of highly contaminated liquids, raising additional difficulties for the control of the doses to workers and increasing the risks of accidental leakages to the environment.

On the other hand, the activities for the on-site stabilization and the *Roadmap* are an essential part of the general efforts for the recovery after the accident, in coordination with the remediation programme of the off-site affected areas. Achieving a balance of the development of the two efforts would benefit both of them and the general target of enhancing the living condition of the people affected by the accident.

Advice 10

The IAEA team encourages the Government of Japan and TEPCO to establish a frank and informed discussion with the relevant authorities and stakeholders, including the NRA and local authorities, to assess the balance of risks and benefits of the dose limit to the public and its practical implementation, particularly from the direct exposures at the site-boundary arising from contaminated solids and accumulated liquids on the site and for the possibility of controlled discharges of liquids from the site. The discussions should include an assessment of the balance of off-site and on-site exposure risks, as well as the consideration of the *parallel progress of the off-site remediation programme and the roadmap for on-site decommissioning and their mutual interaction. The discussion should also include the definition of the representative member of the public to be considered in the assessments of individual doses in different areas, taking into consideration the real and evolving off-site situation.*

3.2.4. Decontamination within the site for improvement of working environment

Decontamination inside buildings will be performed as part of the overall fuel debris removal project in the phase 2 of the *Roadmap*. That operation is necessary to allow access of workers for inspections, preparatory works, and fuel debris removal operations. For these purposes, the dose rate objective in the areas is less than 5 mSv/h.

Following the hydrogen explosion, all kinds of debris are currently inside the buildings, creating high dose environment. Debris is referring to dust, steel and concrete part. Decontamination will also permit the free access to the working place; therefore some materials already present during operation time must also be removed.

Inspection of the Unit 1 to 3 first floor has already been done and samples have been taken; dose rates vary from 3.2 to 8.9 mSv/h on unit 1, 6.8 to 30.3 mSv/h for unit 2, and 15.8 to 124.7 mSv/h for unit 3. Sample analysis has determined that the contamination depth is less than 1 mm, which corresponds to the thickness of the EPOXY protection layer (on floor and 2 metres high walls). It is assumed that concrete will be likely not contaminated.

Radiation surveys and analysis did not identify significant alpha contamination in any of the units.

The decontamination strategy developed by TEPCO consists of partial decontamination of the building performed in two steps and directed toward the decontamination of the areas where workers will have to work or circulate during the fuel debris removal and packaging operation. Therefore, decontamination will just involve two floors: the first floor and the operating floor.

- First floor, because TEPCO is intending to drill a hole in the slab to allow the bottom PCV examination for leaks repairs. First floor decontamination is a priority.
- Operating floor, because the fuel debris removal operations will be conducted from this floor.

Intermediate floors will not be decontaminated at that time. Second floor slab thickness is 70 cm, and therefore there may not be significant risk of dose issues coming from the second floor.

The first floor will be decontaminated in two steps: Step 1 includes removal of debris and rubble and the decontamination of the floor and walls up to 2 metres; Step 2 represents decontamination of areas higher than 2 metres.

Removal of debris and obstacles will be remotely performed using small environment adapted robots. For example, some places in the floors extend less than 3 metres and the robots caterpillars must be retractable. TEPCO intends to develop robots with two arms, which will allow heavy handling and cuttings materials, and dust aspiration.

Decontamination to 5 mSv/h is also forecasted to be remotely performed using robot. The first floor decontamination includes floor wall and roof, TEPCO considers one process for the floor and the wall up to 2 metres and another for wall above to 2 metres and for the roof. The reason is that TEPCO wants to perform quickly the floor decontamination and also considers that a robot using long arm is more difficult to be developed.

The choice of decontamination technique depends on the radionuclide source and dose level. Contamination type (fixed and not fixed) and hot spot location are currently not known. In addition there is no particular reason to have a homogenous contamination on the floor and on the walls, the contamination should likely be in the debris and dust removed during the rubble and dust removal, therefore dose environment should be much better during the surface decontamination.

Currently TEPCO is studying three decontamination techniques adapted to concrete decontamination:

- High pressure water decontamination
- Dry ice blasting decontamination
- Metallic abrasive blasting

Major development is directed toward robotics, especially regarding the robot access to all surface to treat and robot rescue. Access will be difficult and robot may be lost, especially during debris removal.

Decontamination is a major operation, on the critical path of the *Roadmap* phase 2. Robots that will be applied for the decontamination work are currently under testing and step 1 of the debris (rubble) removal will start in Unit 3 by the end of 2013.

The IAEA team considers that a decontamination strategy based on necessity and on prioritization of the areas is the best approach to be followed. In the case of Fukushima Daiichi NPS, TEPCO is considering that it is urgent to remove the source term as fast as possible, therefore the global duration of fuel debris removal is optimized and this is recognized as a good practice.

Building decontamination is taken into consideration in the *Roadmap* correctly, and its overall objective is dose reduction and improvement of accessibility of the working areas currently covered with contaminated rubble. However the IAEA team also considers that 5 mSv/h objective should be periodically reassessed by TEPCO when referring to working activities within controlled areas.

Referring to the data presented, decontamination techniques intended to be used by TEPCO are adapted; the processes studied are covering the majority of the concrete contamination types identified by TEPCO, and these decontamination processes are well known and used by others nuclear operators.

TEPCO decontamination plan is considering development of remote operated robot for both rubbles removal and surface decontamination. The IAEA team suggests optimizing the global decontamination process on the basis of the type and origin of decontamination following those items:

- *Take into account that floors contamination will likely be inhomogeneous, with hot spots;*
- *Pay particular attention to the robot rescue, especially for step 1 (for example study a remotely dismantling robot);*
- *Consider that the end state to achieve for step 1 will be fixed remaining contamination;*
- *Implement a full gamma inspection to locate and measure the decontaminated area (and identify potential remaining hot spots) after the debris removal and dust aspiration;*
- *Examine the possibility of a simplified decontamination process after debris removal in step 2, using semi-remote techniques (or manual if adapted), for areas not directly accessible by robot.*

TEPCO may consider intensifying the exchange of experience and lessons learned with others countries. Cooperation mechanisms available through the International Decommissioning Network may be useful for that.

Advice 11

The IAEA team suggests that TEPCO defines an adequate end state of debris removal and then considers a simplification of the floor decontamination techniques (semi-remote techniques). The IAEA team also suggests that TEPCO should reassess the operational dose-rates objectives for defining the different working areas, especially referring to controlled areas, taking into consideration the best international practices in this field as well as the possibility for using extra localized decontamination or shielding, in order to further optimise the management of radiation protection for workers. It is also suggested to make the mentioned reassessments on a periodical basis taken into consideration the evolution of the radiological conditions in the relevant areas.

3.2.5. Structural integrity of reactor buildings and other constructions

Unit 4 Reactor Building assessment of structural integrity

The IAEA team was presented with the following information:

- "Report on the structural Integrity Evaluation of the Spent Fuel Pool (extracted from "report on the current seismic safety and reinforcement of the reactor buildings at Fukushima Daiichi Nuclear Power Station (Part 1)(Supplement)(Revision 2)" with partial correction)" (Report),

- "Results of the Fourth soundness inspection of Unit 4 Reactor Building at Fukushima Daiichi Nuclear Power Station" (Presentation).

The presented material contained background information on the seismic analysis that has been performed on the Unit 4 reactor building. The background information included identification of the load and geometry changes from the original design state, data on the identified damage, input ground motions, dynamic analysis model, and 3D finite element model, results and their interpretation in determining the integrity of the building. To account for uncertainties, one model with different assumptions for the building stiffness was analysed. Soil properties have been modelled with their best estimate values. Concrete strength used is based on actual data from site investigations.

The approach and techniques used in the in-situ investigation of building condition were presented (building tilt measurements, outer wall deformation measurements, visual inspection, concrete strength evaluation, corrosion prevention measures). TEPCO demonstrated a comprehensive approach in identifying the structural condition of the reactor building. The implementation in the analysis is almost exclusively based on best estimate assumptions.

TEPCO analysis shows that the strength of the Unit 4 reactor building is sufficient to withstand the design seismic event.

Units 1-3 Reactor Building assessment of structural integrity

The IAEA team was presented with the following information:

- "Overview of the 'Report on Current Seismic Safety and Reinforcement of the Reactor Buildings at Fukushima Daiichi NPP to NRA (No.1)(Supplement)" (Report),

- "Overview of the 'Report on Current Seismic Safety and Reinforcement of the Reactor Buildings at Fukushima Daiichi NPP to NRA (No.2)" (Report), and

- "Overview of the "Report on Current Seismic Safety and Reinforcement of the Reactor Buildings at Fukushima Daiichi NPP to NRA (No.3)" (Report).

The presented material examined the dynamic seismic analyses performed for Units 1, 2, and 3, and the 3D finite element model for Unit 3. It is known that the reactor building structures (except for Unit 2) have sustained damage resulting in modified building characteristics. Due to the high radiation environments of these units, detailed information regarding the condition of the reactor buildings is not currently available. Assumptions were made as to the current condition of the structures using externally taken photographs and judgement. There is a research and development project for creating robotic equipment that can be used to facilitate data collection about the condition of the structures. The option for inspection in person will be feasible only after radiation levels are reduced to acceptable limits. The lack of detailed inspection data poses a significant challenge in creating realistic structural models. In the performed analyses, soil properties have been modelled with their best estimate values.

TEPCO analysis shows that the strengths of the Unit 1, 2, and 3 are sufficient to withstand the design seismic event.

Common spent fuel pool assessment of structural integrity

The IAEA team was presented with the following information:

- "Estimation of seismic safety against the basic earthquake ground motion Ss for seismic resistant wall of the site common spent fuel pool in Fukushima Daiichi NPPs" (Presentation).

The presented material covered the work performed in assessing the spent fuel building concrete structure including the site inspections, modelling, dynamic analysis, evaluation, and conclusions.

TEPCO personnel have not identified any significant damage to the structure from the 2011 earthquake. There are some cracks that have been identified since the 2009 inspection (with width less than 1 mm). The concrete strength used is based on actual data from the site investigation, not on design values.

TEPCO analysis shows that the strength of the common spent fuel pool is sufficient to withstand the design seismic event.

Acknowledgement 8

The work presented by TEPCO in the above sections was well organized, executed in a logical manner and examined the different areas of concern in a conscientious way. The task of evaluating the structural integrity is very complex, in general, and even more so under the specific circumstances of the conditions at the plant. The analysis presented by TEPCO shows that the reactor buildings have margin against design seismic events.

In order to confirm and further support TEPCO's analysis, the following advices should be considered for improving upon the current and future evaluations.

Advice 12

Seismic and structural integrity analysis could be enhanced by the following items:

- *The uncertainty associated with capacity under seismic loads, especially in damaged parts of the structure, should be addressed through additional parametric analysis to cover the possible range of distribution of critical parameters;*
- *The ability of the dynamic analysis model to capture the response of the building and also variability as per the previous bullet should be carefully assessed further;*
- *When performing 3D finite element analysis, the use of shell elements should be carefully applied. Mesh refinement studies should be performed to ensure convergence of the results. In addition, detailed local models may be necessary to verify that potential initiation locations for progressive collapse during design load conditions do not exist;*
- *It is advised that, especially for the common pool structure the assessment should further examine the appropriateness of use of the actual concrete strength versus the design strength in light of maintaining the design safety margin;*
- *It is advised to consider the variability of the ground properties in conducting the assessment, especially for the structures that have sustained significant damage and modification (e.g. Units 1, 3, 4).*

Advice 13

Additional peer review and/or independent confirmatory analyses by experts in the areas of dynamic seismic analysis, finite element modelling, progressive collapse, thermal effects on structures, and reinforced concrete inelastic behaviour are advised to improve the confidence of the results and conclusions.

Additional topics discussed with TEPCO staff and the IAEA team advice during the review under the "STRUCTURAL INTEGRITY OF REACTOR BUILDINGS AND OTHER CONSTRUCTIONS" issue

Ageing management

The IAEA team was provided with limited information on the ageing management of the structures, specifically the critical structures within the reactor buildings. Under normal operations of nuclear power plants, ageing management of the structures including the reactor building, spent fuel pool, and the Primary Containment Vessel (PCV), is critical for maintaining long-term integrity. The areas of concern include concrete degradation, corrosion of the steel PCV, and steel embrittlement due to the radiation environment. Units 1 through 4 at Fukushima Daiichi NPS are no longer operating under normal conditions. Significant damage has occurred to the reactor buildings and the current condition of the PCV in Units 1 through 3 is not known. Efforts are underway to develop means of repairing the PCVs if needed. However, the condition of the PCV may degrade further due to the abnormal environment (e.g. enhanced corrosion due to the presence of water and potential embrittlement due to higher radiation levels). The PCV is expected to contain water during the eventual removal of the fuel debris and the integrity of the PCV will be critical for the decommissioning process. There is also the potential for degradation to the reinforced concrete structures due to water entrainment and other abnormal environmental factors.

Advice 14

Ageing management programme could be enhanced by the following items:

- *Develop or expand upon current structural and materials ageing management programmes for the reactor buildings and other critical structures to provide for the long term decommissioning efforts;*

- *Consult with experts in the international community in the areas of materials degradation including corrosion and corrosive environments, steel embrittlement due to the high radiation levels, and reinforced concrete degradation;*

- *Prepare methods and procedures to mitigate and repair additional damage that may occur due to future ageing-related degradation to the critical structures required to function for the long term decommissioning.*

Re-evaluation of External Hazards

The input for the seismic evaluation of critical structures is currently the design earthquake from before the 2011 earthquake. TEPCO stated that the definition of all other hazards remain unchanged from the licensing basis before 2011. Currently TEPCO has a project underway to re-evaluate some external hazards (e.g. seismic, tsunami).

For tsunami protection, the flood barrier at the sea next to part of the site has been upgraded and strengthened. Measures have been taken to provide continuous safety functions in case of tsunami flooding.

Advice 15

Re-evaluation of External Hazards programme could be enhanced by the following items:

- *To complete the external hazard re-evaluations for the site of Fukushima-Daiichi as early as possible with broad involvement from the scientific community and the results from it be* *disseminated to the public. This will enable an up-to-date input for the evaluation of structural integrity of Fukushima Daiichi structures. For external hazards re-evaluation, the requirements and guidelines as given in "Site Evaluation for Nuclear Installations", IAEA Safety Standards Series No. NS-R-3, IAEA, Vienna (2003) and "Seismic Hazards in Site Evaluation for Nuclear Installations" Specific Safety Guide No. SSG-9 should be considered.*

- *To continue assessing the tsunami protection to ensure consistency with the hazard.*

Seismic monitoring and collection of data to assist in building realistic modelling

The IAEA team has been informed that the existing seismic monitoring systems in reactor buildings 1-4 were destroyed or made inoperable during the accident. There are operational downhole arrays on-site and the Seismic Monitoring Systems for Units 5 and 6 that can be used to assess seismic activity at the site.

Advice 16

To install accelerometers with recording capability on the building structures (e.g., reactor buildings) at characteristic locations to allow for the proper establishment of the level of shaking being experienced during possible future earthquakes. Data recorded during such event(s) will be a valuable input in validating and calibrating the models used for the prediction of the seismic response for the reactor buildings.

Systems and equipment in use at the plant

There are systems and equipment in use that have been deployed as part of the emergency response. Due consideration of possible long-term use calls for meeting design requirements. Currently work is underway that is progressing towards those systems/equipment being capable of withstanding design basis events and measures are being put in place to allow for the maintenance of necessary processes through alternative means.

3.2.6. Reduction of radioactive exposure of the employees

Regarding the item 3.2.6 the following documents were presented:

- Dose Reduction Countermeasure for Existing Exposure Situation (February 1, 2013, TEPCO);
- Mid-and-long-Term Roadmap towards the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Station Units 1-4, TEPCO (July 30, 2012, Nuclear Emergency Response Headquarters Government and TEPCO's Mid-to-Long Term Countermeasure Meeting);
- Change of the Rules Related to Radiation protection Gear (Expansion of Area Allowing the Use of Mask with a Dust Filter Attached);
- Radiation Dose Limit for Emergency Work (December 17, 2012);
- Measures for Enhancing Radiation Management at Fukushima Nuclear Power Station;

- Dose Reduction in Front of Seismic Isolation Building at Fukushima Daiichi Nuclear Power Station (October 18, 2012);
- Overview of the Radiation Exposure Doses of the Workers at Fukushima Daiichi Nuclear Power Station (December 3, 2012).

Based on these TEPCO documents and presentations and the observations during the site visit related to reduction of radioactive exposure of the employees, the IAEA team formulates the findings and Advices.

General evaluations

It is clearly reflected in the *Roadmap* that TEPCO is highly committed to the enhancement of radiation protection and implementation of individual radiation management, the examination and implementation of measures for reduction of dose optimized for individual work activities, and the rationalization of protective measures. The IAEA team wants to emphasize several measures applied in order to reduce the dose to the workers during performance of individual work operations to the lowest reasonably achievable level:

- employment of shielding structures;
- avoidance of unnecessary stays in highly contaminated and high-dose areas;
- development of equipment enabling remote performance of the work (applying robots etc.);
- shortening work time in the higher dose areas by extensive trainings on mock-ups;
- use of low-dose-rate areas for most of the activities and reduction of doses by decontamination in the areas where there is a frequent worker traffic;
- providing detailed information on radiation levels by displaying survey maps;
- ensuring further decontamination of work areas; and
- advance training in work operations.

By taking such dose reduction measures, exposure dose is gradually decreasing. There is a stable decrease of average dose equivalent below 20 mSv/year. In the future, continuous dose reduction measures will be implemented for further reduction of personal and collective doses. The applied dose limits (for normal work 20 mSv/year, 100 mSv/5 years) and dose limits for emergency work (100 mSv/emergency) are in good accordance with the IAEA requirements and international good practices.

TEPCO’s efforts to improve working conditions in the site are appreciated. This has already allowed working in some areas without full face masks. Going forward, in conjunction with monitoring and evaluating the level of concentration of radioactive material in the air and decontamination, the areas in which full face masks are not required will be gradually expanded.

Acknowledgment 9

The IAEA team acknowledges that TEPCO is highly committed to enhance radiation protection and implementation of individual radiation management, examination and implementation of measures for reduction of dose optimized for individual work activities, and rationalization of protective measures. Several measures were applied in order to reduce the dose to the workers during individual work operations to the lowest reasonably achievable level. By taking such dose reduction measures, exposure dose is gradually decreasing. In the future, additional dose reduction measures will be implemented for further reduction of individual and collective doses. The applied dose limits are in accordance with international good practice.

Advice 17

The IAEA review team suggests further improvement and enhancement of operational radiation protection system for reduction of radioactive exposure of the workers. It may include following measures:

- *Application of passive dosimeters*

Dosimeters are placed on the fence of the site boundaries. It is advisable to place similar dosimeters for workplace monitoring on different parts of the site. The density and location of these detectors should depend on expected radiation level on a given location and on the planned activities there. In case of outage of electricity, loss of personal dosimeters, etc., the readings from the passive detectors will enable a retrospective estimation of exposures of workers and verification of compliance with the dose limits.

- *Increasing the number of online monitoring stations*

There are four continuous air monitors in operation on site (total site area is about 3.5 km^2). In parallel with the dose reduction by improving workability with no masks, it is advisable to increase the number of such continuous air monitors to verify that the criteria for not using full-face mask are satisfied.

- *Clarification of high radiation dose areas*

Actual dose rate measurements identified several high radiation areas on the site. Avoiding high exposure of workers by preventing random access by fencing and marking of the areas is suggested (for example at standby gas treatment area where the dose rate is higher than 10 Sv/h). Work teams should be provided with clear information about the highest and lowest dose rates at their working area. These locations should clearly be marked and any team discussions during the work or the rest time should take place in the designated low radiation area. Additional shielding should be considered to be placed in the high radiation areas.

- *Application of ventilated masks in special situations*

As a measure to improve the working conditions during the work inside the reactor buildings (Unit 1-3), consideration of use of ventilated masks with particulate filters is suggested. This may significantly contribute to the reduction of the possibility of internal exposure and to the reduction of the time spent in the high radiation zone.

- *Application of dose optimization software when possible*

In some cases use of special dose optimization software could contribute to additional reduction of the worker exposure. Latest available source inventories and dose maps of the working areas should be used as input for such analyses.

- *Increasing the whole body counting possibilities by gamma spectrometry*

In order to improve the internal dose assessment, the number of whole body counting analyses involving spectrometry is suggested. By this sophisticated method the identification and quantification of incorporated radionuclides and the place of their accumulation in the human body could be determined more precisely. If justified, the whole body counting results should be verified by bioassay analyses (saliva, urine and faecal samples).

4. TENTATIVE TOPICS FOR THE SECOND MISSION

The scope of the second mission should cover a holistic review of the revised and updated *Roadmap* and mid-term challenges including specific topics.

Tentative specific topics proposed to be covered during the second mission are listed below (not in any particular order or priority):

- Public relation and communication issues;
- Waste management (R&D for problematic waste streams, liquid waste management including discharges / tritium issue, solid waste, storage, waste acceptance criteria, etc.);
- Spent fuel and fuel debris removal and further management;
- R&D Roadmap (topics in addition to waste R&D, e.g. technologies for remote decontamination, development of technologies for investigation of PCV/RPV interiors, etc.);
- Specific decommissioning programmes and decommissioning planning;
- Regulatory issues accomplishment (e.g. licensing structure and documents, safety assessments, fuel material accountancy, etc.);
- Public radiation exposure;
- Programme and processes to maintain and to enhance stability and reliability of structures, systems and components until decommissioning (including regulatory oversight processes).

The second mission can be organized in October or November 2013. Duration will be about one week, including a visit to Fukushima Daiichi NPS site.

The mission team will consist of the IAEA and external experts.

APPENDIX I - MISSION PROGRAMME

Monday, 15 April (venue: Meeting room 108 on the 1st floor of METI ANNEX Bldg.)

09:30– 09:50 **Team leader media interview**
10:00 – 10:45 **Opening (METI, TEPCO and the IAEA)**

10:45 – 11:15 **Preparatory meeting (introduction, schedule, and logistics)**

11:30 – 16:00 **Plenary meeting Part1**

11:30 – 12:30 The Roadmap and organisational structure towards decommissioning from government (Presentation from METI and Q&A)

13:30 – 14:30 Overview / stakeholders involvement / progress status of the Roadmap (Presentation from TEPCO and Q&A)

15:00 – 16:00 Preparation of the decommissioning licensing (Presentation from TEPCO and Q&A)

16:30 – 18:30 **Meeting with the NRA**

Tuesday, 16 April (venue: Meeting room 850 on the 8th floor of METI ANNEX Bldg.)

09:00 – 18:00 **Plenary meeting Part 2**
09:00 – 09:30 Organisational structure towards decommissioning (Presentation from TEPCO and Q&A)
09:30 – 10:30 Leak survey and repair for reactor building and PCV (Presentation from TEPCO and Q&A)
10:30 – 11:30 Investigation on the inside of PCV (Presentation from TEPCO and Q&A)

11:30 – 12:00 **Courtesy visit to Vice Minister Akaba**

13:00 – 15:00 Accumulated water processing (including issue of underground water tank) (Presentation from TEPCO and Q&A)
15:00 – 15:45 Mid-and-long-term process in preparation for spent fuel removal (Presentation from TEPCO and Q&A)

16:00 – 18:00 Waste processing and disposal (Presentation from TEPCO and Q&A)

Wednesday, 17 April (Fukushima Daiichi site visit)

08:30 – 18:00 **Visit to Fukushima Daiichi NPS site (The photo and video during the site visit will be taken by TEPCO and be uploaded to TEPCO's website)**

Detailed schedule of Fukushima Daiichi NPS site visit is provided in Annex.

Thursday, 18 April (Meeting at Fukushima Daini and Fukushima Daiichi Stabilization Center)

09:00 – 09:15 Greeting remark (Meeting Room 326)

09:15 – 12:00 Parallel meetings Part 1

<Team1> (Meeting Room 326)		<Team2> (Meeting Room 323)		<Team3> (Meeting Room 3C)	
09:15 – 10:15	Management of radioactive releases and assessment of associated doses (Presentation from TEPCO and Q&A)	09:15 – 10:15	Implementation of individual radiation management(Presentation from TEPCO and Q&A)	09:15 – 10:15	Investigation and evaluation of the seismic safety and periodical inspections of Unit 4 reactor buildings (Presentation from TEPCO and Q&A)
10:30 – 12:00	Influence of gaseous radioactive materials in the site on doses (Presentation from TEPCO and Q&A)	10:30 – 12:00	Examination and implementation of measures for reduction of dose optimized for individual work activities (Presentation from TEPCO and Q&A)	10:30 – 12:00	Investigation and evaluation of the seismic safety and periodical inspections of Unit 4 reactor buildings (Presentation from TEPCO and Q&A)

13:00 – 15:00 Plenary meeting Part 3 (Meeting Room 326)
13:00 – 15:00 Assessment of the current condition of reactors (including issue of spent fuel pool) (Presentation from TEPCO and Q&A)

15:30 – 18:30 Parallel meetings Part 2

<Team1 Item 2-2> (Meeting Room 326)		<Team2:Item 2-3 and Item 2-5> (Meeting Room 323)		<Team3 Item 2-4> (Meeting Room 3C)	
15:30 – 17:00	Influence of solid radioactive materials in the site on doses (Presentation from TEPCO and Q&A)	15:30 – 16:30	Examination and implementation of measures for reduction of dose optimized for individual work activities (Presentation from TEPCO and Q&A)	15:30 – 17:30	Investigation and evaluation of the seismic safety of Units 1-3 reactor buildings(Presentation from TEPCO and Q&A)
17:00 – 18:00	Influence of liquid radioactive materials in the	16:30 – 18:00	Decontamination within the site for improvement of working	17:30 – 18:30	Team discussion

	site on doses (Presentation from TEPCO and Q&A)		environment (Presentation from TEPCO and Q&A)	
18:00 – 18:30	Team discussion	18:00 – 18:30	Team discussion	

Friday, 19 April (Meeting at Fukushima Daini and Fukushima Daiichi Stabilization Center)

09:00 – 12:00 Parallel meetings Part 3

<Team1> (Meeting Room 326)		**<Team2>** (Meeting Room 323)		**<Team>** (Meeting Room 3C)	
09:00 – 10:30	Result of dose assessment at the site boundary (Presentation from TEPCO and Q&A)	09:00 – 10:00	Building internal decontamination(Presentation from TEPCO and Q&A)	09:00 – 11:00	Investigation and evaluation of the seismic safety and periodical inspections of site common spent fuel pool buildings (Presentation from TEPCO and Q&A)
10:30 – 12:00	Radioactive materials concentration of Seawater in Port Area (Presentation from TEPCO and Q&A)	10:00 – 12:00	Reduction of radioactive exposure of the employees (Presentation from TEPCO and Q&A)	11:00 – 12:00	General discussion

13:00 – 17:40 Plenary meeting Part 4 (Meeting Room 326)

13:00 – 17:40 General Discussion on a series of recent accidents and incidents (emergency responses and reliability improvement) and others

Saturday, 20 April (Venue: meeting room at the TEPCO)

09:00 – 18:00 This day is reserved for drafting the preliminary report.

Sunday, 21 April (Venue: meeting room at the TEPCO)

13:00 – 18:30 Meeting for fact checking

18:30 – 19:00 Presentation from the IAEA about international cooperation on R&D

Monday, 22 April (venue: Meeting room 1107 on the 11th floor of METI ANNEX Bldg.)

09:30 – 10:30 **Plenary meeting Part 5**
Discussion for deciding the scope and tentative date for the second mission

10:30 – 11:30 **Closing meeting**

13:00 – 13:30 **Final remarks from METI, TEPCO and the IAEA followed by the deliberation of the preliminary report**

15:20 – 16:00 **Press conference organised by the IAEA**
Venue: Foreign Press Centre/Japan

ANNEX: Fukushima Daiichi NPS Site Visit Schedule on April 17th (Wed.)

Time	Item	Place
7:20-8:30	Chartered Bus Hotel -> WBC Facility near J Village	
8:30-8:50	Whole Body Counting	WBC Facility near J Village
8:50-9:00	Chartered Bus WBC Facility near J Village -> J Village (Main Entrance)	
9:00-9:30	Identification Confirmation, Taking necessary equipment, Mask leak check Clothes for respective person: (Bringing) full face mask, foot cover, cotton glove, plastic glove, surgical mask	J Village Alpine Rose
9:30-10:10	TEPCO Off-Site Bus J Village -> Fukushima Daiichi NPS	
10:10-10:20	Fukushima-Daiichi NPS Executive Greeting Remarks	Fukushima Daiichi Seismic Isolated Building Meeting Room No.2
10:20-10:30	Change of Clothes Clothes for respective person: cotton glove, rubber glove, foot cover, surgical mask, (Bringing) full face mask	Fukushima Daiichi Seismic Isolated Building Meeting Room No.2
10:30-12:00	Fukushima Daiichi NPS Site Tour ・Reactor Feed Water Pump ・Highly Radioactive Rubbles Container ・Soil-covered Rubbles Storage Area ・Multi-nuclide Removal Equipment (ALPS) Installation Area ・Underground Cistern ・Accumulated (contaminated/treated) Water Storage Tank ・Temporary Storage Area for Spent Vessels ・Monitoring Post No.8	Fukushima Daiichi NPS Site
12:00-12:30	Lunch/Break	Fukushima Daiichi Seismic Isolated Building Meeting Room No.2
12:30-13:20	Seismic Isolated Building Tour ・Site Emergency Response Center ・Remote Control Room for Units 1 through 4 ・Dosimeter Lending Area/ Surface Contamination Survey Area ・Protective Gear Lending Area ・Remote Control Room for Heavy Machinery	Fukushima Daiichi Seismic Isolated Building
13:20-13:50	Change of Clothes Clothes for respective person: tyvek, full face mask, foot cover	Fukushima Daiichi Seismic Isolated Building Meeting Room No.2
13:50-15:40	Fukushima Daiichi NPS Site Tour ・Main Control Room for Units 1 and 2 ・Sub-drain Pit ・Torus Room, Equipment Hatch, Seismically Reinforced Area for SFP and Operating Floor in Unit 4 Reactor Building	Fukushima Daiichi NPS Site
15:40-16:10	Surface Contamination Survey, Change of Clothes Clothes for respective person: (Bringing) full face mask, foot cover, cotton glove, surgical mask	Fukushima Daiichi Seismic Isolated Building Meeting Room No.2
16:10-17:10	TEPCO Off-Site Bus Fukushima Daiichi NPS -> J Village (Main Entrance)	
17:10-17:30	Surface Contamination Survey, Return of necessary equipment,	J Village Alpine Rose
17:30-17:40	Chartered Bus J Village (Main Entrance) -> WBC Facility near J Village	
17:40-18:00	Whole Body Counting	WBC Facility near J Village
18:00-19:00	Chartered Bus WBC Facility near J Village -> Hotel	

APPENDIX II - LIST OF PARTICIPANTS

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