Feature 1 Recovery and Reconstruction from the Great East Japan Earthquake through Science and Technology

In this special feature, we summarize the situation of recovery and reconstruction from the Great East Japan Earthquake (GEJE), including the efforts of the Japanese government. We also introduce the process of tackling the challenges of the recovery and reconstruction through science and technology, in accordance with the basic guidelines for reconstruction[1] pursuant to the *Basic Act on Reconstruction in Response to the Great East Japan Earthquake* (Act No. 76 of 2011).

1 The Current Situation of Recovery and Reconstruction from the Great East Japan Earthquake and the Efforts of the Japanese Government

(1) Support for disaster victims

Evacuees in afflicted regions numbered approximately 470,000[2] immediately after the earthquake, but that number has decreased to 260,000[3] (as of March 13, 2014). Approximately 100,000 have been living in emergency temporary housing[4] (as of March 2014).

Regarding support for disaster victims, victims have been monitored so that support can be giving to them when necessary, and mental and other care has been provided. Progress is being made in improving infrastructure and networking among care providers, toward incorporating community-wide care into medical and nursing services. Progress has also been made in establishing subsidies for the relocation of communities to areas of higher elevation, the promotion of house reconstruction and the provision of support for the return of residents who evacuated due to the accident at the Fukushima Daiichi Nuclear Power Station of Tokyo Electric Power Company (TEPCO). Other programs support infrastructure enhancement and industrial recovery from the accident (Refer to Feature 1-1 (2), (3) and (4)).

(2) Regional development

With respect to the recovery of infrastructure, utilities such as electricity and gas had mostly recovered by the middle of FY2011. The recovery of public infrastructure, including traffic networks and waterworks, had also been nearly completed. The restoration rate of directly administered national highways[5] in Iwate, Miyagi and Fukushima (hereinafter: the three affected prefectures) was 99% as of the end of March 2014, and the railway restoration rate was 90% as of April 6, 2014.

By of the end of March 2014, Iwate Prefecture and Miyagi Prefecture had completed the disposal of disaster waste. In contrast, in Fukushima Prefecture, 74% of the disaster waste had been disposed (as of the end of March 2014), excluding "the region with contaminated waste control." Fukushima is making continuous efforts to complete the disposal of disaster waste as early as possible.

Work has started on house reconstruction and the relocation of communities to areas of higher

1 *The Basic Guidelines for Reconstruction in Response to the Great East Japan Earthquake* (determined by the Reconstruction Headquarters in Response to the Great East Japan Earthquake on July 29, 2011)
2 Six prefectures: Aomori, Iwate, Miyagi, Fukushima, Ibaraki and Tochigi (as of March 14, 2011)
3 The number of people residing in shelters (public halls, schools), inns/hotels, residences (public/temporary/private housing, hospitals) and elsewhere (relative's/acquaintance's housing) throughout Japan
4 Seven prefectures: Iwate, Miyagi, Fukushima, Ibaraki, Tochigi, Chiba, and Nagano
5 National Highways 4, 6 and 45, which run through the three affected prefectures

elevation. Of the districts that are subject to the project for collective relocation for disaster mitigation[1] (two districts in Ibaraki Prefecture, and 337 districts elsewhere that are subject to a land restructuring project in the residence reconstruction roadmap)[2], construction has already started in 90% of the districts and has been completed in 15% of the districts (as of the end of March 2014). The three affected prefectures announced that they need approximately 22,000 reconstructed houses, 2,241 of which have been constructed (as of the end of November 2013).

In addition, regarding medical facilities, approximately 93% (171 hospitals) of hospitals that had limited hospitalization or that had no capability to admit patients immediately after the disaster have recovered in all three of the affected prefectures. As for school facilities, approximately 96% (2,210 schools) of the schools that had applied for the National Treasury's Sharing of Expenses for Recovery of Public School Facilities Damaged by Disaster have completed their recovery (as of the end of March 2014).

(3) Industry and employment

1) Industry

As for the mining and manufacturing industries, according to the estimated production value of plants in tsunami-inundated regions[3] (59 plants), their production has mostly recovered to pre-earthquake levels. However, some types of business need more time for recovery. With respect to cash flow support, approximately 270,000 loans have been provided (5.6 trillion yen in total), and approximately 100,000 cases have been guaranteed (2.2 trillion yen in total). The great need for financing has been addressed by this support (as of the end of February 2014).

As for agriculture, tsunami-affected farmland accounts for approximately 21,000 ha[4], and about 63% of the affected farmland (approximately 13,000 ha, as of December 2013), is ready to resume farming.

As for the fisheries industry, about 45% of all the affected fishing ports have restored their unloading quays (143 of 319 fishing ports, as of the end of February 2014), and the main fish markets in the three affected prefectures have recovered to about 70%[5] of their pre-disaster catch.

As for tourism, the number of people staying at accommodations mainly used by tourists in the three affected prefectures has decreased to 82%[6] of the pre-earthquake figure. Tourism in the three affected prefectures remains below the national level.

In response to issues facing these industries, the following measures have been taken: promoting the consolidation of farmland plots, promoting restarts of fish processing facilities and other small and mid-sized businesses through support, including financing, and assisting business restarts, with special focus on small and mid-sized businesses, by addressing their "double loan" problem (the problem of disaster victims who had outstanding business debts but were obliged to take out new loans because the assets which were mortgaged for the loans had been destroyed or could not be used any longer because of the disaster).

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1 A project established based on *The Act Concerning Special Financial Support for Promoting Group Relocation for Disaster Mitigation* (Act No. 132 of 1972) for promoting collective relocation of residents in an uninhabitable zone in the affect areas

2 A roadmap has been drafted, so that disaster victims can have some idea of when they will be able to move in. The roadmap summarizes the status of the development of residential land for private housing and disaster public housing to be supplied through land restructuring plans carried out as a part of the project to promote collective relocation for disaster mitigation.

3 Tsunami-affected regions of the following six prefectures: Aomori, Iwate, Miyagi, Fukushima, Ibaraki and Chiba

4 Tsunami-affected farmland of the following six prefectures: Aomori, Iwate, Miyagi, Fukushima, Ibaraki and Chiba

5 Catch from February 2013 to January 2014 as a share of that from March 2010 to February 2011

6 Down 17.5% from the same month in 2010, as of December 2013

2) Employment

With regard to the employment situation in the three affected prefectures, although the effective ratio of job openings to applicants had decreased to 0.45 in April 2011, the ratio rose to 1.24 as of March 2014. However, in some coastal areas, the number of employees has not yet recovered to pre-earthquake levels, due to depopulation. In addition, mismatches[1] between employment demand and supply have occurred in the building and mining industries.

In response to these issues, the government is promoting support so that unemployed people can find jobs. Such support includes employment support as a part of the industrial policy, careful vocational counseling at public employment agencies and, vocational training.

(4) Reconstruction after the nuclear power disaster

As a basic policy for the reconstruction and revival of Fukushima, in December 2013 the government made the Cabinet decision *For Accelerating the Reconstruction of Fukushima from the Nuclear Disaster*. This established three basic principles. 1) Back up Fukushima by offering support both for early return and for starting new lives. 2) Strengthen efforts for settling the accident at the Fukushima Daiichi Nuclear Power Station. 3) Accelerate the reconstruction of Fukushima after the nuclear disaster under the initiative of the national government.

As for the status of evacuees, evacuees throughout Fukushima Prefecture numbered approximately 135,000 as of March 10, 2014. Approximately 81,000 of them were evacuated from areas under evacuation orders, and approximately 21,000 of them were from areas where the orders had already been lifted (former areas prepared for emergency evacuation[2]). As of August 2013, all the municipalities concerned had revised the designations for areas that were subject to evacuation orders. In April 2014, the evacuation order was lifted from an area in the city of Tamura. It was the first such lifting after the accident at the TEPCO Fukushima Daiichi Nuclear Power Station.

Regarding systematic efforts for the reconstruction and revival of Fukushima, an act[3] to reassure the disaster victims and to help them to realize stability in daily life has been drafted, and living support that gives careful attention to children has been provided.

Regarding compensation for nuclear damages, the Dispute Reconciliation Committee for Nuclear Damage Compensation[4] has arranged a settlement of compensation damages, and the committee has been formulating successive guidelines that indicate which items can be regularly categorized as damage and which items shall receive compensation, as well as indicating the extent of compensation. In addition, since the Nuclear Damages Dispute Resolution Center has received complaints about its response to TEPCO, in May 2014, the Ministry of Education, Culture, Sports, Science and Technology (MEXT) corresponded with TEPCO by making a formal written request for a more sincere response.

As for measures taken to reduce harm to health from radiation, the government is helping Fukushima Prefecture to conduct the Fukushima Health Management Survey, so as to ensure mid- to long-term health management for people in Fukushima. With regard to the Basic Survey, which is part of the Fukushima

1 A situation where a job applicant does not meet the qualification requirements necessary for an occupational category or an industry
2 Areas mainly within a 20- to 30-kilometer radius of the TEPCO Fukushima Daiichi Nuclear Power Station, except for the evacuation order area
3 *Act on the Promotion of Measures regarding Life Support for Disaster Victims to Protect and Support the Lives of Residents, Including Children Afflicted by the TEPCO Nuclear Accident* (Act No. 48 of 2012)
4 Created by MEXT based on *The Act on Compensation for Nuclear Damage* (Act No. 147 of 1961)

Health Management Survey, as of the end of December 2013, Fukushima had completed the estimation of external radiation dose for approximately 470,000 people who were exposed during the four months after the accident. Based on the estimation results, the review committee of the Fukushima Health Management Survey in Fukushima Prefecture concluded that "radiation-related health problems are unlikely to occur." Additionally, the committee has taken measures to prevent the distribution of food that contains radioactive substances exceeding standard values and has promoted effective risk communication regarding fears about the impact of low radiation doses on the health of people around the nation. A study on the impact of long-term exposure on health and on methods of reducing such impact is being conducted at the National Institute of Radiological Sciences.

As for decontamination, based on the Act[1] and the basic guidelines set under the Act, the Japanese government has carried out decontamination in cooperation with local governments in order to promptly reduce the effects of radioactive pollutants originating from the accident on human health and on living environments. As for decontamination special areas, decontamination based on the plan was completed in four cities/towns, and the decontamination work will continue in parallel with the progress of reconstruction in other municipalities. Additionally, in the "pollution status important point investigation areas," municipalities are taking the lead in advancing the decontamination work based on the plan.

With regard to securing the safety of the TEPCO Fukushima Daiichi Nuclear Power Station, and in response to the emergency that occurred after the accident, the government and TEPCO have achieved their goal[2] of stabilizing the plant by cold shutdown condition and by remarkably suppressing the emission of radioactive substances. Since then, they have been working to decommission the reactors based on the *Mid-and-Long-Term Roadmap towards the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Station Units 1-4* (revised in June 2013, hereinafter referred to as the *Mid-and-Long-Term Roadmap*).

Regarding responses to the issue of declines in agriculture, forestry, fisheries and tourism due to rumor and misinformation, the Japanese government has provided accurate information, both domestically and internationally, about inspection results regarding radioactive substances and has promoted support for reconstruction and tourism, and for risk communication, in order to increase consumers' understanding. Furthermore, Fukushima Prefecture has conducted inspections on its own initiative and has taken other measures, such as the inspection of all rice bags, which are stricter than the requirements issued in the guidelines formulated by the Nuclear Emergency Response Headquarters.

As for the issues of industry and employment throughout Fukushima Prefecture, research and development sites utilizing renewable energy and medical and healthcare devices are being improved to promptly carry out the reconstruction of Fukushima Prefecture, which has suffered significant damage as a result of the nuclear disaster. In addition, to rebuild the industrial infrastructure of the Hamadori area and to realize the reconstruction of the regional economy, the Fukushima International Research Industry City Vision (Innovation Coast Vision) Study Group, which consists of representatives of local governments and knowledgeable persons from industry, academia and government and is chaired by the director-general of the Local Nuclear Emergency Response Headquarters, is taking the lead in setting a clear vision for the regional economy and in reviewing necessary support that will lead to the creation of new industries and

1 *The Act Concerning Special Measures to Deal with Contamination of the Environment by Radioactive Substances Emitted by the Nuclear Power Plant Accidents Caused by the Tohoku-Pacific Ocean Earthquake of March 11, 2011* (Act No. 110 of 2011)
2 Step 2 was completed on December 16, 2011.

employment (as of the end of March 2014).

(5) Efforts for recovery and reconstruction with the *Comprehensive Strategy on Science, Technology and Innovation*

In the *Comprehensive Strategy on Science, Technology and Innovation* (cabinet decision of June 7, 2013), it has been decided to maximize the use of science, technology and innovation and to effectively and efficiently promote activities during the reconstruction of the affected regions, so that they can become "places of possibilities and new creations."

As one of "the challenges to be addressed by science, technology and innovation," the strategy set "early recovery and revitalization from the Great East Japan Earthquake," under which are the following five focused issues.

1) Realizing a society where residents' health is protected from disasters and where children and the elderly are sound and healthy
2) Establishing an energy system that is resilient against disasters
3) Developing business models for local industries
4) Establishing next-generation infrastructure that is resilient against disasters
5) Mitigating and resolving the influences of radioactive materials

Additionally, when tackling these issues, in order to accelerate reconstruction and restoration, prompt solutions to these issues need to be achieved in a short period of time so as to hasten the reconstruction and restoration of the affected regions; meanwhile, outcomes obtained through working on mid- and long-term issues shall be utilized sequentially. Furthermore, the strategy articulates the goal that the affected regions will proactively inform people in Japan and overseas about these results and that the practical nature of those results will be a shining example for other countries throughout the world to follow.

In addition, on the basis of the strategy, the Council for Science and Technology Policy included efforts toward "the early reconstruction and recovery from GEJE" in the *Action Plans for Science and Technology Priority Measures 2014*, thus directing special attention to these issues.

Column Feature-1

Efforts toward the Creation of "a New Tohoku region"

Even before the GEJE, the Tohoku district had many problems, such as depopulation, demographic aging and industrial hollowing. In light of this, the government is making efforts to overcome these problems and to make the earthquake disaster reconstruction a turning point for creating "a new Tohoku region" that will serve as a role model to our country and the world, rather than simply restoring Tohoku to its former state.

In addressing the problems resulting from the GEJE and the subsequent TEPCO Fukushima nuclear power station accident, it is particularly important to create original Tohoku technology and industries by utilizing ICT and cutting-edge techniques, in addition to making new efforts to promote the use of renewable energy and to improve the use efficiency of energy toward the creation of a sustainable society.

For example, the world's first experimental research project on floating ocean wind-power generation is being conducted off the coast of Fukushima Prefecture. Toward the full-scale commercialization of this project, efforts are being made to evaluate the safety, reliability and economic efficiency of this technology, in

Floating offshore wind-power generation facility
Courtesy of METI

addition to establishing the technology. From FY2014, the installation and evaluation of two world-class floating offshore wind-power generation facilities (output: 7MW) will start. These facilities are expected to serve as a symbol of reconstruction and restoration for Fukushima Prefecture, where renewable energy is regarded as a pillar supporting the restoration.

Also, the government is working on the introduction of binary electric power generation[1] at Tsuchiyu-Onsen (hot spring) in Fukushima Prefecture as part of the "new Tohoku region" leading model project, by utilizing hot spring water gushing from the source at about 150℃ and using the residual heat from the hot spring. At the same time, land-based aquaculture farms that rely on the cooling water used for binary power generation have been developed, and further efforts are being made to develop an innovative "eco hot spring resort" and to vitalize the regional economy, such as by creating products of "the sixth industry" from products produced in land-based aquaculture.

2 Examples of Efforts toward Recovery and Reconstruction through Science and Technology

Various efforts have been made by practically applying science and technology toward the recovery and reconstruction of the affected regions.

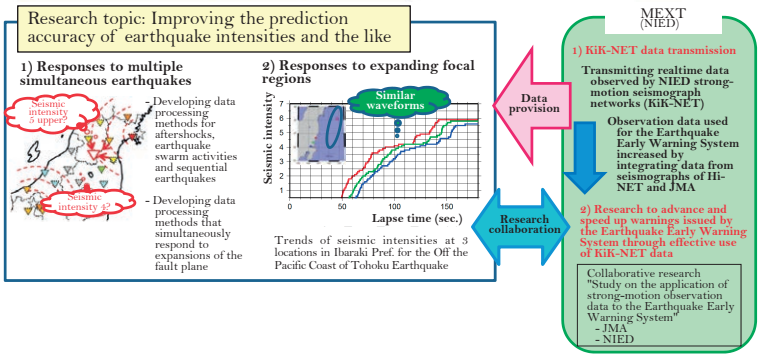
Of the various efforts taken, below we discuss examples of those made by the national government, local governments, universities and other organizations, including various private companies.

(1) Efforts for disaster-resilient regional development

1) Efforts to improve the accuracy of the Earthquake Early Warning System

When the GEJE occurred, it was recorded as having an intensity of "6 upper" on the Japanese scale in the Kanto region; however, the earthquake intensity predicted by the Earthquake Early Warning System did not exceed 4; thus, the earthquake intensity was not predicted accurately. Also, subsequent aftershocks were predicted to have intensities higher than they ended up having. Thus, inappropriate information was released. The following were pointed out as major factors responsible for these problems. 1) The Earthquake Early Warning System estimates earthquake magnitude within a short time of a few seconds to several tens of seconds, based on which the system provides advance announcements of the estimated seismic intensities; however, when a major earthquake occurs, the destruction of the earthquake source fault continues for a long time, which makes it impossible to accurately understand the magnitude in a short time. 2) When several earthquakes occur in quick succession, the system may process the multiple earthquakes as a single one; it may not make appropriate announcements.

In light of these circumstances, the Japan Meteorological Agency (JMA)



Overall Framework for Efforts to Improve the Prediction Accuracy of Intensity and Other Factors of Earthquakes

Courtesy of JMA

1 A method of generating electrical power by using steam produced through heat exchange with a medium that has a lower boiling point than water (a mixture of water and ammonia) to drive a turbine.

has made efforts to improve the system by reviewing the judgment criteria for multiple earthquakes. The Meteorological Research Institute is leading the development of a method that predicts the range and amplitude of seismic motion propagation within a few seconds to tens of seconds after the start of the motion, based on the seismic motion observed within a certain time period when an earthquake occurs. The study concluded that this prediction method can keep errors of predicted seismic intensity within one unit on the Japanese intensity scale and can reduce the number of earthquakes that are not predicted to one-third in an area where there are sufficient observation sites.

In the future, the system will utilize the observation data obtained from a large-depth seismometer of the National Research Institute for Earth Science and Disaster Prevention (NIED) and an ocean-bottom seismometer (DONET[1]) of the Japan Agency for Marine-Earth Science and Technology to issue early warnings of earthquakes more rapidly and accurately and thus to contribute to the prevention and mitigation of seismic damage.

2) Efforts for the development of disaster rescue technology

In the GEJE, there were many cases where water and disaster debris prevented firefighters from quickly accessing fires and rescue sites.

In response to these circumstances, the Ministry of Internal Affairs and Communications (MIC) developed prototypes of firefighting vehicles in FY2012 after carrying out basic research on the requirements of such vehicles for fire-fighting, rescue work and ambulance transport in areas surrounded by tsunami disaster debris. Also, the MIC is experimentally producing an aerial monitoring system that uses a helicopter drone.

Prototypes of firefighting vehicles
Courtesy of the National Research Institute of Fire and Disaster

The MIC is directing its efforts toward the practical application of these prototypes in FY2018, which are expected to save many lives by speeding up rescue activities at disaster sites.

3) Efforts pertaining to nondestructive structural diagnosis

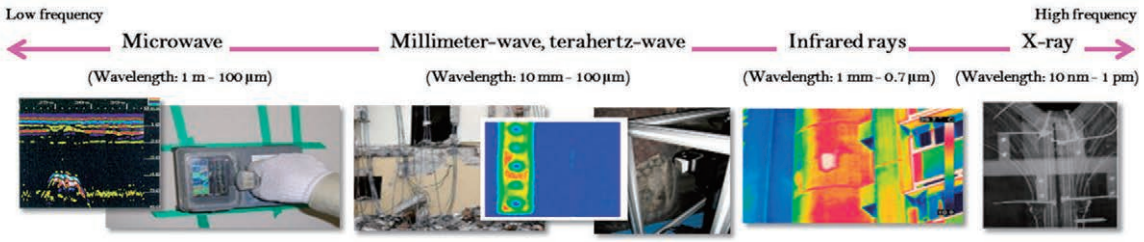
It was pointed out that, in addition to buildings that were partially or completely destroyed in the GEJE, there are many buildings that suffered damage which cannot be recognized by appearance. However, since structural diagnosis is done mainly by expert visual inspection, it takes a lot of time to diagnose all the buildings. Therefore, it is required that a technique that facilitates the rapid diagnosis of structural deterioration will be established.

In light of the above, the National Institute of Information and Communications Technology (NICT), in collaboration with Tohoku University, has engaged, since FY2011, in the development of a tool that can diagnose damage to the inside of walls of buildings or the like by utilizing electromagnetic waves. The NICT and Tohoku University have already selected the most effective frequency of electromagnetic wave, and they completed a prototype in March 2014. They will be conducting verification tests towards practically applying this technique by FY2015.

This diagnostic method will make it possible to efficiently and reliably perform diagnoses of buildings ranging from large-scale structures to conventional houses. The method is expected to enable the early

1 Dense Oceanfloor Network System for Earthquakes and Tsunamis

identification of structures that are unsound despite being in use and to contribute to the creation of disaster-resilient cities.



Schematics of visualization and analysis of the internal structure and surface conditions of building materials by means of various electromagnetic waves

Courtesy of NICT

4) Efforts toward preventing the occurrence of oil tank damage caused by tsunamis

The GEJE damaged oil tanks so severely that oil and other hazardous materials spilled from the tanks. The earthquake also marked the first tsunami-generated fire at a petrochemical complex in Japan. To prevent oil-spill-induced fires and the spread of damage, including marine pollution, and to ensure the rapid distribution of oil to affected areas, it is necessary to investigate the causes of the damage and to make efforts toward damage prevention in the future.

A devastated petrochemical complex

Courtesy of the National Research Institute of Fire and Disaster

Research and investigations by the MIC on the damage mechanism of oil tanks found that tsunami inundation depths exceeding 3 m cause damage to piping and that tsunami inundation depths exceeding 5 m cause damage to the tanks themselves. Toward damage prevention, the MIC is advancing the development of a simulator to predict and estimate the liquid surface oscillation (sloshing) of oil tanks, which is a major factor in oil spills and fires.

In the future, the MIC will make further efforts to utilize the observation data obtained from a strong-motion seismometer installed at each petrochemical complex in sloshing simulations. Further contributions to disaster mitigation are also expected to be realized by the design of dangerous large-scale facilities, the drafting of land use plans for industrial complex areas and the design of evacuation plans for disaster prevention, based on damage mechanism analyses and sloshing simulations.

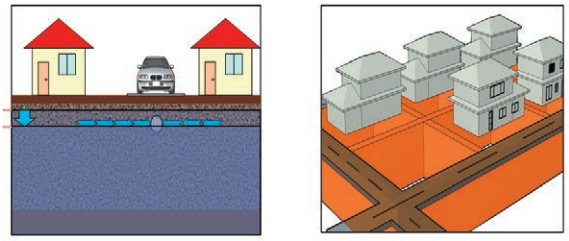
5) Efforts for liquefaction prevention

In the GEJE, severe liquefaction occurred not only in the severely affected regions, but also in coastal areas of Chiba Prefecture. In taking post-disaster reconstruction measures, it was pointed out that the occurrence of such severe liquefaction was attributable to the fact that technologies had not been established for liquefaction countermeasures in built-up areas.

To solve this problem, the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) examined the effectiveness of new technologies for liquefaction countermeasures. These include a "groundwater level lowering" method, in which underground drainpipes discharge groundwater to prevent liquefaction, and an "underground grid diaphragm" method, in which grid-shaped cement diaphragm walls are installed to

contain liquefaction-prone ground. They performed verification experiments and numerical calculations. The MLIT then compiled the data on the effectiveness of these countermeasures in a brief assessment sheet and published it.

Designing and constructing road areas and residential areas systematically by using the aforementioned two methods is expected to lower the costs of liquefaction countermeasures.



Schematics of
the "groundwater level lowering" method (left);
the "underground grid diaphragm wall" method (right)

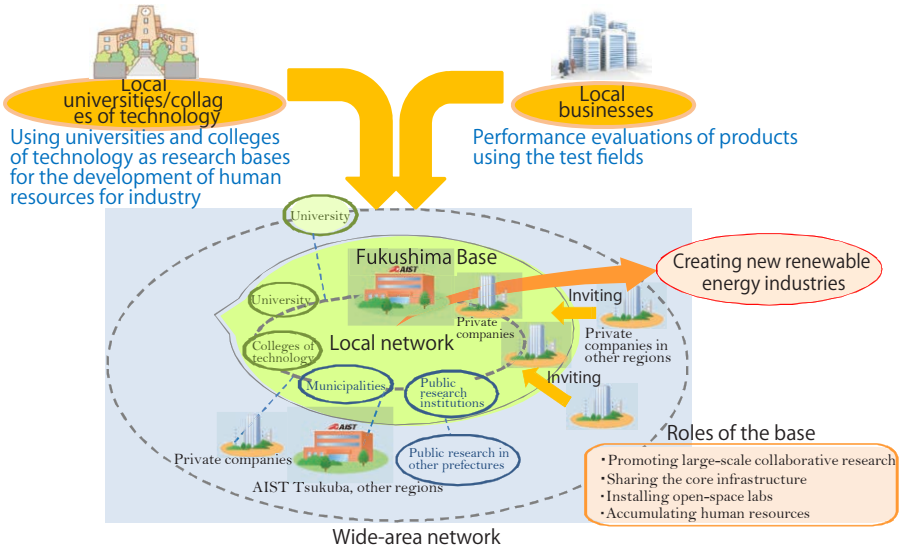
Courtesy of National Institute for Land and Infrastructure Management

(2) Efforts for the restoration of everyday life and economic activities in regions

1) Efforts to reconstruct affected regions by promoting renewable energy industry

Reconstruction in the affected areas must enhance industry in a way that will lead to development greater than that before the earthquake, instead of merely affording recovery from the earthquake damage. Toward the creation of a representative industry that will serve as a pillar of reconstruction, MEXT and AIST are making efforts to support local businesses related to renewable energy and to develop human resources. Also, they are leading the world in research on renewable energy.

(i) R&D on renewable energy at the Fukushima Renewable Energy Institute



Overview of the center for renewable energy research in Fukushima

Courtesy of METI

AIST established the Fukushima Renewable Energy Institute in Fukushima Prefecture in April 2014 for research on renewable energy.

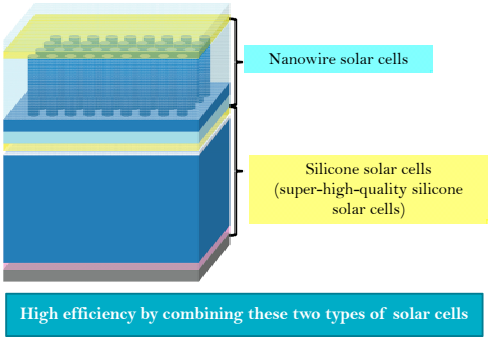
Toward the further introduction of renewable energy, the institute is engaged in the production of hydrogen carriers, the development of high-efficiency wind power technology, the formulation of a potential map for ground thermal power and more. In addition, the institute is making efforts to cultivate

highly skilled human resources who will be able to play active roles in the local renewable energy industry through collaborative research utilizing research equipment at the institute in collaboration with local universities, technical colleges and other organizations.

Also, the institute is conducting performance evaluations on technology seeds produced by renewable-energy-related enterprises in the three affected prefectures by utilizing cutting-edge knowledge, through which the institute is also supporting local private companies toward the market introduction of products in which their technology seeds are utilized.

In FY2013, so that the institute could better fulfill its roles, the institute started to develop a base for the testing, evaluation and research of a large-scale power conditioner (power conversion equipment). Such a facility is necessary for increasing the introduction of renewable energy. The development of the research center will make it possible to issue product certifications for power conditioners in Japan and to develop new methods of experimentation and evaluation that can be used at the research center with an eye to future international standardization. Those efforts are being made with a view to enhancing the competitiveness of our country in overseas markets.

Furthermore, MEXT has made efforts to systematically advance R&D, from basic research to practical application, by conducting R&D on super-high-efficiency solar cells on the premises of the institute.



Outline of a super-high-efficiency solar cell
Courtesy of MEXT

(ii) Research and development related to renewable energy to be put into practical use in the affected regions

Considering the cultural background and regional characteristics of Tohoku, since FY2012 MEXT has been supporting R&D on three types of renewable energy that will contribute to the development of the affected region as an environmentally advanced area through the future commercialization and practical application of those energies.

Specifically, a consortium centered on Tohoku University implemented the following R&D with the support of local governments and businesses: 1) R&D on ocean energy from wave power and tidal currents on the Sanriku Coast, 2) R&D that uses microalgae to integrate oil (hydrocarbon) production into sewage treatment and 3) R&D aiming at the creation of disaster-resilient towns and the efficient use of local renewable energy by utilizing electric vehicles.

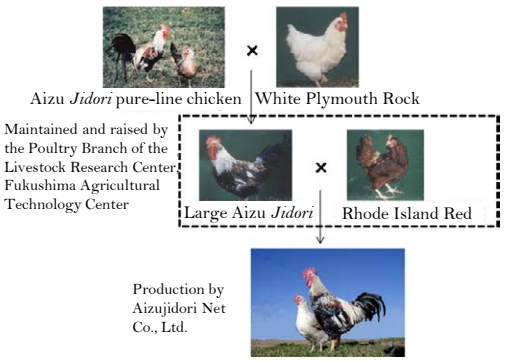
Rendering of an ocean energy generation facility (left) and **Microalgae producing oil** (right)
Courtesy of MEXT

R&D on the projects described in (i) and (ii) has just started; however, their results are expected to contribute to the reconstruction and economic development of the affected regions.

2) Efforts for supporting businesses in affected regions by utilizing technology seeds of research institutions

The Japan Science and Technology Agency (JST) has been implementing the Program for Revitalization Promotion since FY2012. In the program, "matching planners" ("connoisseurs") are deployed in affected regions to determine the needs of businesses in affected regions and to introduce technologies that match their needs from technologies possessed by universities and the like in the country. Through this program, they had successfully introduced 245 technologies matching their needs by the end of FY2013. The following are some examples of matching.

Aizu *Jidori* free-range chickens have been given the Fukushima Ippin certification for outstanding products of Fukushima Prefecture. However, after the TEPCO Fukushima nuclear power station accident, their consumption dropped and production declined, and the production base weakened. Additionally, it takes twice as long to raise Aizu free-range chickens to market compared to ordinary chickens, which also made it difficult to increase the production quantity.



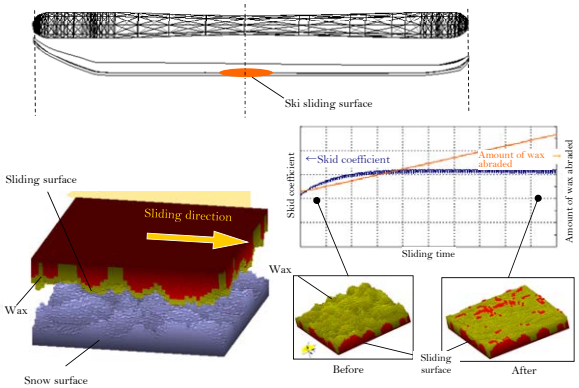
Bleeding system of Aizu *Jidori* chickens
Courtesy of JST

The National Agriculture and Food Research Organization (NARO), Fukushima Prefecture and local businesses have been making efforts to improve the growth of chickens toward shortening the rearing period and improving feeding efficiency. Specifically, since the growth of Aizu *Jidori* chickens is determined by the growth of the parents, a technique for selecting the breed of parent chickens possessed by NARO and the genetic information on growth possessed by the Fukushima Agricultural Technology Center were utilized toward improving the parent chickens, and the effect of the improvement was demonstrated by local private companies.

It is expected that increasing the production efficiency of Aizu *Jidori* chickens and broadly advertising the products in various areas will lead to the increase in consumption and the revitalization of the local economy.

In Miyagi Prefecture, the development of a new ski wax has been conducted. Ski wax is produced by adding various compounds to paraffin, the main constituent of ski wax. It is a major factor in the outcome of a race. However, there is no specific guideline for the selection of additives.

Tohoku University and local private companies are cooperating to clarify the friction phenomenon between the ski surface and the snow surface, water repellency and the penetration of wax into the ski surface by combining a simulation technique of Tohoku University and the evaluation and measuring



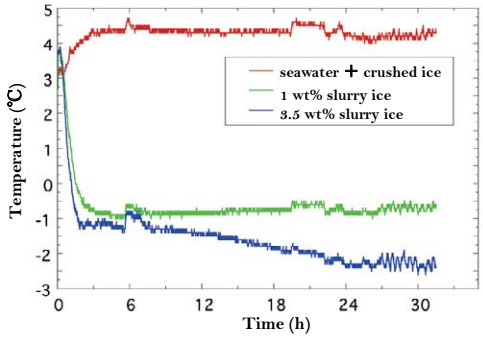
Outline of the friction phenomenon between the ski surface and the snow surface
Courtesy of JST

techniques of local businesses.

They are developing a high-performance wax that far exceeds conventional ones by adding the optimal additives, with the aim of having their wax used by Japanese ski teams in the Olympics.

In Iwate Prefecture, Kochi University of Technology, Iwate Prefecture, Iwate University and local businesses are conducting collaborative research toward applying a slurry ice production technique to fish preservation and to transportation methods that can maintain fish freshness without freezing.

Some fish can currently be eaten only near the production area, because they deteriorate rapidly. The new technique will make it possible to ship these fish without freshness deterioration. This will enable a certain amount of fish to be supplied stably, regardless of the fishing conditions. This is expected to lead to the creation of a new brand and to the revitalization of the local fishing industry.



Time-series variations in the center temperature of a bonito in 3.5% slurry ice, 1% slurry ice and brackish ice

Courtesy of JST

These efforts are expected to lead to the utilization of technology seeds of research institutions, to the creation of new employment at private companies in affected regions and to the reconstruction of these regions.

(3) Efforts for recovery from the nuclear power disaster

1) Efforts for reducing radioactive substances in farmland

For the reconstruction of the affected regions, including Fukushima Prefecture, the recovery of agriculture, which suffered tremendous damage from the TEPCO Fukushima nuclear power station accident, is essential. The Ministry of Agriculture, Forestry and Fisheries (MAFF) has been engaging in the development and verification of decontamination techniques for farmland and in R&D for reducing the soil-to-plant transfer of radioactive substances.

(i) Efforts for removing radioactive substances from agricultural soil

Since the TEPCO Fukushima nuclear power station accident, MAFF has been engaging in the development of basic decontamination techniques for farmland and the development of machinery for decontamination work. In FY2012, MAFF developed an effective and efficient decontamination technique that enables decontamination to be tailored to the farmland type (rice paddy, upland field and pasture) and the site conditions.

With regard to decontamination techniques for rice paddies and upland fields, these techniques were examined during decontamination in Iitate Village and Kawamata Town in Fukushima Prefecture. The effectiveness was confirmed. For example, it was found that by scraping away the topsoil (about 5 cm), the radiocesium level in the plow layer (soil up to 15 cm in

Machine for scraping farmland topsoil

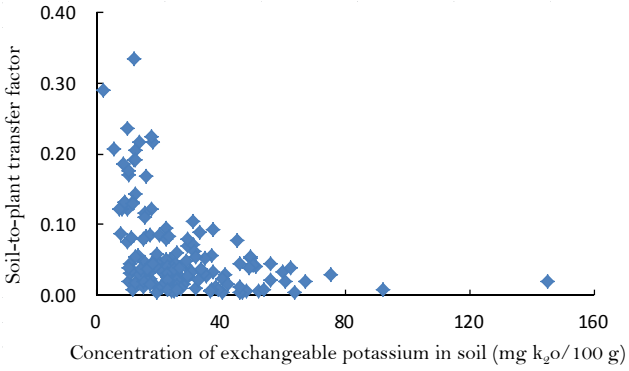
Courtesy of NARO

depth) could be reduced by 80 to 90%, and the air dose rate at 1 m above the ground could be reduced by about 60 to 80%.

MAFF summarized these demonstration results, based on which MAFF formulated and published a technical manual on farmland decontamination measures.

(ii) Research and study on the reduction of soil-to-plant transfer of radioactive substances

To determine the soil factors that are associated with increases in the radiocesium level of crops, the Cabinet Office and MAFF conducted investigations to determine the main factors promoting the intake of radioactive substances by crops such as rice, soybeans, buckwheat and pasture grass, and they developed measures. To suppress radiocesium absorption, it was found effective to increase the content of exchangeable potassium[1] to a certain level by potassium fertilizer application. It was also found that grass growing on pasture with a low potassium concentration is likely to have high levels of radiocesium.

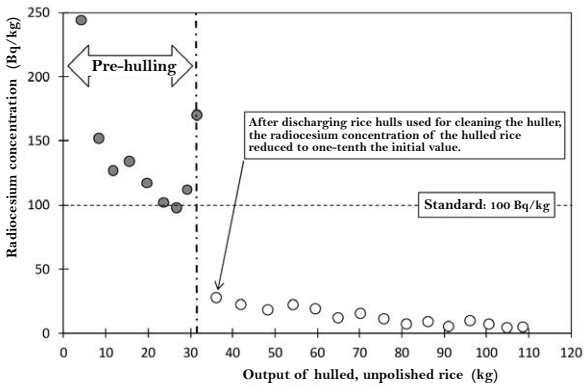


Relationship between exchangeable potassium content and soil-to-soybean transfer factor

* The values of the content of exchangeable potassium in soil were obtained after cultivation.

Courtesy of MAFF

In addition, it was found possible to prevent the contamination in brown rice that can occur when a contaminated huller is used by Pre-hulling[2] the huller with uncontaminated unhulled rice.



Change in radiocesium level of brown rice by pre-hulling

Courtesy of MAFF

Knowledge obtained from the above-mentioned R&D on actual decontamination and crop production is expected to contribute to the recovery of agriculture in the affected regions, which suffered extensively damage from the TEPCO Fukushima nuclear power station accident.

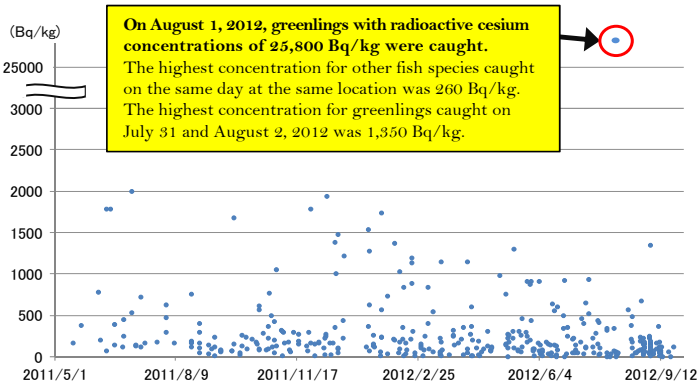
1 Amount of potassium absorbable by plants

2 Here, " Pre-hulling " means removing radioactive substances on the inside of the huller by using uncontaminated unhulled rice in advance.

2) Efforts at securing the confidence of consumers and the safety of marine products by conducting investigations of radioactive substances in marine products

In Fukushima Prefecture and its neighboring prefectures, radiation tests are conducted about once a week, and when fish with a radioactive level close to or exceeding the reference value are detected, necessary measures such as shipment restrictions and self-imposed control of fishing are taken. The tests show that in the April–June quarter of 2011, which is just after the TEPCO Fukushima nuclear power station accident, the percentage of samples exceeding the reference value was as high as 53.0%. However, that declined to 1.7% in the January–March quarter of 2014[1].

Changes in radiocesium levels of greenlings landed at ports in Fukushima Prefecture



Changes in radiocesium levels in greenlings landed at ports on the Fukushima Prefecture coast

Courtesy of the Fisheries Agency

In contrast, in August 2012, greenlings containing radioactive cesium at the highest concentration (25,800 Bq/kg), several hundred times as high as that of other samples, were collected off the coast of Fukushima Prefecture, about 20 km from the TEPCO Fukushima Daiichi Nuclear Power Station.

The Cabinet Office and the Fisheries Agency conducted a study to establish a technique for analyzing radioactive substances found in otoliths extracted from heavily contaminated fishes in FY2012, to determine the period when they were contaminated and to understand the history of their habitat and the like.

An otolith

Courtesy of Fisheries Research Agency

It was found that the aforementioned greenlings were most likely to be the ones that were contaminated to the degree of 400,000 to 500,000 Bq/kg in the port and harbor of the TEPCO Fukushima Daiichi Nuclear Power Station or in nearby waters by the extremely concentrated polluted water released from the power station during the spring and summer of 2011 and that then moved to waters about 20 km from the harbor of the power station, during which movement their radiocesium level fell. At the same time, it was also proven effective to install migration-prevention nets at the harbor entrance, which was implemented by TEPCO, and to get rid of fishes and the like inhabiting the harbor of the power station, based on requests from fishermen.

It is expected that providing the knowledge gained from the outcomes of this study and continuously conducting radiation tests will help to secure the safety of marine products and the confidence of consumers.

1 In the year after the accident, the percentage of samples exceeding the reference value halved, and even though, since April 2012, the research has focused on the types of fish in which not less than 50 Bq/kg of radioactive cesium was detected after the accident, the percentage of samples exceeding the reference level has continued to decrease. In prefectures other than Fukushima, the percentage of samples exceeding the reference value gradually decreased, and since the October–December quarter of 2012, the percentage has remained below 1%.

3) Implementation of monitoring based on the comprehensive monitoring plan

Radioactive substances were released into the environment in large amounts from the accident at the TEPCO Fukushima Daiichi Nuclear Power Station. For this reason, relevant ministries, Fukushima Prefecture and other organizations are cooperatively conducting radiation monitoring pertaining to the accident at the TEPCO Fukushima Daiichi Nuclear Power Station based on the *Comprehensive Monitoring Plan*[1], for the purpose of understanding the distribution of radioactive substances around residential areas for the medium and long term and of understanding the dispersion and deposition of radioactive substances released into the environment.

Specifically, various kinds of monitoring have been conducted, such as the measurement of air doses at monitoring posts[2], nuclide-based analyses of radioactive substances in soil, analyses of radioactive substances in the water of rivers and of the sea and soil, and analyses of radioactive substances in food and tap water.

The monitoring results are immediately available on their website.

Main monitoring in accordance with the Comprehensive Monitoring Plan (modified on April 1, 2013)

*** Monitoring implementation system of each ministry in accordance with the Comprehensive Monitoring Plan**

Monitoring of the environment in general throughout Japan (Nuclear Regulation Authority, relevant prefectural authorities)
- Real-time publication of measurement results of air dose rate at monitoring posts in each prefecture
- Monthly concentration measurement of radioactive substances for precipitation composition (dust in rain or the air), once three months for clean water (at the faucet) to the same accuracy of analysis as the level research before the accident
- Aerial monitoring in the area of a relatively-high level of deposition amount of radioactive substances in the prefectures adjacent to Fukushima Prefecture

Monitoring of the environment in general throughout Fukushima Prefecture (Nuclear Regulation Authority, Nuclear Emergency Response Headquarters, Fukushima Prefecture, TEPCO and others)
- Real-time publication of measurement results of air dose rate at portable monitoring posts placed in Fukushima Prefecture and the prefectures adjacent to Fukushima Prefecture.
- Continuous measurement of air dose rate, airborne dust etc. around the NPP
- Check of distribution of air dose rate and deposition situations of various radioactive substances on the ground as well as survey of radioactive substances transfer in the land areas
- Periodical aerial monitoring within 80 km of the NPP
- Detailed monitoring of the evacuation order areas

Monitoring in marine areas (Nuclear Regulation Authority, MLIT, MAFF, Japan Coast Guard, MOE, Fukushima Prefecture, TEPCO and others)
- Concentration measurement of radioactive substances in marine water, soil and organisms in (1) marine areas adjacent to TEPCO Fukushima Daiichi NPS, (2) coastal areas, (3) offshore areas, (4) oceanic regions and (5) Tokyo Bay, centering on Fukushima Prefecture and neighboring prefectures

Monitoring of schools and nursery centers (Nuclear Regulation Authority MEXT, MHLW and Fukushima Prefecture)
- Real-time publication of measurement results of air dose rate at about 2,700 real-time dose measurement systems placed at schools in Fukushima Prefecture
- Concentration measurement of radioactive substances in water in outdoor pools
- Check of radioactive substances concentration in school lunches

Monitoring of seaports, airports, parks, sewage etc. (MLIT, Fukushima Prefecture, local authorities and others)
- Concentration measurement of radioactive substances in sewage sludge
- Measurement of air dose rate at seaports, airports, urban parks etc.

Monitoring of waste in water environment, natural parks etc. (MOE, Fukushima Prefecture, municipalities, TEPCO and others)
- Concentration measurement of radioactive substances and measurement of air dose rate in water, sediment and environment samples from rivers, lakes, marshes, water sources, ground waters and coasts in Fukushima Prefecture and neighboring prefectures
- Analysis of concentration measurement of radioactive substance in wild plants and animals
- Concentration measurement of radioactive substances in influent water from refuse incineration plants and measurement of air dose rate on the boundary zones according to the Act on Special Measures in relation to Measures for Environmental Pollution by Radioactive Materials

Monitoring of farm soil, forests and pasture (MAFF, Forestry Agency, relevant prefectural authorities Prefecture)
- Understanding of alteration in concentration of radioactive substances and clarification of the transfer characteristics in Fukushima Prefecture and neighboring prefectures
- Concentration measurement of radioactive substances in forest soil, branches, leaves, bark, forests wood and others in test areas in Fukushima Prefecture
- Concentration measurement of radioactive substances in pasture by prefectures
- Concentration measurement of radioactive substances in reservoirs in Fukushima Prefecture.

Monitoring of foods (MHLW, MAFF, Fisheries Agency, Fukushima Prefecture and relevant prefectural authorities)
- Concentration measurement of radioactive substances in foods
- Measurement of actual exposure dose due to ingestion of contaminated foods

Monitoring of tap water (MHLW, Nuclear Emergency Response Headquarters and relevant prefectural authorities)
- Concentration measurement of radioactive substances in pure water from purification plants or raw water from intake sources by prefectures and in tap water by water sources in Fukushima Prefecture

*** The results of each monitoring as shown above are collectively published via the portal site set up on the Nuclear Regulation Authority website.**

Implementation system of each ministry and agency for monitoring based on the *Comprehensive Monitoring Plan*
Courtesy of Nuclear Regulation Authority

4) Efforts at comprehending the distribution of radioactive substances

Various telemetry techniques to determine the distribution of radioactive substances in areas of high radiation doses have been developed.

MEXT and the Japan Atomic Energy Agency (JAEA) are developing a telemetry technique that can visualize radiation and understand the distribution of radioactive substances from the air by using a Compton camera installed in an unmanned helicopter. In conventional methods, some errors occur when telemetry measurements are conducted from the air, due to the influence of

Schematic for understanding the distribution of radioactive substances
Courtesy of MEXT

1 Decided at the Monitoring Coordination Meeting in August 2011, and revised in March and April 2012 and April 2013
2 Apparatus that can continuously measure the radiation dose in the air

radiation from forest slopes, which makes it difficult to create a detailed distribution map. For this reason, they have been developing a technique to measure the distribution of radiation only on the surface of the ground just below an unmanned helicopter by utilizing the features of a Compton camera, toward putting the technique to practical use by FY2015.

This technique will make it possible for the time series change in the distribution of radioactive substances to be understood extensively and accurately. Therefore, the development of the technique is expected to contribute to the rapid provision of information to residents and local governments and to the evaluation of migration by radioactive substances in the environment.

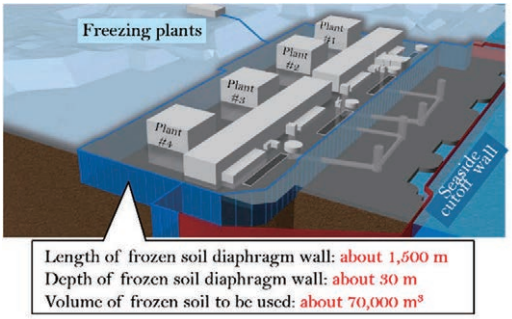
5) Efforts for the stabilization and decommissioning of the TEPCO Fukushima Daiichi Nuclear Power Station

(i) The road and efforts toward decommissioning

The Japanese government and TEPCO started to make efforts to stabilize and decommission the TEPCO Fukushima Daiichi Nuclear Power Station after dividing the period of time until the end of decommissioning into three phases and setting a goal for each phase based on the Mid- to Long-Term Roadmap. As to the start of removal of fuel from the spent fuel pool, which was the goal for the first phase, they successfully achieved that goal by accelerating the original plan by one month and starting the extraction of the spent fuel in Unit 4 in November 2013.

Removal of fuel from the spent pool of Unit 4
Courtesy of TEPCO

With regard to Unit 4, they have continued to work toward completing the removal of the fuel by around the end of FY2014. In addition, they are decontaminating the insides of buildings, inspecting leakage locations in the reactor containment vessels, removing disaster waste in the spent fuel pools and doing other activities toward commencing the removal of spent fuel and fuel debris[1] in Units 1 to 3.



Full view of a frozen soil wall and its cross section
Courtesy of Kajima Corporation

In addition, with regard to measures against contaminated water, it is imperative to create a fundamental solution. In September 2013, the Nuclear Emergency Response Headquarters formulated the *Basic Policy for the Contaminated Water Issue at the TEPCO's Fukushima Daiichi Nuclear Power Station* and determined to promote the steady implementation of the measures, in addition to strengthening systems, such as by establishing a council of ministers and promoting the thorough implementation of process control by the government. Moreover, in December 2013, the headquarters adopted the *Additional Measures for Decommissioning and Contaminated Water Issues at TEPCO's Fukushima Daiichi NPS* and determined to implement preventive and multi-tiered measures and to strengthen the system.

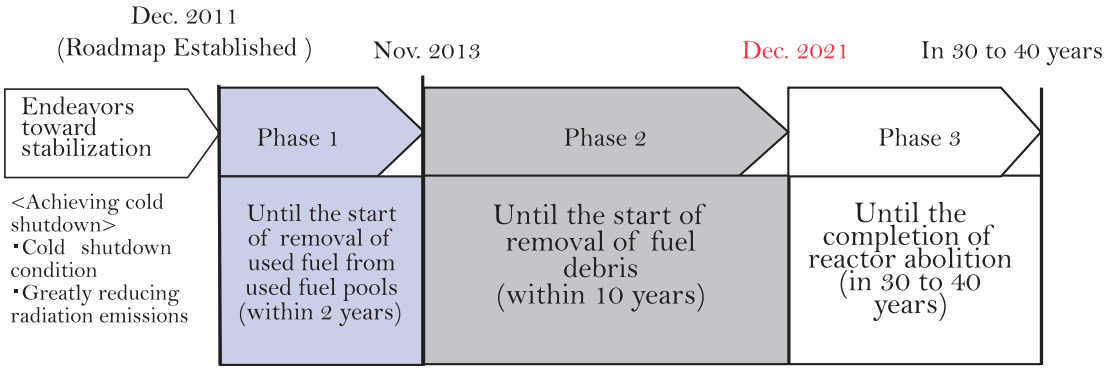
In the light of these decisions, the measures against contaminated water are being implemented based on the following three guidelines: "Remove the source of contamination," "Keep water away from the source of contamination" and "Keep contaminated water from leaking." Specifically, with regard to measures for

1 Re-solidified fuel, cladding tubes and the like that had melted and re-solidified

removing sources of contamination, preparations are made toward the operation of multi-nuclide removal equipment that generates less waste than existing equipment does. Also, with regard to measures for keeping water away from the sources of contamination, preparatory work is being done toward the construction of land-side frozen-soil diaphragm walls that will enter service around the spring of 2015. Moreover, with regard to measures for preventing the leakage of contaminated water, the completion of soil improvement on the sea side and the construction of cutoff walls on the sea side have been progressing.

Furthermore, in order to establish a technical basis for the analysis and research of radioactive substances and the development of disaster-response robots, the JAEA is taking the lead in the construction and operation of facilities for the development and verification of remote-control equipment and devices (mock-up facilities) and the development of facilities for analyzing and studying radioactive substances.

Toward achieving the second-phase goal of commencing the removal of the fuel debris, the wisdom in Japan and overseas are brought together so that the needed steps can be steadily taken, and further efforts are made toward improving the labor environment of workers and the establishment of the Nuclear Damage Compensation and Decommissioning Facilitation Corporation. Thus, continuous efforts are being undertaken toward the goal of complete abolition in 30 to 40 years.

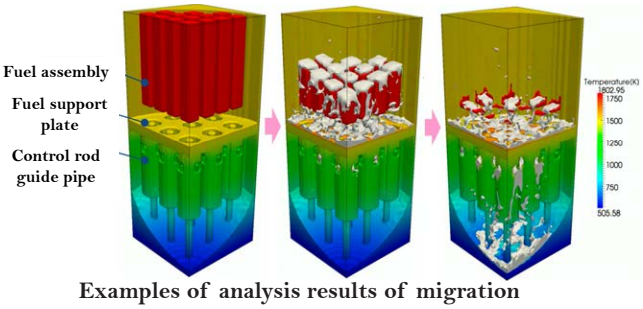


Mid-and-Long-Term Roadmap towards the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Station Units 1 to 4

Courtesy of METI

(ii) Research and development toward the abolition of the reactor facilities

Since the abolition of the TEPCO Fukushima Daiichi Nuclear Power Station is expected to take a long period of time and to involve unprecedented technical difficulties, technology research associations, the International Research Institute for Nuclear Decommissioning, the JAEA, private companies and other organizations cooperatively engaged in R&D on the handling of fuel removed from the spent fuel pool, preparations for the removal of fuel debris and the processing and disposal of solid waste based on the *Mid-and-Long-Term Roadmap*.



Examples of analysis results of migration behavior of molten fuel

Courtesy of JAEA

Specifically, the integrity evaluation[1] of spent fuel assemblies for evaluating the integrity related to the long-term storage of fuel assemblies that were affected by high temperature, seawater injection, the fall of rubble and the like have been done. Measures to prevent recriticality that consider the change in the shape of fuel debris and water amount due to the removal of fuel debris have been developed in order to prevent criticality at the time of the removal of such debris. Criticality control techniques for examining the criticality conditions by computational mechanical simulation have been developed. And accident progression analysis techniques for simply simulating and analyzing fuel assemblies in a pressure vessel, fuel support plates and control rod guide tubes have been developed, toward determining the migration behavior of molten fuel in a lower part of the core.

It is expected that there will be a long way ahead of us toward the decommissioning of the TEPCO Fukushima Daiichi Nuclear Power Station, in the midst of which this R&D has to be advanced rapidly and the obtained results have to be applied in the actual decommissioning work.

(iii) Utilization of robots at nuclear disaster sites

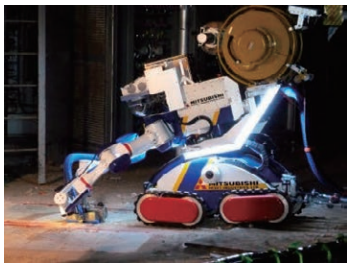
To understand the situation inside of reactor buildings where people have not been able to enter due to high radiation doses and rubble, disaster robots[2] that can obtain the data on radiation doses, images and the like started to be utilized at the site immediately after the accident.

Robot for surveying high places (left) and **Boat** (right)
Courtesy of TEPCO

In addition, to promote the various efforts described in (i), the government and TEPCO are developing, introducing and utilizing robots that can do the following: acquire data at locations that have been inaccessible, decontaminate reactor buildings, and perform the research and work needed for the decontamination of the reactor buildings.

In 2013, for example, the following were done. A robot for surveys of high places (introduced in June) was utilized for investigating high, narrow spaces. The boat (introduced in November, it had detected leakage before) was utilized for identifying leakage from the bottom of a containment vessel at Unit 1 of the TEPCO Fukushima Daiichi Nuclear Power Station. A decontamination robot (Raccoon, introduced in November) was utilized for decontaminating Unit 2 of the power station. And a rubble removal robot (ASTACO-SoRa, introduced in July) was utilized for removing the rubble from Unit 3 of the power station.

Raccoon (left) and **ASTACO-SoRa** (right)
Courtesy of TEPCO



Suctioning/blasting decontamination apparatus
Courtesy of TEPCO

Additionally, in February 2014, a demonstration test of a suctioning/blasting decontamination apparatus that can remove contamination by suctioning rubble and scraping the surface of objects by blasting abrasive compounds was implemented at Unit 1 of the power station.

The government and TEPCO will continue to develop and utilize robots for nuclear disaster sites and to make efforts toward the decommissioning.

1 By using the components of spent fuel stored by JAEA, the impact of immersion in hot seawater on mechanical strength and the like are evaluated.
2 Quince, Survey Runner, etc.