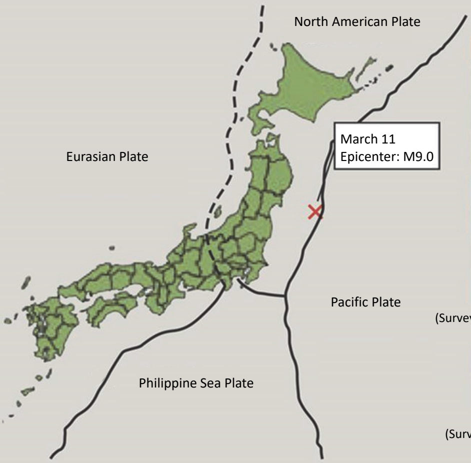
Fukushima Daiichi Nuclear Power Station (NPS) Accident

Damage due to the Great East Japan Earthquake

- ○ A 9.0-magnitude earthquake occurred off the coast of Sanriku at 14:46 p.m. on Friday, March 11, 2011. The Earthquake and subsequent tsunami caused severe damage mainly to the Tohoku region.
- ○ The earthquake was the largest ever recorded in Japan and the fourth biggest in the world since 1900.



Human damage	
Dead	15,894
Missing	2,546
Injured	6,156

Damage to buildings	
Completely destroyed	121,772
Half destroyed	280,921
Partially destroyed	726,509

(Surveyed by the National Police Agency; as of December 8, 2017)

Disaster victim support	
Evacuees nationwide	75,206

(Surveyed by the Reconstruction Agency; as of January 16, 2018)

A big earthquake centered off the coast of Sanriku occurred, at 14:46 p.m. on Friday, March 11, 2011. The seismic intensity of 7 on the Japanese earthquake scale was measured in Kurihara City, Miyagi Prefecture. This 9.0-magnitude earthquake was the biggest recorded in Japan since 1923 and the highest level in the world, equivalent to the 2010 Chili Earthquake (M8.8).

Included in this reference material on March 31, 2013
Updated on February 28, 2018

Fukushima Daiichi Nuclear Power Station (NPS) Accident

Accident at the Nuclear Power Station

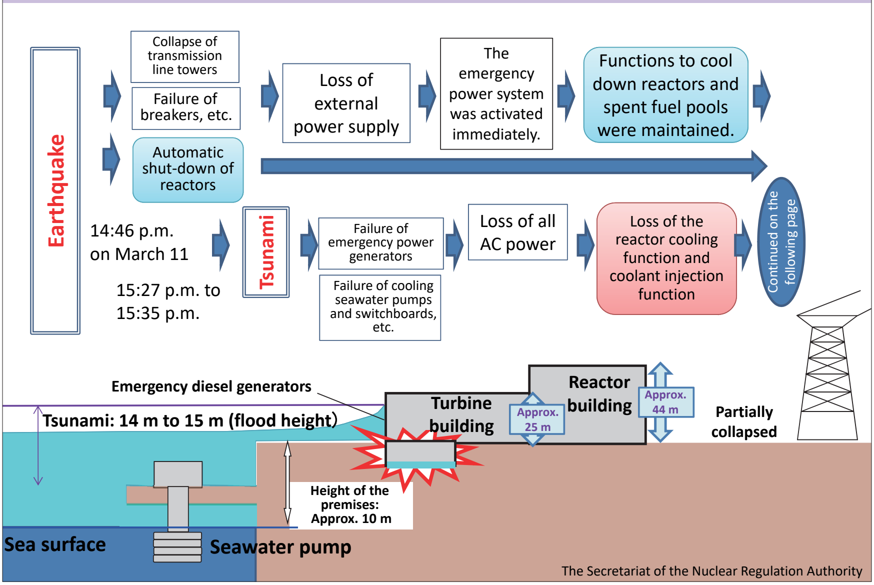
Tokyo Electric Power Company (TEPCO)'s Fukushima Daiichi NPS Unit 3 (shot from the air)
(Shot on March 16, 2011; Provided by TEPCO)

Tokyo Electric Power Company (TEPCO)'s Fukushima Daiichi NPS Unit 1, Unit 2 and Unit 3, which were in operation at the time of the earthquake, lost all AC power due to the earthquake and subsequent tsunami. This led to the stop of the cooling system and loss of means to cool down nuclear fuels, eventually resulting in the melt of nuclear fuel. In the process of the melt, a large amount of hydrogen gas was generated and hydrogen gas accumulated in reactor buildings caused an explosion at Unit 1 on March 12 and at Unit 3 on March 14. Additionally, at Unit 4 adjacent to Unit 3, a hydrogen explosion occurred due to hydrogen gas that is considered to have flowed into it from Unit 3.

Included in this reference material on March 31, 2013

Fukushima Daiichi Nuclear Power Station (NPS) Accident

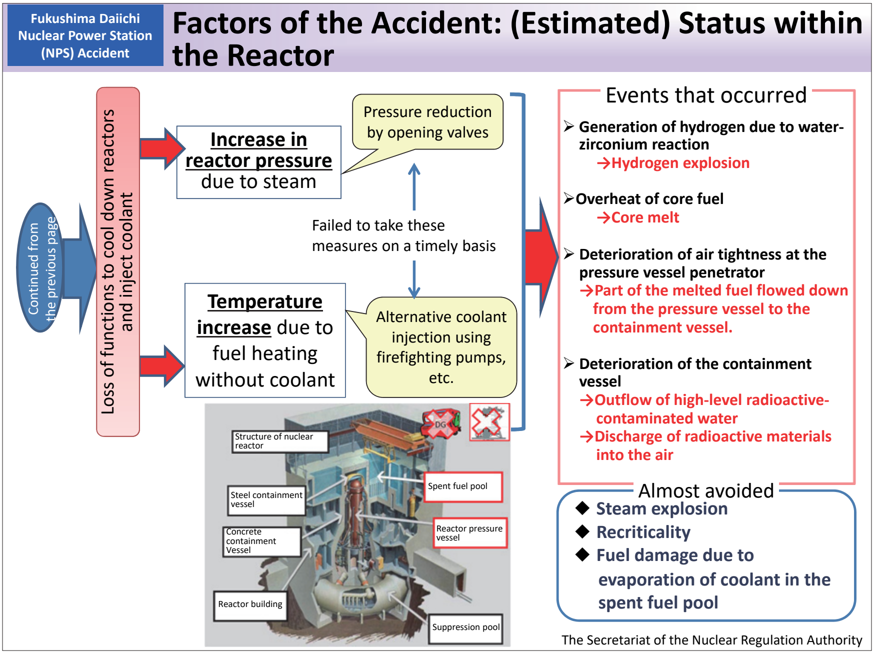
Factors of the Accident: (Estimated) Influence of the Earthquake and Tsunami



Immediately after the earthquake, at Unit 1, Unit 2 and Unit 3 at Tokyo Electric Power Company (TEPCO)'s Fukushima Daiichi NPS, which were in operation, all reactors were shut down automatically. As external electrical power supply was lost due to the collapse of transmission line towers, etc., emergency diesel generators were automatically activated. However, the tsunami hit the NPS and flooded those emergency diesel generators, switchboards and other equipment. All Units except for Unit 6 lost all AC power and cooling seawater pumps stopped functioning. As a result, Unit 1 lost all functions to cool down the reactor. Unit 2 and Unit 3 continued cooling reactors for some time using the Reactor Core Isolation Cooling System (RCIC) and the High Pressure Coolant Injection System (HPCI), respectively, which can work without AC power. However, these systems also stopped soon.

Under such circumstances, NPS staff worked to shift to alternative coolant injection using fire pumps or other equipment at Unit 1, Unit 2 and Unit 3, but until those alternative measures were commenced, reactor cores were left uncooled. Coolant injection is considered to have been suspended for around 14 hours at Unit 1 and for around 6.5 hours at Unit 2 and Unit 3.

Included in this reference material on March 31, 2013



As coolant injection to the reactor core was suspended, the water level in the reactor declined and the fuel was exposed. This caused core melt and damaged the pressure vessel. Additionally, under high temperature due to core damage, steam and zirconium of the fuel clad reacted to generate a large amount of hydrogen, which was released within the containment vessel together with steam.

In the meantime, core damage increased the temperature and pressure in the containment vessel and deteriorated its confinement function, causing gaps in such parts as the penetrator that extends to the outside of the containment vessel. Hydrogen generated due to the reaction of the steam and metal of the clad covering nuclear fuel leaked through the gaps into the reactor building and accumulated there. It led to a hydrogen explosion.

Coolant injected into the reactor leaked from the pressure vessel and containment vessel and a large amount of high-level radioactive-contaminated water accumulated underground below the reactor building and turbine building and partially flowed out into the ocean.

The damage to the pressure vessel and deterioration of the confinement function of the containment vessel caused a leak of steam containing radioactive materials. In addition, radioactive materials were discharged into the air due to hydrogen explosions at the reactor buildings and containment vessel vent operations.

In this manner, radioactive materials were released into the environment in the form of outflow of high-level contaminated water into the ocean and discharge of radioactive materials into the air.

Included in this reference material on March 31, 2013
Updated on January 18, 2016

Responses Immediately after the Accident

Time	Event	Responses by Tokyo Electric Power Company (TEPCO)	Responses by the national government (Nuclear and Industrial Safety Agency)
March 11 14:46	The Great East Japan Earthquake occurred. (Seismic intensity 6 upper at Fukushima Daiichi Nuclear Power Station (NPS))	Fukushima Daiichi NPS Unit 1, Unit 2 and Unit 3 are automatically shut down by earth quake. Unit 4, Unit 5 and Unit 6 were under suspension due to periodic inspection.	The government established the Headquarters for Emergency Disaster Control, assembled officials at the Emergency Response Center, and dispatched officials to disaster-stricken areas by helicopter.
15:15			The Nuclear and Industrial Safety Agency held a press conference and provided information online.
15:27 15:35	The first tsunami (4m in height) arrived. The second tsunami (15m in height) arrived.		
15:42		Report under Article 10 of the Act on Special Measures Concerning Nuclear Emergency (Emergency generators activated at Units 1 to 5, which had lost all AC power, were damaged due to the tsunami.)	The government established the Nuclear Accident Vigilance Headquarters.
16:36	Aftershocks with seismic intensity 5 upper or less occurred several times.	TEPCO judged that the events fall under Article 15 of the Act on Special Measures Concerning Nuclear Emergency.	
19:03			The government issued a Declaration of a Nuclear Emergency Situation and established the Nuclear Emergency Response Headquarters.
21:23			The government issued an evacuation order to residents within a 3-km radius of the NPS and ordered those within a 10-km radius to shelter indoors.
March 12 5:44			The government issued an evacuation order to residents within a 10-km radius of the NPS.
18:25			The government issued an evacuation order to residents within a 20-km radius of the NPS.

From the report by the Aomori Prefecture Nuclear Safety Measure Verification Committee
Prepared by the Nuclear and Industrial Safety Agency

The Secretariat of the Nuclear Regulation Authority

As the emergency core cooling system stopped at Unit 1 and Unit 2 of TEPCO's Fukushima Daiichi NPS, the government issued, based on the Act on Special Measures Concerning Nuclear Emergency, a Declaration of a Nuclear Emergency Situation and established the Nuclear Emergency Response Headquarters at 19:03 p.m. on March 11, 2011.

At 21:23 p.m. on the same day, based on the same Act, the government issued an evacuation order to residents within a 3-km radius of the NPS and ordered those within a 10-km radius to shelter indoors.

Thereafter, the government expanded the coverage of the evacuation order, which was targeted to residents within a 3-km radius of the NPS, to cover those within a 10-km radius. As a result, a total of 51,207 residents in four towns within a 10-km radius were placed under the evacuation order.

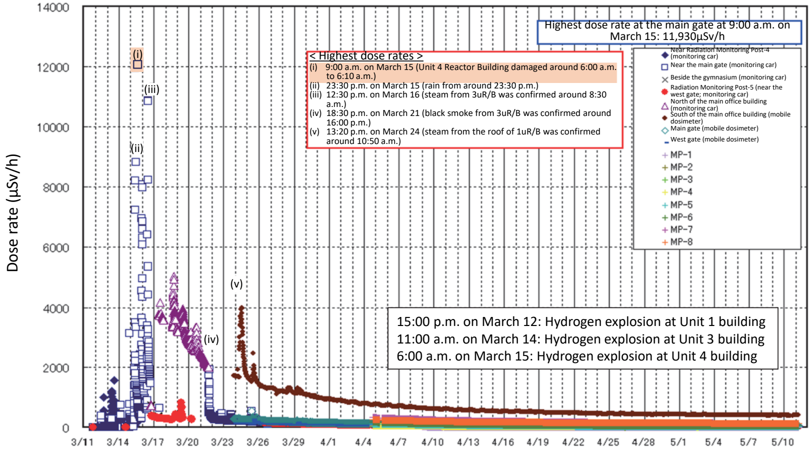
As a hydrogen explosion occurred within the reactor building at Unit 1 at 15:36 p.m. on March 12, the coverage of the evacuation order was further expanded from residents within a 10-km radius to those within a 20-km radius of the NPS.

Included in this reference material on March 31, 2013

Ambient Dose Rates during Two Months after the Accident

(Within and around of the premises of the Tokyo Electric Power Company (TEPCO)'s Fukushima Daiichi Nuclear Power Station (NPS))

Hydrogen explosions occurred at buildings, etc. at Unit 1 to Unit 4 and the highest dose rates were measured in the morning of March 15.



Report of Japanese Government to the IAEA Ministerial Conference on Nuclear Safety, June 2011
Nuclear Emergency Response Headquarters, Attachment V-9

µSv/h: micro sievert per hour

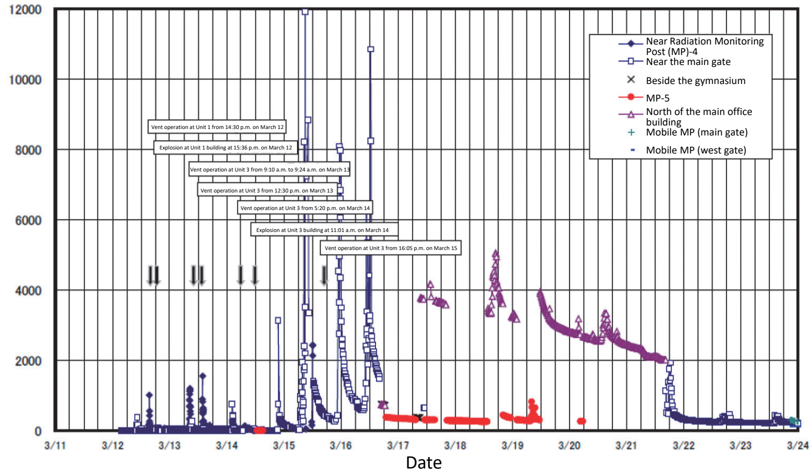
The Secretariat of the Nuclear Regulation Authority

In the early morning of March 12, 2011, monitoring cars measured higher ambient dose rates within the premises of TEPCO's Fukushima Daiichi NPS and the release of radioactive materials was first confirmed after the earthquake. At Unit 1, after an abnormal pressure rise in the containment vessel was observed, the pressure declined slightly. Therefore, it is considered that radioactive materials leaked from the containment vessel at Unit 1 and were discharged into the air. Thereafter, temporary rises of ambient dose rates were observed several times after the vent operations and explosions at the buildings. The highest ambient dose rate was measured at 9:00 a.m. on March 15. A monitoring car near the main gate measured the highest rate of approx. 12 mSv/h.

Included in this reference material on March 31, 2013

Ambient Dose Rates during Two Weeks after the Accident
(Within and around of the premises of the Tokyo Electric Power Company (TEPCO)'s Fukushima Daiichi Nuclear Power Station (NPS))

● **Changes in ambient dose rates measured by monitoring cars within and around the NPS**



Additional Report of the Japanese Government to the IAEA - The Accident at TEPCO's Fukushima Nuclear Power Stations - (Second Report)

μSv/h: micro sievert per hour

The Secretariat of the Nuclear Regulation Authority

In accordance with the progress of events, radioactive materials were released into the air due to containment vessel vent operations and explosions at reactor buildings. Vent operation at Unit 1 was considered to be successful as the pressure in the containment vessel declined at 14:30 p.m. on March 12. Due to the radioactive plume discharged at that time, an ambient dose rate of approx. 1 mSv/h was detected. On March 13, the following day, the ambient dose rate clearly increased again. This is considered to have been caused by vent operation at Unit 3 conducted after the water level in the reactor declined and the fuel was exposed from cooling water. At 9:00 a.m. on March 15, the highest rate of approx. 12 mSv/h was observed. Early in the morning at around 6:00 a.m. of that day, the pressure of the pressure suppression chamber declined at Unit 2 with the sound of an explosion. Therefore, the high dose rate on March 15 is considered to have been caused by the release of radioactive materials from Unit 2.

Ambient dose rate increases were also measured at 23:00 p.m. on March 15 and at 12:00 p.m. on March 16. Pressure decline in the containment vessel was observed in Unit 3 and Unit 2, respectively, and these ambient dose rate increases are considered to have been caused by the release of radioactive materials from Unit 3 and Unit 2.

Included in this reference material on March 31, 2013

Outline of the Accident

International Nuclear Event Scale (INES)

	Level	Accident examples
Accident	7 Major accident	Former Soviet Union: Chernobyl Nuclear Power Plant accident (1986) Japan: Tokyo Electric Power Company (TEPCO)'s Fukushima Daiichi Nuclear Power Station (NPS) accident (2011) Provisionally evaluated as Level 7 on April 12, 2011
Accident	6 Serious accident	
Accident	5 Accident with wider consequences	UK: Windscale Nuclear Power Plant fire accident (1957) US: Three Mile Island Nuclear Power Plant accident (1979)
Accident	4 Accident with local consequences	Japan: JCO criticality accident (1999) France: Saint-Laurent Nuclear Power Plant accident (1980)
Abnormal incident	3 Serious incident	Spain: Fire at Vandellos Nuclear Power Plant (1989)
Abnormal incident	2 Incident	Japan: Damage to steam generator heat exchanger tube at Unit 2, Mihama NPS (1991)
Abnormal incident	1 Anomaly	Japan: Sodium leak accident at Monju (1995) Japan: Primary coolant leak at Unit 2, Tsuruga NPS (1999) Japan: Pipe rupture in the residual heat removal system at Unit 1, Hamaoka NPS (2001) Japan: Pipe failure in the secondary system at Unit 3, Mihama NPS (2004)
Below scale	0 Below scale	(No safety significance)
Below scale	Not covered	(Events unrelated to safety)

Prepared based on "The International Nuclear and Radiological Event Scale User's Manual" (IAEA) and "Report of Japanese Government to the IAEA Ministerial Conference on Nuclear Safety" (June 2011; Nuclear Emergency Response Headquarters)

The International Nuclear Event Scale (INES) is the international indicator to show the level of the seriousness in terms of safety of accidents or trouble at nuclear power plants.

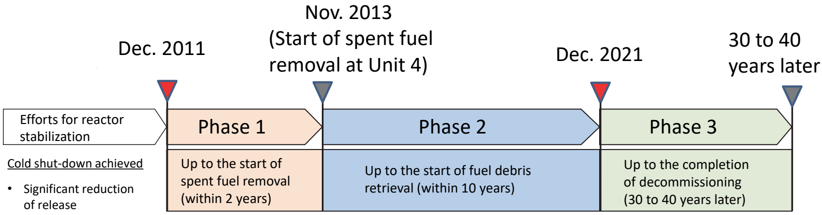
The accident at TEPCO's Fukushima Daiichi NPS was evaluated as Level 7 (radiation impact converted to the amount of I-131 exceeds several tens of thousands TBq (1016 Bq)), equivalent to the level of the Chernobyl accident.

(Related to p.28 of Vol. 1, "International Nuclear and Radiological Event Scale")

Included in this reference material on March 31, 2013
Updated on January 18, 2016

Procedures for Decommissioning and Contaminated Water Management at Tokyo Electric Power Company (TEPCO)'s Fukushima Daiichi NPS

Overall framework of decommissioning procedures



- ◯ Decommissioning procedures by roughly dividing the whole process into three phases
- ◯ This overall framework is maintained in the Mid- and Long-term Roadmap revised in September 2017.
- ◯ Fuel debris retrieval is scheduled to be commenced by the end of 2021.

Efforts to stabilize damaged nuclear reactors have been continued at Tokyo Electric Power Company (TEPCO)'s Fukushima Daiichi NPS. At present, cooling of reactors is continued at all Units and they are all being kept stable and under control.

Procedures for decommissioning and contaminated water management are unprecedentedly challenging and the government of Japan takes the initiative to carry out measures stably and steadily in line with the Mid- and Long-term Roadmap towards the Decommissioning of Tokyo Electric Power Company Holdings' Fukushima Daiichi NPS (Mid- and Long-term Roadmap).

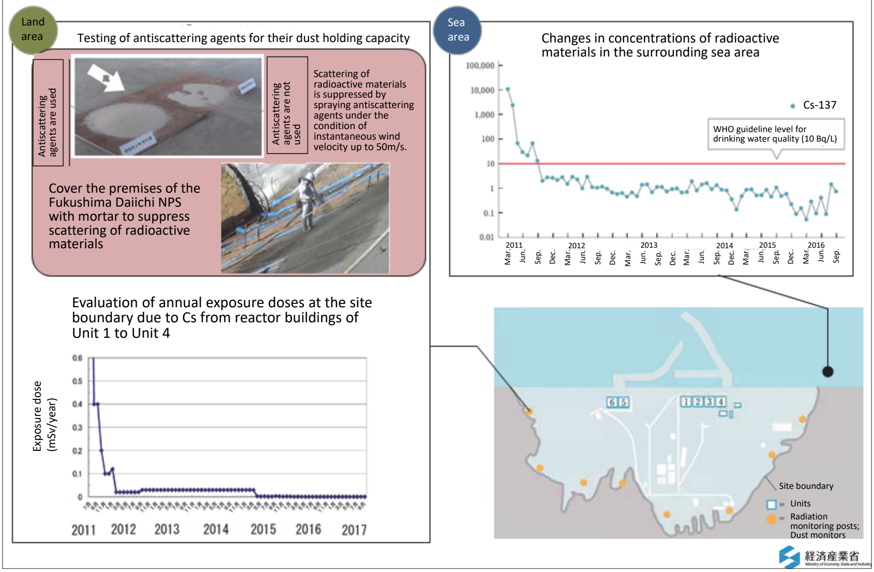
In September 2017, the Mid- and Long-term Roadmap was revised to incorporate the policy on fuel debris retrieval. However, the overall framework for completing the decommissioning in 30 to 40 years is maintained.

Decommissioning procedures will continuously be implemented while collecting wisdom from all over the world.

Included in this reference material on February 28, 2018

Efforts for Decommissioning and Progress

Reduction of Radiation Doses in Surrounding Environment



< Sea area monitoring >

By the sea-side impermeable wall consisting of driven steel piles, which was completed in October 2015, and other various measures, concentrations of radioactive materials in the surrounding environment were reduced and have maintained levels far below the World Health Organization (WHO) guideline level for drinking water quality.

< Surrounding area monitoring >

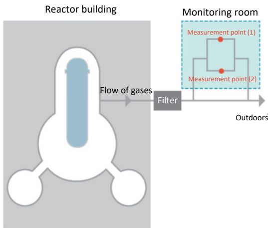
At the Fukushima Daiichi NPS, various measures are taken to prevent scattering of radioactive materials to outside of its premises. Representative measures being taken are spraying of antiscattering agents and facing of the ground with mortar. These measures have worked to stabilize measurement results at radiation monitoring posts within the premises.

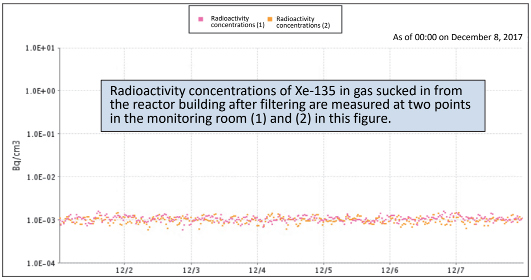
Included in this reference material on February 28, 2018

Efforts for Decommissioning and Progress

Measures against Recriticality and Future Earthquakes and Tsunamis

■ Amount of noble gases generated





■ **Measures against earthquakes and tsunamis**

Through computer analyses and other means, it has been confirmed that reactor buildings and other major facilities are sound enough to withstand any earthquakes or tsunamis equivalent to or even bigger than the Great East Japan Earthquake.

Securing of power sources in an emergency

In preparation for power loss, ordinary power sources have been multiplexed and emergency power supply vehicles and gas turbine vehicles are put in place. These vehicles are to be used to supply power to water injection facilities in an emergency.

Water injection drill

Emergency power supply vehicle

Fire engines

Backup power sources such as emergency power supply vehicles and water injection means such as fire engines are placed at a higher area where tsunamis are unlikely to reach.

Temporary seawall
(Source: Website of Tokyo Electric Power Company)

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< Recriticality >

When criticality occurs, Xe-135 and other noble gases increase in an unexpected fashion. At the Fukushima Daiichi NPS, generation of noble gases is being monitored at all hours. At present, the amount of noble gases has been stable, which suggests that recriticality has not occurred. However, in preparation for any risks of recriticality, a boric acid water system to suppress nuclear fission in the event of criticality has been installed.

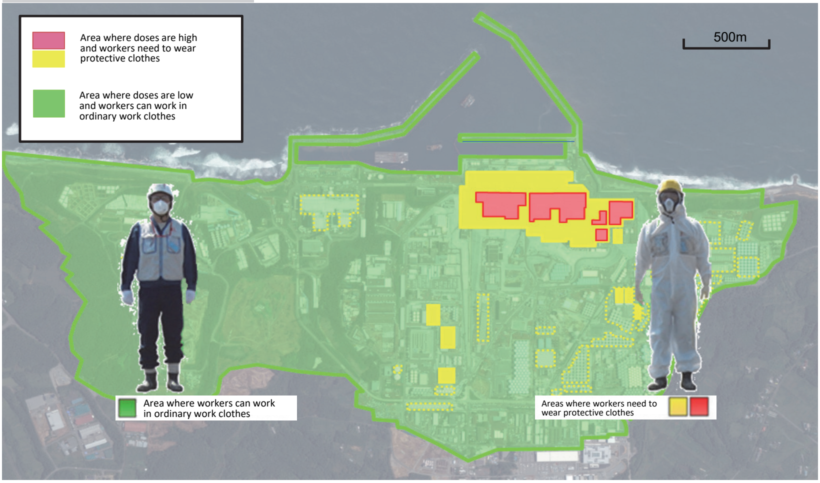
< Measures against earthquakes and tsunamis >

As measures against any earthquakes and tsunamis of the same level as the Great East Japan Earthquake, a temporary seawall has been constructed and the work to block openings of the buildings has been underway to prevent inflow of seawater in the event of a tsunami. Additionally, backup power sources such as emergency power supply vehicles and water injection means such as fire engines are placed at a higher area where tsunamis are unlikely to reach.

Included in this reference material on February 28, 2018

Improvement of Working Environment at the Fukushima Daiichi NPS

Premises of the Fukushima Daiichi NPS



Provided by Japan Space Imaging Corporation and (c) Digital Globe
Prepared by the Ministry of Economy, Trade and Industry based on the materials of Tokyo Electric Power Company

In order to improve safety and workability by reducing workers' load, efforts to improve the working environment, such as debris retrieval and facing, have been made at Tokyo Electric Power Company (TEPCO)'s Fukushima Daiichi NPS. As a result, areas where workers can work in ordinary work clothes expanded to approx. 95% of the entire premises in March 2017.

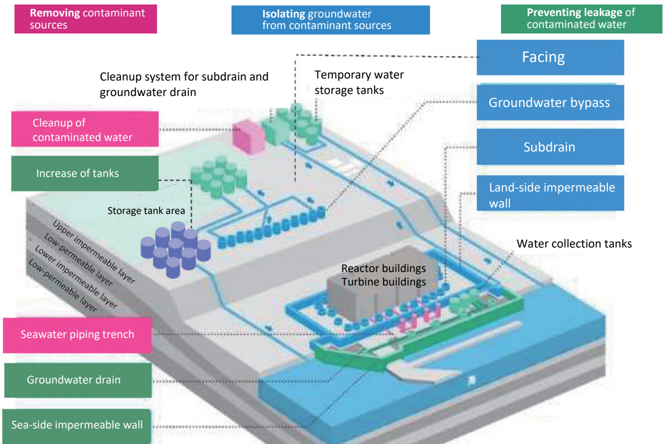
In May 2015, a large rest house was opened and workers are served with hot meals prepared at the food service center and can take a shower and buy things at a convenience store. They can thus work under normal working conditions at present.

Included in this reference material on February 28, 2018

Efforts for Decommissioning and Progress

Measures against Contaminated Water

Preventive and multi-layered measures are being taken against contaminated water based on policies of (i) removing contaminant sources, (ii) isolating groundwater from contaminant sources, and (iii) preventing leakage of contaminated water.



Prepared by the Ministry of Economy, Trade and Industry based on the materials of Tokyo Electric Power Company

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< Policy 1: Removing contaminant sources >
(i) Clean up contaminated water with regard to 62 types of radionuclides excluding tritium(*) by the use of the Advanced Liquid Processing System (ALPS) and other systems
(ii) Pump up highly contaminated water accumulated in the underground tunnel (trench) on the sea side of the buildings and fill and block the trench at the same time
⇒ Removal of contaminated water from the seawater piping trench and filling thereof was completed at Units 2 to 4 by December 2015.
* Tritium is an isotope of hydrogen and exists in nature, in tap water and even in the human body. Comprehensive deliberations not only from a technological perspective but also from a social perspective are underway concerning the management of the water that has been treated and is stored in tanks.

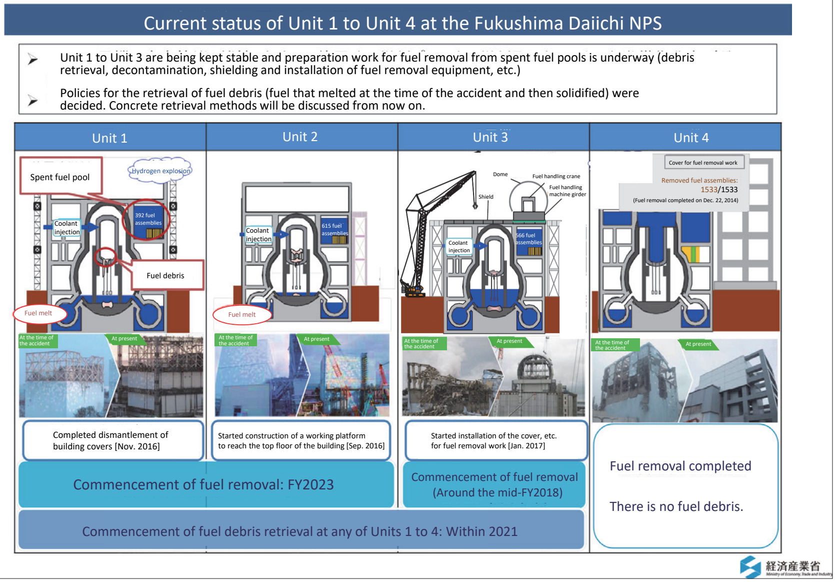
< Policy 2: Isolating water from contaminant sources >
(i) Pump up groundwater on a hill on the mountain side of the buildings to suppress inflow of groundwater around the buildings (groundwater bypass)
(ii) Pump up groundwater using the subdrain (a well near the buildings) to lower the groundwater level, thereby suppressing inflow of groundwater into the buildings and outflow of groundwater into the area on the sea side of the buildings
(iii) Construct a frozen soil wall closely around the buildings to suppress inflow of groundwater from outside of the frozen soil wall
(iv) Suppress infiltration of rainwater into soil by facing (pavement of the surface) to reduce the amount of groundwater and suppress inflow of groundwater into the buildings
⇒ By these preventive and multi-layered measures, the amount of contaminated water generated in a day decreased from 500m3 in May 2014 to 200m3 in the first half of FY2017.

< Policy 3: Preventing leakage of contaminated water >
(i) Construct a sea-side impermeable wall made of steel pipes to reduce outflow of groundwater containing radioactive materials into the sea
(ii) Pump up groundwater using the groundwater drain in the seawall area to suppress outflow of groundwater into the sea
(iii) Secure tanks to store contaminated water generated every day and accumulated water in the buildings in a planned manner
⇒ The sea-side impermeable wall was completed in October 2015 and radioactivity concentrations in the port decreased significantly.

Included in this reference material on February 28, 2018

Efforts for Decommissioning and Progress

Decommissioning Measures



< Removal of spent fuel >

Removal of all 1,533 fuel assemblies from the spent fuel pool was completed at Unit 4 in December 2014 and risks were significantly reduced.

At present, preparations are being steadily progressed at Unit 1 to Unit 3 for removal of rubble. At Unit 3, a dome was installed and fuel removal is scheduled to be commenced around the mid-FY2018.

< Retrieval of fuel debris >

The Mid- and Long-term Roadmap revised in September 2017 indicates a step-by-step approach to first try to access the fuel debris existing at the bottom of the containment vessels (CVs) from the side in the air and then to expand the scale gradually.

Investigations of the inside of CVs by using robots based on cutting-edge technologies have been conducted so far. Investigations and R&D will be further continued with the aim of commencing removal of fuel debris at any Unit by the end of 2021.

(Source: Subcommittee on Management of ALPS-treated Water (1st meeting) on November 11, 2016)
http://www.meti.go.jp/earthquake/nuclear/osensuitaisaku/committtee/takakusyu/pdf/001_02_01.pdf (in Japanese)

Included in this reference material on February 28, 2018