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Fukushima Daiichi Nuclear Power Plant

The **Fukushima Daiichi Nuclear Power Plant** (福島第一原子力発電所, *Fukushima Daiichi Genshiryoku Hatsudensho*, Fukushima number 1 nuclear power plant) is a disabled nuclear power plant located on a 3.5-square-kilometre (860-acre) site[1] in the towns of Ōkuma and Futaba in Fukushima Prefecture, Japan. The plant suffered major damage from the magnitude 9.1 earthquake and tsunami that hit Japan on March 11, 2011. The chain of events caused radiation leaks and permanently damaged several of its reactors, making them impossible to restart. The working reactors were not restarted after the events.

First commissioned in 1971, the plant consists of six boiling water reactors. These light water reactors[2] drove electrical generators with a combined power of 4.7 GWe, making Fukushima Daiichi one of the 15 largest nuclear power stations in the world. Fukushima was the first nuclear plant to be designed, constructed, and run in conjunction with General Electric and Tokyo Electric Power Company (TEPCO).[3] The sister nuclear plant Fukushima Daini ("number two"), 12 km (7.5 mi) to the south, is also run by TEPCO. It also suffered serious damage during the tsunami, at the seawater intakes of all four units, but was successfully shut down and brought to a safe state. See the timeline of the Fukushima II nuclear accidents.[4]

The March 2011 disaster disabled the reactor cooling systems, leading to releases of radioactivity and triggering a 30 km (19 mi) evacuation zone surrounding the plant; the releases continue to this day. On April 20, 2011, the Japanese authorities declared the 20 km (12 mi) evacuation zone a no-go area which may only be entered under government supervision. In November 2011, the first journalists were allowed to visit the plant. They described a scene of devastation in which three of the reactor buildings were destroyed; the grounds were covered with mangled trucks, crumpled water tanks and other debris left by the tsunami; and radioactive levels were so high that visitors were only allowed to stay for a few hours.[5]

In April 2012, Units 1–4 were shut down. Units 2–4 were shut down on April 19, while Unit 1 was the last of these four units to be shut down on April 20 at midnight. In December 2013 TEPCO decided none of the undamaged units will reopen. In April 2021, the Japanese government approved the discharge of radioactive water, which has been treated to remove radionuclides other than tritium, into the Pacific Ocean over the course of 30 years.[6]

Fukushima Daiichi Nuclear Power Plant

Aerial photo from 2007

Country	Japan
Location	Ōkuma, Fukushima
Coordinates	37°25′23″N 141°01′59″E
Status	Being decommissioned
Construction began	July 25, 1967
Commission date	March 26, 1971
Decommission date	11 March 2011
Owner(s)	TEPCO
Operator(s)	Tokyo Electric Power Company
Nuclear power station	
Reactor type	BWR
Reactor supplier	General Electric Toshiba Hitachi
Power generation	
Units cancelled	2 × 1,380 MW
Units decommissioned	1 × 460 MW (Unit 1) 4 × 784 MW (Units 2, 3, 4 and 5) 1 × 1,100 MW (unit 6)
Nameplate capacity	5,306 MW (1979–2011)
External links	
Website	www.tepco.co.jp/en/nu/press/f1-np/index-e.html (http://www.tepco.co.jp/en/nu/press/f1-np/index-e.html)
Commons	Related media on Commons

Power plant information

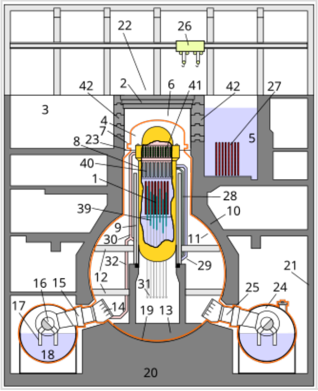
The reactors for Units 1, 2, and 6 were supplied by General Electric, those for Units 3 and 5 by Toshiba, and Unit 4 by Hitachi. All six reactors were designed by General Electric.[7][8] Architectural design for General Electric's units was done by Ebasco. All construction was done by Kajima.[9] Since September 2010, Unit 3 has been fueled by a small fraction (6%)[10] of plutonium containing mixed-oxide (MOX) fuel, rather than the low enriched uranium (LEU) used in the other reactors.[11][12] Units 1–5 were built with Mark I type (light bulb torus) containment structures.[13][14] The Mark I containment structure was slightly increased in volume by Japanese engineers.[15] Unit 6 has a Mark II type (over/under) containment structure.[13][14][16]

Unit 1 is a 460 MWe boiling water reactor (BWR-3) constructed in July 1967. It commenced commercial electrical production on March 26, 1971, and was initially scheduled for shutdown in early 2011.[17] In February 2011, Japanese regulators granted an extension of ten years for the continued operation of the reactor.[18] It was damaged during the 2011 Tōhoku earthquake and tsunami.[19]

Unit 1 was designed for a peak ground acceleration of 0.18 g (1.74 m/s^2) and a response spectrum based on the 1952 Kern County earthquake, but rated for 0.498 g.[13][20] The design basis for Units 3 and 6 were 0.45 g (4.41 m/s^2) and 0.46 g (4.48 m/s^2)

respectively.[21] All units were inspected after the 1978 Miyagi earthquake when the ground acceleration was 0.125 g (1.22 m/s^2) for 30 seconds, but no damage to the critical parts of the reactor was discovered.[13] The design basis for tsunamis was 5.7 metres (18 ft 8 in).[22]

The reactor's emergency diesel generators and DC batteries, crucial components in helping keep the reactors cool in the event of a power loss, were located in the basements of the reactor turbine buildings. The reactor design plans provided by General Electric specified placing the generators and batteries in that location, but mid-level engineers working on the construction of the plant were concerned that this made the backup power systems vulnerable to flooding. TEPCO elected to strictly follow General Electric's design in the construction of the reactors.[23]



Cross-section sketch of a typical BWR Mark I containment, as used in Units 1 to 5. The reactor core (1) consists of fuel rods and control rods (39) which are moved in and out by the device (31). Around the pressure vessel (8), there is an outer containment (19) which is closed by a concrete plug (2). When fuel rods are moved in or out, the crane (26) will move this plug to the pool for facilities (3). Steam from the dry well (11) can move to the wet well (24) through jet nozzles (14) to condense there (18). In the spent fuel pool (5), the used fuel rods (27) are stored.

Site layout

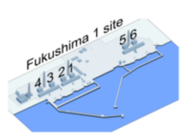
The plant is on a bluff which was originally 35 meters above sea level. During construction, however, TEPCO lowered the height of the bluff by 25 meters. One reason for lowering the bluff was to allow the base of the reactors to be constructed on solid bedrock in order to mitigate the threat posed by earthquakes. Another reason was the lowered height would keep the running costs of the seawater pumps low. TEPCO's analysis of the tsunami risk when planning the site's construction determined that the lower elevation was safe because the sea wall would provide adequate protection for the maximum tsunami assumed by the design basis. However, the lower site elevation did increase the vulnerability for a tsunami larger than anticipated in design.[24]

The Fukushima Daiichi site is divided into two reactor groups, the leftmost group – when viewing from the ocean – contains units 4, 3, 2 and 1 going from left to right. The rightmost group – when viewing from the ocean – contains the newer units 5 and 6, respectively, the positions from left to right. A set of seawalls protrude into the ocean, with the water intake in the middle and water discharge outlets on either side.

Aerial view of the plant area in 1975, showing separation between Units 5 & 6, and the majority of the complex
· Unit 6: direction of Sōma
· Unit 4: direction of Iwaki

Aerial view of the Fukushima I plant area in 1975, showing sea walls and completed reactors

Closeup of Units 4, 3, 2 and 1



Major buildings

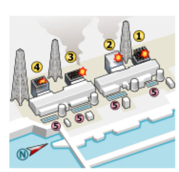


Illustration of post-accident state of 1–4 reactors, all but 2 display obvious damage to secondary containment

Reactor data

Units 7 and 8 were planned to start construction in April 2012 and 2013 and to come into operation in October 2016 and 2017 respectively. The project was formally canceled by TEPCO in April 2011 after local authorities questioned the fact that they were still included in the supply plan for 2011, released in March 2011, after the accidents. The company stated that the plan had been drafted before the earthquake.[25]

Unit[26]	Type[27] (Containment)	Net power[28]	Start construction[28]	First criticality[28]	Commercial operation[28]	Shutdown[28]	NSSS[27]	A-E[9]	Builder[9]
1	BWR-3 (Mark I)	439 MW	July 25, 1967	October 10, 1970	March 26, 1971	May 19, 2011	General Electric	Ebasco	Kajima
2	BWR-4 (Mark I)	760 MW	June 9, 1969	May 10, 1973	July 18, 1974	May 19, 2011	General Electric	Ebasco	Kajima
3	BWR-4 (Mark I)	760 MW	December 28, 1970	September 6, 1974	March 27, 1976	May 19, 2011	Toshiba	Toshiba	Kajima
4	BWR-4 (Mark I)	760 MW	February 12, 1973	January 28, 1978	October 12, 1978	May 19, 2011	Hitachi	Hitachi	Kajima
5	BWR-4 (Mark I)	760 MW	May 22, 1972	August 26, 1977	April 18, 1978	December 17, 2013	Toshiba	Toshiba	Kajima
6	BWR-5 (Mark II)	1067 MW	October 26, 1973	March 9, 1979	October 24, 1979	December 17, 2013	General Electric	Ebasco	Kajima
7 (planned)	ABWR	1380 MW	Canceled 04/2011	Planned 10/2016					
8 (planned)	ABWR	1380 MW	Canceled 04/2011	Planned 10/2017					

Electrical connections

The Fukushima Daiichi plant is connected to the power grid by four lines, the 500 kV Futaba Line (双葉線), the two 275 kV Ōkuma Lines (大熊線) and the 66 kV Yonomori Line (夜の森線) to the Shin-Fukushima (New Fukushima) substation.

The Shin-Fukushima substation also connects to the Fukushima Daini plant by the Tomioka Line (富岡線). Its major connection to the north is the Iwaki Line (いわき幹線), which is owned by Tohoku Electric Power. It has two connections to the south-west that connect it to the Shin-Iwaki substation (新いわき).

Operating history

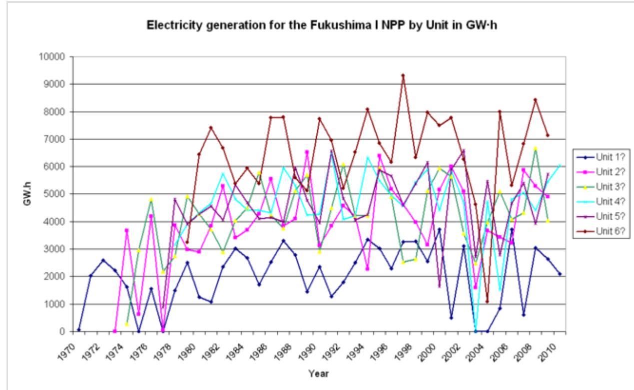
Plant still under construction circa 1971

The plant reactors came online one at a time beginning in 1970 and the last in 1979. From the end of 2002 through 2005, the reactors were among those shut down for a time for safety checks due to the TEPCO data falsification scandal.[29][30] On February 28, 2011, TEPCO submitted a report to the Japanese Nuclear and Industrial Safety Agency admitting that the company had previously submitted fake inspection and repair reports. The report revealed that TEPCO failed to inspect more than 30 technical components of the six reactors, including power boards for the reactor's temperature control valves, as well as components of cooling systems such as water pump motors and emergency power diesel generators.[31] In 2008, the IAEA warned Japan that the Fukushima plant was built using outdated safety guidelines, and could be a "serious problem" during a large earthquake.[32] The warning led to the building of an emergency response center in 2010, used during the response to the 2011 nuclear accident.[32][33]

On April 5, 2011, TEPCO vice president Takashi Fujimoto announced that the company was canceling plans to build Reactors No. 7 and 8.[34][35] On May 20 TEPCO's board of directors' officially voted to decommission Units 1 through 4 of the Fukushima Daiichi nuclear power plant and to cancel plans to build units 7 and 8. It refused however to make a decision regarding units 5 and 6 of the station or units 1 to 4 of the Fukushima Daini nuclear power station until a detailed investigation is made. In December 2013 TEPCO decided to decommission the undamaged units 5 and 6; they may be used to test remote clean-up methods before use on the damaged reactors.[36]

[show] **Electricity generation for the Fukushima I NPP by Unit in GW·h[28]**

Year	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6
1970	60.482					
1971	2024.3					
1972	2589.1					
1973	2216.8	5.949				
1974	1629.7	3670.1	284.7			
1975	0	622.1	2961.8			
1976	1563.9	4191.4	4807.1			
1977	0	49.7	2171.1		875.1	
1978	1497.6	3876.3	2753.7	3163.2	4806.7	
1979	2504.4	2976	4916.3	3917.4	3898.6	3235.6
1980	1249.5	2889	4287	4317	4282.6	6441.1
1981	1084.8	3841.8	3722.8	4667.5	4553.9	7418.6
1982	2355	5290.2	2886.8	5734.7	4061.3	6666.5
1983	3019.5	3422.7	4034	4818.2	5338.8	5387.8
1984	2669.761	3698.718	4497.326	4433.166	4691.482	5933.242
1985	1699.287	4266.285	5798.641	4409.031	4112.429	5384.802
1986	2524.683	5541.101	4234.196	4315.241	4157.361	7783.537
1987	3308.888	3851.078	3748.839	5964.048	3995.012	7789.201
1988	2794.464	4101.251	5122.991	5309.892	5952.712	5593.058
1989	1440.778	6516.393	5706.694	4232.648	4766.535	5128.362
1990	2352.405	3122.761	2919.548	4273.767	3956.549	7727.073
1991	1279.986	3853.054	4491.022	6483.384	6575.818	6948.662
1992	1794.061	4568.531	6098.742	4082.747	4841.234	5213.607
1993	2500.668	4186.704	4204.301	4206.577	4059.685	6530.932
1994	3337.532	2265.961	4202.304	6323.277	4246.206	8079.391
1995	3030.829	6396.469	5966.533	5485.662	5878.681	6850.839
1996	2298.589	5192.318	4909.655	4949.891	5666.866	6157.765
1997	3258.913	4618.869	2516.651	4556.81	4609.382	9307.735
1998	3287.231	3976.16	2632.682	5441.398	5369.912	6328.985
1999	2556.93	3158.382	5116.09	5890.548	6154.135	7960.491
2000	3706.281	5167.247	5932.485	4415.901	1647.027	7495.577
2001	487.504	5996.521	5637.317	5858.452	5905.13	7778.874
2002	3120.2	5101.018	3567.314	4687.718	6590.488	6270.918
2003	0	1601.108	2483.557	0	2723.76	4623.905
2004	0	3671.49	3969.674	4728.987	5471.325	1088.787
2005	851.328	3424.939	5103.85	1515.596	2792.561	7986.451
2006	3714.606	3219.494	4081.932	4811.409	4656.9	5321.767
2007	610.761	5879.862	4312.845	5050.607	5389.565	6833.522
2008	3036.562	5289.599	6668.839	4410.285	3930.677	8424.526
2009	2637.414	4903.293	4037.601	5462.108	5720.079	7130.99
2010	2089.015			6040.782		



Electricity generation for the Fukushima I

Warnings and design critique

In 1990, the U.S. Nuclear Regulatory Commission (NRC) ranked the failure of the emergency electricity generators and subsequent failure of the cooling systems of plants in seismically very active regions one of the most likely risks. The Japanese Nuclear and Industrial Safety Agency (NISA) cited this report in 2004. According to Jun Tateno, a former NISA scientist, TEPCO did not react to these warnings and did not respond with any measures.[37]

Filmmaker Adam Curtis mentioned the risks of the type of boiling water reactors cooling systems such as those in Fukushima I,[38] and claimed the risks were known since 1971[39] in a series of documentaries in the BBC in 1992 and advised that PWR type reactors should have been used.

Tokyo Electric Power Company (TEPCO) operated the station and was warned their seawall was insufficient to withstand a powerful tsunami, but did not increase the seawall height in response. The Onagawa Nuclear Power Plant, operated by Tohoku Electric Power, ran closer to the epicenter of the earthquake, but had much more robust seawalls of greater height and avoided severe accident.[40]

Incidents and accidents

Prior to March 2011

1978

Fuel rods fell in reactor No. 3, causing a nuclear reaction.[41] It took about seven and a half hours to place the rods back into proper positions. There was no record of the incident, as TEPCO had covered it up; interviews of two former workers in 2007 led to its discovery by TEPCO management.[42]

February 25, 2009

A manual shutdown was initiated during the middle of a start-up operation. The cause was a high pressure alarm that was caused by the shutting of a turbine bypass valve. The reactor was at 12% of full power when the alarm occurred at 4:03 am (local time) due to a pressure increase to 1,030 psi (7,100 kPa), exceeding the regulatory limit of 1,002 psi (6,910 kPa). The reactor was reduced to 0% power, which exceeded the 5% threshold that requires event reporting, and pressure dropped back under the regulatory limit at 4:25 am. Later, at 8:49 am the control blades were completely inserted, constituting a manual reactor shutdown. An inspection then confirmed that one of the 8 bypass valves had closed and that the valve had a bad driving fluid connection. The reactor had been starting up following its 25th regular inspection, which had begun on October 18, 2008.[43]

March 26, 2009

Unit 3 had problems with over-insertion of control blades during outage. Repair work was being done on equipment that regulates the driving pressure for the control blades, and when a valve was opened at 2:23 pm a control blade drift alarm went off. On later inspection, it was found that several of the rods had been unintentionally inserted.[44]

November 2, 2010

Unit 5 had an automatic SCRAM while an operator was conducting an adjustment to the control blade insertion pattern. The SCRAM was caused by a reactor low water level alarm. The turbine tripped along with the reactor and there was no radiation injury to workers.[45]

Nuclear disaster of March 11, 2011

Three of the reactors at Fukushima Daiichi overheated, causing meltdowns that eventually led to explosions, which released large amounts of radioactive material into the air.[46]

On March 11, 2011, an earthquake categorized as 9.1 M_W on the moment magnitude scale occurred at 14:46 Japan Standard Time (JST) off the northeast coast of Japan, one of the most powerful earthquakes in history. Units 4, 5 and 6 had been "shut down" prior to the earthquake for planned maintenance.[47][48] The remaining reactors were shut down/SCRAMed automatically after the earthquake, and the remaining decay heat of the fuel was being cooled with power from emergency generators. The subsequent destructive tsunami with waves of up to 14 metres (46 ft) that over-topped the station, which had seawalls, disabled emergency generators required to cool the reactors and spent fuel pools in Units 1–5. Over the following three weeks there was evidence of partial nuclear meltdowns in units 1, 2 and 3: visible explosions, suspected to be caused by hydrogen gas, in units 1 and 3; a suspected explosion in unit 2, that may have damaged the primary containment vessel; and a possible uncovering of the Spent fuel pools in Units 1, 3 and 4.[49] Units 5 & 6 were reported on March 19, by the station-wide *alert log updates* of the IAEA, to have gradually rising spent fuel pool temperatures as they had likewise lost offsite power, but onsite power provided by Unit 6's two diesel generators that had not been flooded, were configured to do double-duty and cool both Unit 5 and 6's spent fuel pools "and cores".[50] As a precautionary measure, vents in the roofs of these two units were also made to prevent the possibility of hydrogen gas pressurization and then ignition.[50]

Radiation releases from Units 1–4 forced the evacuation of 83,000 residents from towns around the plant.[51] The triple meltdown also caused concerns about contamination of food and water supplies, including the 2011 rice harvest, and also the health effects of radiation on workers at the plant.[52][53][54] Scientists estimate that the accident released 18 quadrillion becquerels of caesium-137 into the Pacific Ocean, contaminating 150 square miles (390 km^2) of the ocean floor.[55]

The events at units 1, 2 and 3 have been rated at Level 5 each on the International Nuclear Event Scale, and those at unit 4 as Level 3 (Serious Incident) events, with the overall plant rating at Level 7 (major release of radioactive material with widespread health and environmental effects requiring implementation of planned and extended countermeasures), making the Fukushima disaster and the Chernobyl disaster worldwide the only Level 7 events up to date.[56]

Japanese wheelchair basketball player Akira Toyoshima revealed that he was working as an accountant at the Fukushima Daiichi Nuclear Power Plant when the 2011 Tōhoku earthquake and tsunami struck Japan and the tsunami eventually claimed the lives of thousands of people.[57] Toyoshima insisted that he was focused on organizing a set of important and urgent documents in the main office building of the Fukushima Daiichi Nuclear Power Plant as a member of the accounting team.[58]

After March 2011

IAEA Experts at Fukushima Daiichi Nuclear Power Plant Unit 4, 2013

April 3, 2011

2 bodies were discovered in the basement turbine room, most likely because the workers ran there during the tsunami.

April 9, 2013

TEPCO publicly admits Radionuclide contaminated water may have leaked from the storage units, possibly contaminating the soil and water nearby. The leak was controlled and stored in containment tanks. Contaminated water continued to accumulate at the plant, and TEPCO announces plans to filter radioactive particles and discharge purified water.[59]

July 9, 2013

TEPCO officials reported that radioactive caesium was 90 times higher than it was 3 days prior (July 6), and that it may spread into the Pacific Ocean. TEPCO reported that the caesium-134 levels in the well water were measured at 9 kilobecquerel per liter, 150 times the legal level, while Caesium-137 was measured at 18 kilobecquerel per liter, 200 times the permitted level.

August 7, 2013

Japanese officials said highly radioactive water was leaking from Fukushima Daiichi into the Pacific Ocean at a rate of 300 tons (about 272 metric tons) per day. Japanese Prime Minister Shinzo Abe ordered government officials to step in.[60]

April 12, 2016

Reactors were being cooled with 300 tonnes of water each day.

September 10, 2019

Since the 3 plants were damaged by the earthquake, tsunami, and subsequent hydrogen gas explosions in 2011, TEPCO has continued to pump water onto the previously melted-down fuel cores to prevent them from once again overheating. Contaminated cooling water has collected on site, where more than 1 million tons has been stored in hundreds of tall steel tanks. Large filtration systems are used to clean the water of its radioactive contaminants, but cannot remove tritium, a radioactive isotope of hydrogen (Hydrogen-3) bonded into water molecules (tritiated water). In 2016, only 14 grams of tritium in total was estimated to be contained in 800,000 cubic meters of contaminated water stored on site.[61] As the tritium-contaminated water continued to accumulate, according to TEPCO, the immediate site will run out of space by 2022. TEPCO plans to solve this problem by releasing the contaminated water into the Pacific Ocean. This proposed measure is heavily criticised by environmental groups, local fishermen and several Asian governments, who claim that storage area is available in the extensive, contaminated exclusion zone around the reactor.[62] It is not known yet how much contaminated water will be released by TEPCO.[63]

April 13, 2021

Japan's government approved the release of treated radioactive water from the plant into the Pacific Ocean – beginning in 2023 – over the course of an estimated 40 years.[6]

July 23, 2021

A note in the 2020 Tokyo Olympic games opening speech referenced the disaster and how Japan has recovered from the disaster.

November 2, 2023

The plant begins releasing its third batch of radioactive wastewater which has been deemed treated and diluted.[64]

Dismantling of reactors

The reactors will take 30–40 years to be decommissioned.[65] On August 1, 2013, the Japanese Industry Minister Toshimitsu Motegi approved the creation of a structure to develop the technologies and processes necessary to dismantle the four reactors damaged in the

Fukushima accident.[66]

Prime Minister Yoshihide Suga inspected the Daiichi Nuclear Power Plant on September 26, 2020.

To reduce the flow of contaminated water into the Pacific Ocean, TEPCO spent ¥34.5 billion (approx. $324 million) to build a 1.5 kilometer-long underground wall of frozen soil around the plant, constructed by Kajima Corporation. 1,500 one-hundred-foot long (thirty-metre), supercooled pipes were inserted into the ground in order to freeze the surrounding groundwater and soil. The wall ultimately failed to significantly decrease the groundwater flowing into the site.[67][68]

The cost of decommissioning and decontamination of the Fukushima Daiichi nuclear power plant has been estimated at $195 billion, which includes compensation payouts to victims of the disaster. The amount also includes decommissioning of Fukushima Daiichi reactors, which is estimated at $71 billion.[69] TEPCO will shoulder $143 billion of decommissioning and decontamination, while the Ministry of Finance of Japan will provide $17 billion. Other power companies will also contribute to the cost.[69]

On September 26, 2020, Prime Minister Yoshihide Suga visited the Daiichi Nuclear Power Plant to show that his cabinet prioritized the reconstruction of areas that were affected by natural and nuclear disasters.[70]

As of 2023, the three reactors host 880 tonnes of highly radioactive melted nuclear fuel.[71]

See also

- GE Three
- List of boiling water reactors
- List of earthquakes in Japan
- List of nuclear power plants in Japan
- Nuclear power in Japan

Japan portal

Nuclear technology portal

Energy portal

2011 earthquake and tsunami accident

- Fukushima Daiichi nuclear disaster
- International reactions to the Fukushima Daiichi nuclear disaster
- Japanese reaction to Fukushima Daiichi nuclear disaster
- Radiation effects from the Fukushima Daiichi nuclear disaster

References

1. "Tepco site (Japanese). One Week Plant Grounds Course. 福島第一原子力発電所 I PR施設：構内見学コース" (https://web.archive.org/web/20110407093419/http://www.tepco.co.jp/nu/f1-np/pavilion/course1-j.html). April 7, 2011. Archived from the original (http://www.tepco.co.jp/nu/f1-np/pavilion/course1-j.html) on April 7, 2011. Retrieved October 27, 2016. "３５０万平方メートルの広い敷地に = 3.5 km^2"
2. "Tokyo Electric Power Co. Fukushima Daiichi Nuclear Power Station" (https://web.archive.org/web/20110314081817/http://www2.jnes.go.jp/atom-db/en/general/atomic/ke02a13/info_f.html). jnes.go.jp. Archived from the original (http://www2.jnes.go.jp/atom-db/en/general/atomic/ke02a13/info_f.html) on March 14, 2011. Retrieved March 17, 2011.
3. "The Asahi Shimbun" (https://web.archive.org/web/20110407215925/http://www.asahi.com/english/TKY201104060126.html). Archived from the original (http://www.asahi.com/english/TKY201104060126.html) on April 7, 2011. Retrieved February 7, 2017.
4. *The Fukushima Daiichi Accident* (https://www-pub.iaea.org/MTCD/Publications/PDF/AdditionalVolumes/P1710/Pub1710-TV1-Web.pdf) (PDF). Wienna: IAEA – International Atomic Energy Agency. 2015. pp. 131–132. ISBN 978-92-0-107015-9. Retrieved October 12, 2018.
5. Fackler, Martin (November 12, 2011). "Eyewitness Report: Inside the Wreckage of Japan's Fukushima Nuclear Plant" (https://www.telegraph.co.uk/news/worldnews/asia/japan/8886466/Eyewitness-report-inside-the-wreckage-of-Japans-Fukushima-nuclear-reactor.html). *The Daily Telegraph*. Retrieved July 27, 2019.
6. Yamaguchi, Mari, *Japan to start releasing Fukushima water into sea in 2 years (https://apnews.com/article/japan-tsunamis-tokyo-d35637331403c59bbdf61e5ee1f09dbc)*, The Associated Press, April 13, 2021
7. Dedman, Bill (March 13, 2011). "General Electric-designed reactors in Fukushima have 23 sisters in U.S" (https://web.archive.org/web/20120320141531/http://openchannel.msnbc.msn.com/_news/2011/03/13/6256121-general-electric-designed-reactors-in-fukushima-have-23-sisters-in-us). MSNBC. Archived from the original (https://openchannel.msnbc.msn.com/_news/2011/03/13/6256121-general-electric-designed-reactors-in-fukushima-have-23-sisters-in-us) on March 20, 2012. Retrieved March 14, 2011.
8. Asami, Eiichi (Kyodo News), "American's Fukushima legacy lives on (http://search.japantimes.co.jp/cgi-bin/nn20110914f2.html)", *Japan Times*, September 14, 2011, p. 3.

9. "Nuclear Reactor Maps: Fukushima-Daiichi" (https://web.archive.org/web/20130115221836/http://nuctrans.org/Nuc_Trans/locations/daiichi/daiichi.htm). Council for Security Cooperation in the Asia Pacific. Archived from the original (http://nuctrans.org/Nuc_Trans/locations/daiichi/daiichi.htm) on January 15, 2013. Retrieved March 14, 2011.
10. "Plutonium In Fuel Rods: Cause For Concern?" (https://www.npr.org/2011/03/16/134600825/plutonium-in-fuel-rods-cause-for-concern). *National Public Radio*. March 16, 2011. Retrieved March 20, 2011.
11. "Fukushima to Restart Using MOX Fuel for First Time" (http://nuclearstreet.com/nuclear_power_industry_news/b/nuclear_power_news/archive/2010/09/17/fukushima-to-restart-using-mox-fuel-for-first-time-091704.aspx). *Nuclear Street*. September 17, 2010. Retrieved March 12, 2011.
12. "Third Japanese reactor to load MOX" (https://web.archive.org/web/20110317230056/http://www.world-nuclear-news.org/newsarticle.aspx?id=28211). *World Nuclear News*. August 10, 2010. Archived from the original (http://www.world-nuclear-news.org/newsarticle.aspx?id=28211) on March 17, 2011. Retrieved March 12, 2011.
13. Brady, A. Gerald (1980). Ellingwood, Bruce (ed.). *An Investigation of the Miyagi-ken-oki, Japan, earthquake of June 12, 1978* (https://books.google.com/books?id=qEuWntnoZzYC&pg=PA123). NBS special publication. Vol. 592. United States Department of Commerce, National Bureau of Standards. p. 123.
14. "Fact Sheet on Fukushima Nuclear Power Plant" (http://www.nirs.org/reactorwatch/accidents/Fukushimafactsheet.pdf) (PDF). Nuclear Information and Resource Service. March 13, 2011. Retrieved March 13, 2011.
15. Lahey, R.T. and Moody, F.J., "The Thermal-Hydraulics of a Boiling Water Reactor", second edition, 1993.
16. Sandia National Laboratories (July 2006). "Containment Integrity Research at Sandia National Laboratories – An Overview" (https://web.archive.org/web/20110721061706/http://www.nrc.gov/reading-rm/doc-collections/nuregs/contract/cr6906/cr6906.pdf) (PDF). U.S. Nuclear Regulatory Commission. NUREG/CR-6906, SAND2006-2274P. Archived from the original (https://www.nrc.gov/reading-rm/doc-collections/nuregs/contract/cr6906/cr6906.pdf) (PDF) on July 21, 2011. Retrieved March 13, 2011. {{cite journal}}: Cite journal requires |journal= (help)
17. "Fukushima Daiichi Information Screen" (https://archive.today/20120801185152/http://www.icjt.org/npp/podrobnosti.php?drzava=14&lokacija=818). Icjt.org. Archived from the original (http://www.icjt.org/npp/podrobnosti.php?drzava=14&lokacija=818) on August 1, 2012. Retrieved March 15, 2011.
18. Yamaguchi, Mari; Donn, Jeff (March 12, 2011). "Japan quake causes emergencies at 5 nuke reactors" (https://archive.today/20110317234445/http://www.forbes.com/feeds/ap/2011/03/12/general-as-japan-quake-power-plant_8352691.html). *Forbes*. Archived from the original (https://www.forbes.com/feeds/ap/2011/03/12/general-as-japan-quake-power-plant_8352691.html) on March 17, 2011. Retrieved March 12, 2011.
19. "Nuke database system: fukushima daiichi-1" (https://web.archive.org/web/20110315080528/http://www.icjt.org/plants/uni/a/uni194a.html). ICJT Nuclear Training Centre. Archived from the original (http://www.icjt.org/plants/uni/a/uni194a.html) on March 15, 2011. Retrieved March 12, 2011.
20. "The detected acceleration at Fukushima Daiichi/Daini sites (draft)" (https://web.archive.org/web/20180725111529/https://isterre.fr/IMG/pdf/acceleration_data_tentative_estimate_.pdf) (PDF). *Institut des Sciences de la Terre*. July 25, 2018. Archived from the original (https://isterre.fr/IMG/pdf/acceleration_data_tentative_estimate_.pdf) (PDF) on July 25, 2018.
21. "Fukushima faced 14-metre tsunami" (http://www.world-nuclear-news.org/RS_Fukushima_faced_14-metre_tsunami_2303113.html). *World Nuclear News*. March 24, 2011. Retrieved March 24, 2011.
22. "Stabilisation at Fukushima Daiichi, update 2" (http://www.world-nuclear-news.org/RS_Stabilisation_at_Fukushima_Daiichi_2003111.html). *World Nuclear News*. March 20, 2011. Retrieved March 20, 2011.
23. Yoshida, Reiji, "GE plan followed with inflexibility (http://www.japantimes.co.jp/news/2011/07/14/national/ge-plan-followed-with-inflexibility)", *Japan Times*, July 14, 2011, p. 1.
24. "Fukushima plant site originally was a hill safe from tsunami" (http://search.japantimes.co.jp/cgi-bin/nn20110712x2.html). *The Japan Times*. July 13, 2011. Retrieved September 29, 2011.
25. Asahi. Tepco Withdrawal of Plans for New Construction at Fukushima Daiichi (http://www.asahi.com/business/update/0405/TKY201104050566.html). (Japanese)
26. "Nuclear Power in Japan" (https://web.archive.org/web/20120220004801/http://www.world-nuclear.org/info/inf79.html). World Nuclear Association. February 24, 2011. Archived from the original (http://www.world-nuclear.org/info/inf79.html) on February 20, 2012. Retrieved March 12, 2011.
27. "Reactors in operation" (http://www-pub.iaea.org/MTCD/publications/PDF/CNPP2010_CD/pages/AnnexII/tables/table2.htm). IAEA. December 31, 2009. Retrieved March 12, 2011.
28. "Japan: Nuclear Power Reactors" (https://web.archive.org/web/20110528122321/http://www.iaea.org/cgi-bin/db.page.pl/pris.powrea.htm?country=JP). *Power Reactor Information System – PRIS*. IAEA. Archived from the original (http://www.iaea.org/cgi-bin/db.page.pl/pris.powrea.htm?country=JP) on May 28, 2011. Retrieved March 14, 2011.
29. "Heavy fallout from Japan nuclear scandal" (https://web.archive.org/web/20110315065851/http://archives.cnn.com/2002/BUSINESS/asia/09/02/japan.tepco/index.html). CNN. September 2, 2002. Archived from the original (http://archives.cnn.com/2002/BUSINESS/asia/09/02/japan.tepco/index.html) on March 15, 2011. Retrieved March 15, 2011.
30. Cooke, Stephanie (2009). *In Mortal Hands: A Cautionary History of the Nuclear Age*. Bloomsbury Publishing. p. 388 (https://archive.org/details/inmortalhandscau00cook/page/388). ISBN 978-1-59691-617-3.
31. "Operator of Fukushima nuke plant admitted to faking repair records" (http://www.heraldsun.com.au/news/special-reports/operator-of-fukushima-nuke-plant-admitted-to-faking-repair-records/story-fn858jk3-1226024977934). *Herald Sun*. Australia. March 20, 2011. Retrieved March 20, 2011.
32. http://www.indianexpress.com/news/iaea-warned-japan-over-nuclear-quake-risk-wikileaks/763709/ IAEA warned Japan over nuclear quake risk: WikiLeaks
33. "Japan tsunami: Fukushima Fifty, the first interview" (https://www.telegraph.co.uk/news/worldnews/asia/japan/8408863/Japan-tsunami-Fukushima-Fifty-the-first-interview.html). March 27, 2011. Retrieved February 7, 2017.
34. *Mainichi Shimbun*, "TEPCO to drop plan to add two reactors at Fukushima nuclear plant", April 5, 2011.
35. Higgins, Andrew, *Washington Post*, "March 26: More reactors sought for plant?", *Japan Times*, April 7, 2011, p. 2.
36. "TEPCO will decommission Fukushima Daiichi 5&6" (http://www.neimagazine.com/news/newstepco-will-decommission-fukushima-daiichi-56-4149387). Nuclear Engineering International. December 19, 2013. Retrieved December 21, 2013.
37. Kitamura, Makiko; Shiraki, Maki (March 16, 2019). "Japan's Reactor Risk Foretold 20 Years Ago in U.S. Agency Report" (https://www.bloomberg.com/news/articles/2011-03-16/japan-s-reactor-risk-foretold-20-years-ago-in-u-s-nuclear-agency-s-report). *Bloomberg News*.
38. Adam Curtis (March 16, 2011). "A Is For Atom" (https://www.bbc.co.uk/blogs/adamcurtis/2011/03/a_is_for_atom.html). *British Broadcasting Corporation*. Retrieved May 19, 2013.

39. Ralf Streck (March 22, 2011). "Notkühlprobleme von Fukushima-Reaktoren seit 1971 bekannt" (https://web.archive.org/web/20110324155438/http://www.heise.de/tp/r4/artikel/34/34395/1.html). *Telepolis*. Heise Zeitschriften Verlag. Archived from the original (http://www.heise.de/tp/r4/artikel/34/34395/1.html) on March 24, 2011. Retrieved April 1, 2011.
40. "Japanese nuclear plant survived tsunami, offers clues" (https://www.reuters.com/article/us-japan-nuclear-tsunami-idUSTRE79J0B420111020). *Reuters*. October 20, 2011. Retrieved July 26, 2022.
41. Norihiko Shirouzu and Rebecca Smith (March 16, 2011). "Plant's Design, Safety Record Are Under Scrutiny" (https://www.wsj.com/articles/SB10001424052748704396504576204461929992144?mod=WSJ_topics_obama). *The Wall Street Journal*.
42. Ikuko Kao, Japan's TEPCO admits 1978 nuclear criticality (http://uk.reuters.com/article/japan-tepco-nuclear-idUKT16854920070322), Reuters, March 22, 2007
43. Tepco official release (Japanese).Manual shutdown during reactor startup operations in Fukushima I-1 (http://www.tepco.co.jp/cc/press/09022501-j.html). February 2, 2009.
44. Tepco official release (Japanese). Over-insertion of control rods in Fukushima I-3 (http://www.tepco.co.jp/cc/press/09032602-j.html).
45. Tepco official release (Japanese). Fukushima I-5 Automatic SCRAM Information (http://www.tepco.co.jp/cc/press/10110201-j.html).
46. Martin Fackler (June 1, 2011). "Report Finds Japan Underestimated Tsunami Danger" (https://www.nytimes.com/2011/06/02/world/asia/02japan.html). *New York Times*.
47. Black, Richard (March 15, 2011). "Reactor breach worsens prospects" (https://www.bbc.co.uk/news/science-environment-12745186). *BBC News*. Retrieved March 17, 2011.
48. Biela Liwag. "Government Scientists on Japan Nuke Meltdown "No need to worry" " (http://www.noypi.ph/index.php/nation/3295-government-scientists-on-japan-nuke-meltdown-no-need-to-worry.html). Noypi.ph. Retrieved March 14, 2011.
49. "Conditions of Fukushima Dai-ichi Nuclear Power Station Unit 2 as of 14:00 March 27, 2011" (https://web.archive.org/web/20110523050242/http://www.nisa.meti.go.jp/english/files/en20110327-2-2.pdf) (PDF). Archived from the original (http://www.nisa.meti.go.jp/english/files/en20110327-2-2.pdf) (PDF) on May 23, 2011. Retrieved February 7, 2017.
50. "Japanese Earthquake Update (19 March 2011, 4:30 UTC) : IAEA Alert Log: Fukushima Daiichi Nuclear Accident" (https://web.archive.org/web/20110607091828/http://www.iaea.org/press/?p=1463). June 7, 2011. Archived from the original (http://www.iaea.org/press/?p=1463) on June 7, 2011. Retrieved February 7, 2017.
51. Fackler, Martin (October 1, 2013). "Japan's Nuclear Refugees, Still Stuck in Limbo" (https://www.nytimes.com/2013/10/02/world/asia/japans-nuclear-refugees-still-stuck-in-limbo.html). *The New York Times*. Retrieved July 27, 2019.
52. "Anxiety in Tokyo over radiation in tap water" (https://web.archive.org/web/20110427132239/http://www.businessweek.com/ap/financialnews/D9M59PR00.htm). Archived from the original (http://www.businessweek.com/ap/financialnews/D9M59PR00.htm) on April 27, 2011.
53. "Radiation leak feared at nuke plant, people urged to stay indoors" (https://web.archive.org/web/20110316145026/http://english.kyodonews.jp/news/2011/03/78123.html). Kyodo News Agency. March 15, 2011. Archived from the original (http://english.kyodonews.jp/news/2011/03/78123.html) on March 16, 2011.
54. Martin Fackler (January 21, 2012). "Japanese Struggle to Protect Their Food Supply" (https://www.nytimes.com/2012/01/22/world/asia/wary-japanese-take-food-safety-into-their-own-hands.html). *The New York Times*.
55. Martin Fackler; Hiroko Tabuchi (October 24, 2013). "With a Plant's Tainted Water Still Flowing, No End to Environment Fears" (https://www.nytimes.com/2013/10/25/world/asia/with-a-plants-tainted-water-still-flowing-no-end-to-environmental-fears.html). *The New York Times*. Retrieved July 27, 2019.
56. "Japan Earthquake Update" (http://www.iaea.org/newscenter/news/2011/fukushimafull.html). *IAEA*. March 19, 2011.
57. "Akira Toyoshima: I want to deliver hope and courage through our performances" (https://www.paralympic.org/feature/akira-toyoshima-i-want-deliver-hope-and-courage-through-our-performances). *International Paralympic Committee*. Retrieved June 15, 2024.
58. "Wheelchair basketball star aims to lift Tohoku with gold at Tokyo Paralympics" (https://www.japantimes.co.jp/sports/2021/03/13/basketball/paralympian-akira-toyoshima-tokyo-paralympics/). *The Japan Times*. March 13, 2021. Retrieved June 15, 2024.
59. RussiaToday. [1] (http://www.dw.de/radioactive-water-leaks-from-fukushima-nuclear-plant/a-16725927).
60. Fackler, Martin (August 7, 2013). "Japan Stepping in to Help Clean Up Atomic Plant" (https://www.nytimes.com/2013/08/08/world/asia/fukushima-nuclear-plant-radiation-leaks.html). *The New York Times*. Retrieved July 27, 2019.
61. "Tritiated Water Task Force Repor" (http://www.meti.go.jp/english/earthquake/nuclear/decommissioning/pdf/20160915_01a.pdf) (PDF). Tritiated Water Task Forc.
62. Dooley, Ben; Inoue, Makiko (April 13, 2021). "Japan's Plan for Fukushima Wastewater Meets a Wall of Mistrust in Asia" (https://www.nytimes.com/2021/04/13/world/asia/japan-fukushima-nuclear-wastewater.html). *The New York Times*. ISSN 0362-4331 (https://www.worldcat.org/issn/0362-4331). Retrieved April 4, 2023.
63. "Japan will have to dump radioactive Fukushima water into Pacific, minister says" (https://www.reuters.com/article/japan-fukushima-water/japan-will-have-to-dump-radioactive-fukushima-water-into-pacific-minister-says-idUSL3N2610YV). *Reuters*. September 10, 2019.
64. Yamaguchi, Mari (November 2, 2023). "Fukushima Daiichi nuclear plant starts 3rd release of treated radioactive wastewater into the sea" (https://apnews.com/article/japan-fukushima-water-release-efe6d5b02b29622707d0a220cdb78b20). Associated Press. Retrieved June 5, 2024.
65. "Fukushima Daiichi Decommissioning Project | TEPCO" (https://web.archive.org/web/20181223030412/https://www7.tepco.co.jp/responsibility/decommissioning/index-e.html). *www7.tepco.co.jp*. Archived from the original (https://www7.tepco.co.jp/responsibility/decommissioning/index-e.html) on December 23, 2018. Retrieved December 22, 2018.
66. Fukushima : une structure dédiée aux technologies de démantèlement des réacteurs (http://www.actu-environnement.com/ae/news/fukushima-structure-technologies-demantelement-reacteurs-fukushima-combustible-fondu-19219.php4), "Actu environnement", August 2, 2013
67. Fackler, Martin (August 29, 2016). "Japan's $320 Million Gamble at Fukushima: An Underground Ice Wall" (https://www.nytimes.com/2016/08/30/science/fukushima-daiichi-nuclear-plant-cleanup-ice-wall.html). *The New York Times*. Retrieved July 27, 2019.
68. "Tepco's 'ice wall' fails to freeze Fukushima's toxic water buildup" (https://www.reuters.com/article/us-japan-disaster-nuclear-icewall/tepcos-ice-wall-fails-to-freeze-fukushimas-toxic-water-buildup-idUSKCN1GK0SY). *Reuters*. March 8, 2018. Retrieved July 2, 2020.
69. "Fukushima Daiichi Nuclear Power Plant Decommissioning" (https://www.nsenergybusiness.com/projects/fukushima-daiichi-nuclear-power-plant-decommissioning/). *NS Energy*. Retrieved June 3, 2022.

70. "PM Suga Makes 1st Fukushima Visit since Taking Office" (https://web.archive.org/web/20201111010221/https://www.nippon.com/en/news/yjj2020092600397/). *Nippon.com*. September 26, 2020. Archived from the original (https://www.nippon.com/en/news/yjj2020092600397/) on November 11, 2020.
71. "Underwater pictures from inside Fukushima nuclear reactor spark safety concerns" (https://amp.abc.net.au/article/102193676). Australian Broadcasting Corporation. April 5, 2023.

External links

- Data from Fukushima Daiichi ALPS Treated Water Discharge I IAEA (https://www.iaea.org/topics/response/fukushima-daiichi-nuclear-accident/fukushima-daiichi-alps-treated-water-discharge/tepco-data)
- Fukushima Daiichi Decommissioning Official site (https://www.tepco.co.jp/en/hd/responsibility/index-e.html)
- Archived photo (https://web.archive.org/web/20170528052410/http://www.panoramio.com/photo/46503912). Units 1–4 can be seen from left to right.
- 3D Google Earth view (http://sketchup.google.com/3dwarehouse/details?mid=f04823398eed697d3fdfd6bc6322f73b) Archived (https://web.archive.org/web/20130914204850/http://sketchup.google.com/3dwarehouse/details?mid=f04823398eed697d3fdfd6bc6322f73b) September 14, 2013, at the Wayback Machine