

## Information on the earthquake in Japan on 11 March 2011

### Compilation by GRS

as at 22 March 2011, 10:30 h (CET)

All times local time unless otherwise indicated (CET = local time minus 8 hours)

### Updated compilation of information

Changes compared with the previous state in Chapter 2 are given in Section 1. The accident sequence so far can be found in Chapter 2. A short description in tabular form of the safety-related situation can be found in Chapter 4. This also includes further specifications and supplementations of events and conditions reported over the past couple of days.

## 1 Changes compared with the previous state

### 1.1 Fukushima Daiichi

According to TEPCO, cobalt, iodine and caesium were detected in the discharge channel of Units 1 to 4 on 21-03-2011.

According to JAIF it was derived that the flood wave at the power plant had a height of 14 m, thus exceeding more than twice the design value.

#### 1.1.1 Unit 1

No change.

### **1.1.2 Unit 2**

At around 18:20 h on 21-03-2011, white smoke was rising from the partially destroyed roof of the reactor building. TEPCO reported that this was water vapour that did not, however, originate from the fuel pool.

According to JAIF, TEPCO reported that the smoke development was abating and that it was no longer visible at approx. 7:00 h on 22-03-2011.

Due to the containment damage and the damage in the electrical system, a longer period is anticipated for re-establishing emergency cooling in Unit 2.

The switchgear of Unit 2 was supplied with voltage on 20-03-2011 at 15:36 h.

### **1.1.3 Unit 3**

According to NISA, containment pressure has fallen from 320 kPa (20-03-2011, 11:00 h) by more than 160 kPa (21-03-2011, 4:00 h) to 120 kPa (21-03-2011, 12:15 h). NISA stated that on 20-03-2011 between 21:39 h and 03:58 h (21-03-2011), water was sprayed into the fuel pool.

According to a press release, grey smoke was visibly rising from Unit 3, and workers subsequently had to evacuate from the plant area temporarily (21-03-2011, 15:55 h local time). No explosion was heard. The smoke development stopped shortly after 18:00 h, with the cause of the smoke still unclear. There were no relevant changes observed in the values of RPV pressure, containment pressure, and radiation level.

The resumption of spraying with water cannons has initially been planned for Tuesday. According to NISA it is unlikely that the smoke originates from the fuel pool as radiation levels showed no significant increases. Since the electricity supply in Unit 3 has not yet been re-established, a short-circuit can be excluded as the cause of the smoke development.

The electricity supply continues to be prepared, cables have been laid, but further preparations were postponed due to the smoke development in Unit 3.

According to French information, the number of fuel assemblies in Unit 3 is 1500 fuel assemblies instead of 1331 fuel assemblies as was thought so far. This difference may be due to approx. fresh 200 fuel assemblies that had not been counted before.

According to information by JAIF of 22-03-2011, 16:00 h, spraying with water cannon was resumed for 1 hour at 15:50 h. The total time of spraying is thus approx. 20 hours.

TEPCO judges the change in the colour of the smoke from grey to white as positive.

#### **1.1.4 Unit 4**

According to NISA, water was sprayed by 13 water cannons into the fuel pool on 21-03-2011 between 06:37 h and 08:41 h.

The electric power supply of the unit continues to be prepared, cables have been laid (approx. 15:00 h, 21-03-2011), but further preparations were postponed due to the smoke development in Unit 3.

#### **1.1.5 Units 5 and 6**

The electricity supply of Unit 5 was switched over via transformers to external electricity supply at 11:36 h on 21-03-2011.

#### **1.1.6 Interim storage facility at the Fukushima Daiichi site**

Cooling of the jointly used interim storage facility by means of water cannon was begun on 21-03-2011 at around 10:37 h.

### **1.2 Fukushima Daini**

No changes in these units.

### **1.3 Onagawa 1-3 and Tokai**

No changes in these units.

## **1.4 Radiological situation**

In the early morning of 22-03-2011, a renewed increase in the local dose rate is measured in the Ibaraki prefecture.

Updated versions of the Figures showing the local dose rates at the Fukushima Daiichi and Fukushima Daini sites and of the survey of the local dose rates measured in the wider surroundings can be found at the end of this report.

## **2 Summary of the plant situation so far**

On 11-03-2011 at 14:46h (6:46 CET), an earthquake struck Japan. This earthquake and the subsequent tsunami also affected the nuclear power plant sites Fukushima I (Daiichi), Fukushima II (Daini), Onagawa and Tokai.

### **2.1 Fukushima Daiichi**

At this site, Units 1-3 were in power operation mode at the time of the onset of the accident. Units 4-6 were shut down when the event set in. At the site, the emergency diesel generators failed as a consequence of the tsunami. Mobile emergency diesel generators were taken to the plant.

Due to the high levels of radiation, the plant was evacuated completely on 16-03-2011 at 10:45 h (2:45 h CET). It is only entered to carry out important measures or record measurements (government press conference at 12:00 h (4:00 h CET)). The local dose rate at the main gate lies within a range of 2.5 – 6.5 mSv/h. In the meantime, part of the personnel has returned as radiation levels have fallen.

NISA reports that TEPCO wants to establish the electricity supply from power lines in the vicinity. Power to these lines is provided by Tohoku Electric Power. A corresponding connection was to be established by the afternoon of 17-03-2011. The exact status of the re-establishment of the electricity supply is presently not known. According to NHK it is intended to repair the auxiliary service water pumps. According to TEPCO (quoted by ASAHI), however, it is not yet guaranteed that the emergency cooling system will work again when the electricity supply is re-established.

### 2.1.1 Unit 1

Pressure inside the containment of Unit 1 rose during the course of 12-03-2011. Filtered containment venting was carried out as from 14:30 h on 12-03-2011. A hydrogen explosion occurred inside the reactor building, but outside the containment, at 15:36 h on 12-03-2011.

Borated sea water was pumped into the reactor pressure vessel (it remains unclear whether the containment was flooded as well). Injection was begun on 12-03-2011 at 20:20 h.

On 13-03-2011 at 11:13 h, the Kyodo news agency reported that the authority suspected a leak in Unit 1.

Government spokesman Edano said that there may have been a core meltdown. According to TBS (Japanese TV station), approx. 70 % of the fuel assemblies are damaged. The number of damaged fuel assemblies is said to have risen from 43% to 70% (source: German Federal Foreign Office, 16-03-2011). According to information of 16-03-2011, the fuel rods inside the reactor pressure vessel are uncovered along 1.8 metres of their length (17:00 h).

The IAEA states that electricity supply by mobile generators is ensured and that the injection of sea water is continuing.

For up-to-date information on physical values such as pressure and temperature, see the Table in Chapter 4.

According to JAIF (Japan Atomic Industrial Forum), as at 9:00 h on 17-03-2011, there is no information about the integrity of the fuel assemblies in the fuel pool of Unit 1.

The cables to the switchgear of Unit 1 and Unit 2 have been connected (report by JAIF, 22:00 h, 20-03-2011).

#### ***INES classification by the authority***

Due to the release to the outside of the plant, on 12-03-2011 the authority provisionally classified the event in Unit 1 as INES 4. This INES classification was revised upwards to INES 5 on 18-03-2011.

### 2.1.2 Unit 2

The coolant level in the reactor pressure vessel of Unit 2 was below the normal level until 14-03-2011. Initially, it did not drop any further. Injection was by means of an emergency cooling system. It was reported by NISA that on 13-03-2011 at 11:55 local time, the electrical power supply was secured (according to the IAEA via mobile generators) and that injection into the reactor was maintained.

On 14-03-2011 at 13:25 h, cooling in Unit 2 failed. For some time, cooling was re-established with sea water. The fuel assemblies were temporarily not covered by water. On 14-03-2011 at about 20:00 h, containment pressure rose to approx. 4.15 bar (corresponds to about design pressure). At 20:37 h, containment venting was begun. According to TEPCO an opening was made in the reactor building to prevent an explosion of the hydrogen in the reactor building.

On 15-3-2011 at 06:20 h, an explosion occurred in Unit 2. According to the IAEA, up to 400 mSv/h were measured on the plant premises. JAIF reports 30 mSv/h between Units 2 and 3, 400 mSv/h next to Unit 3 and 100 mSv/h next to Unit 4. According to press reports, the assumption – based on the fact that containment pressure is falling - is that the pressure suppression pool is damaged.

According to Kyodo, TEPCO says that approx. 33% of the fuel assemblies are damaged. NISA assumes that the high levels of radiation measured since approx. 10:00 h originate from Unit 2. However, it may also be that there is a link between the high radiation levels and the vapour plume emanating from Unit 3.

The fuel rods inside the reactor pressure vessel are uncovered along approx. 1.4 metres of their length.

According to information by NISA of 18-03-2011, 6:00 h, the injection of sea water into the reactor pressure vessel via the fire extinguishing system is being continued. There is white steam rising from the reactor building.

For up-to-date information on physical values such as pressure and temperature, see the Table in Chapter 4.

According to JAIF (Japan Atomic Industrial Forum), as at 10:00 h on 19-03-2011, there is no information about the integrity of the fuel assemblies in the fuel pool of Unit 2.

Information by TEPCO on 19-03-2011, 9:00 h: an external electricity supply via a standby grid transformer has been established. At present, cables are being routed to an auxiliary switchgear system.

Sea water injection into the fuel pool was started on 20-03-2011 at 15:05 h. The cables to the switchgear of Unit 1 and Unit 2 have been connected (report by JAIF, 22:00 h, 20-03-2011).

At around 18:20 h on 21-03-2011, white smoke was rising from the partially destroyed roof of the reactor building. TEPCO reported that this was water vapour that did not, however, originate from the fuel pool.

Due to the containment damage and the damage in the electrical system, a longer period is planned for re-establishing emergency cooling in Unit 2.

The switchgear of Unit 2 was supplied with voltage on 20-03-2011 at 15:36 h.

### ***INES classification by the authority***

The event in Unit 2 had been provisionally classified by the authority as INES 3 on 12-03-2011. The classification was revised upwards to INES 5 on 18-03-2011.

### **2.1.3 Unit 3**

In Unit 3, the emergency cooling system failed on 13-03-2011 at around 5:30 h. There followed a depressurisation of the reactor pressure vessel, and borated water was pumped into the reactor from 13:12 h onwards on 13-03-2011. Sea water was injected with the help of fire extinguishing pumps. Containment venting was carried out.

On 14-03-2011 at 11:00 a hydrogen explosion occurred in Unit 3. According to IAEA information, the containment was not damaged. According to TEPCO, containment pressure is stable.

According to NHK, a plume of vapour is said to have been visible above Unit 3 since 8:30 h on 16-03-2011. According to NISA, it is assumed that the containment is damaged after all. Therefore the personnel from the common main control room of Units 3 and 4 were evacuated on 16-03-2011 at 10:45 h. At 11:30 h, the operating personnel returned to resume the injection of water.

On 16-03-2011, the fuel rods inside the reactor pressure vessel are uncovered along approx. 2.30 metres of their length. According to information by NISA of 18-03-2011, 6:00 h, the injection of sea water into the reactor pressure vessel via the fire extinguishing system is being continued.

For up-to-date information on physical values such as pressure and temperature, see the Table in Chapter 4.

The water level in the fuel pool of Unit 3 is low (JAIF, 17-03-2011, 9:00 h). The water level in the fuel pool is dropping (TEPCO at 18:00 h).

It was tried on 16-03-2011 to pour water from a helicopter into the fuel pool. This measure was abandoned without success due to the high activity levels in the surroundings. The military has begun to fill water into the fuel pool by means of five water cannon. NHK reported on 17-03-2011 that according to NISA, 30 t of water had been added to the fuel pool by the military water cannon. Regarding the use of water cannon, the authority NISA states that on 18-03-2011, 6 water cannon from the army sprayed a total of approx. 50 t of water on Unit 4 at around 14:00 h. Also, a US army water cannon was used until 14:45h. It was concluded from the water vapour that became visible that the water had reached the fuel pool.

According to NISA, containment pressure increased on 20-03-2011 to 320 kPa. Measures to reduce pressure were successful. Renewed containment venting was not necessary.

According to NISA, containment pressure has fallen from 320 kPa (20-03-2011, 11:00 h) by more than 160 kPa (21-03-2011, 4:00 h) to 120 kPa (21-03-2011, 12:15 h). NISA stated that on 20-03-2011 between 21:39 h and 03:58 h (21-03-2011), water was sprayed into the fuel pool.

According to a press release, grey smoke was visibly rising from Unit 3, and workers subsequently had to evacuate from the plant area temporarily (21-03-2011, 15:55 h local time). No explosion was heard. The smoke development stopped shortly after 18:00 h, with the cause of the smoke still unclear. There were no relevant changes observed in the values of RPV pressure, containment pressure, and radiation level.

The resumption of spraying with water cannon has initially been planned for Tuesday. According to NISA it is unlikely that the smoke originates from the fuel pool as radiation levels showed not large increase. Since the electricity supply in Unit 3 has not yet been re-established, a short-circuit can be excluded as the cause of the smoke development.

The electricity supply continues to be prepared, cables have been laid, but further preparations were postponed due to the smoke development in Unit 3.

According to French information, the number of fuel assemblies in Unit 3 is 1500 fuel assemblies instead of the 1331 fuel assemblies so far. This difference may be due to approx. fresh 200 fuel assemblies that have so far not been counted.

According to information by JAIF of 22-03-2011, 16:00 h, spraying with water cannon was resumed for 1 hour at 15:50 h. The total time of spraying is thus approx. 20 hours.

### ***INES classification by the authority***

The event in Unit 3 was classified by the authority on 18-03-2011 as INES 5.

#### **2.1.4 Block 4**

The reactor core had been completely unloaded into the fuel pool during the refuelling outage. There are thus no fuel assemblies inside the RPV.

In Unit 4, there were a fire and an explosion in the reactor building in the area of the fuel pool on 15-03-2011 at around 6:00 h. The IAEA confirmed that the fire was extinguished at about 11:14 h. The fire/explosion created two holes in the reactor building, both approx. 8 m<sup>2</sup> wide. According to TEPCO (as reported in media reports) and NISA, another fire broke out in the area of the fuel pool at about 5:45 h (16-03-2011). In this connection, the roof of the reactor building was also severely damaged. The TV station NHK reported that following attempts to extinguish the fire, no flames were visible any

more. Media reports say that two workers have been missing since the fire broke out. On a photo of Unit 4 published by TEPCO, a hole in the outer wall of the reactor building is visible, measuring approx. 8 m<sup>2</sup>. The outer shell of the reactor building facing Unit 3 is damaged severely, also near the ground. The roof of the reactor hall is damaged. According to JAIF (12:30 h), the reactor building is also damaged.



Photo of the Fukushima Daiichi plant, Units 1-4 (from right to left), of 16-03-2011

The fuel assemblies in the fuel pool are presumably damaged. According to media information of 16-03-11, 19:00 h CET, the water in the fuel pool is boiling. The fuel pool is to be injected with the help of fire fighting equipment (fire engine). Police water cannon has arrived at the site but cannot be used yet as rubble first has to be cleared.

Water injection was stopped on 16-03-2011 at 14:00 h (NISA). At this point in time, the IAEA gives no details about the water temperature in the fuel pool (last information had been on 15-03-2011 at 19:00 h).

According to JAIF (Japan Atomic Industrial Forum), as at 9:00 h on 17-03-2011, the water level in the fuel pool of Unit 4 is low. According to Jiji, TEPCO reports at 18:00 h that the fuel assemblies in the fuel pool are partly covered by water.

Data by IAEA on water temperature in the fuel pool (normal levels below 25 °C):

14-03-2011, 19:08 h: 84 °C  
15-03-2011, 19:00 h: 84 °C  
16-03-2011, 14:00 h: no data  
19-03-2011, 10:00 h: no data

According to NISA, water was sprayed by 13 water cannon into the fuel pool on 21-03-2011 between 06:37 h and 08:41 h.

The electric power supply of the unit continues to be prepared, cables have been laid (approx. 15:00 h, 21-03-2011), but further preparations were postponed due to the smoke development in Unit 3.

### ***INES classification by the authority***

The event in Unit 4 was classified by the authority on 18-03-2011 as INES 3.

### **2.1.5 Units 5 and 6**

The IAEA reports about Unit 5 that on 15-03-2011 at 21:00 h (13:00 h CET), the water level in the fuel pool has dropped to 201 cm above the fuel assemblies. This was a drop of 40 cm since 16:00 h (8:00 h CET). It is planned to use an available emergency diesel generator from Unit 6 for water injection.

According to JAIF (8:00 h, 16-3-2011), the water level in the fuel pools of both units is sinking. At 14:00 h, TEPCO reports a fuel pool temperature of approx. 60 °C in both units. The fuel pool temperature is rising.

Further sources say on 16-03-2011 that venting of the reactor building is under preparation to prevent a hydrogen explosion.

On 17-03-2011, 17:30 h, NISA said that in the meantime an emergency diesel generator in Unit was supplying the electricity for injecting water into the fuel pools of Units 5 and 6. Water injection is carried out by the condensate purification system. Once the external grid connection has been re-established, injection into the RPV is to be resumed.

By 19-03-2011, three openings each were made into the roofs of the reactor buildings of Units 5 and 6 to prevent a hydrogen accumulation.

On 19-03-2011 at 04:22 h, a second emergency diesel of Unit 6 became available after repairs. This meant that it was possible to use the residual-heat removal system of Unit 5 from 19-03-2011, 5:00 h onwards and the residual-heat removal system of Unit 6 from 22:00 h onwards for cooling the fuel pools of the two plants.

"Subcritical cold" condition was reached for Unit 5 on 20-03-2011 at 14:30 h and for Unit 6 on 20-03-2011 at 19:27 h.

Fool pool temperatures on 20-03-2011 at 16:00 h were 35.1 °C in Unit 5 and 28.0 °C in Unit 6. Fool pool temperatures on 21-03-2011 at 5:00 h were 39.5 °C for Unit 5 and 32.0 °C for Unit 6.

The electricity supply of Unit 5 was switched over via transformers to external electricity supply at 11:36 h on 21-03-2011.

Data by IAEA/JAIF on water temperature in the fuel pool of Unit 5 (normal levels below 25 °C):

14-03-2011, 19:08 h: 59.7 °C  
15-03-2011, 19:00 h: 60.4 °C  
16-03-2011, 14:00 h: 62.7 °C  
17-03-2011, 3:00 h: 64.2°C  
17-03-2011, 18:00 h: 65.5°C  
19-03-2011, 6:00 h: 68.8 °C  
20-03-2011, 16:00 h: 35,1 °C  
21-03-2011, 5:00 h: 39.5 °C

Data by IAEA/JAIF on water temperature in the fuel pool of Unit 6 (normal levels below 25 °C):

14-03-2011, 19:08 h: 58.0 °C  
15-03-2011, 19:00 h: 58.5 °C  
16-03-2011, 14:00 h: 60.0 °C  
17-03-2011, 3:00 h: 62.5°C

17-03-2011, 18:00 h: 62.0°C  
19-03-2011, 6:00 h: 66.5 °C  
20-03-2011, 16:00 h: 28,0 °C  
21-03-2011, 5:00 h: 32.0 °C

For up-to-date information on physical values such as pressure and temperature, see the Table in Chapter 4.

### **2.1.6 Interim storage facility at the Fukushima Daiichi site**

IRSN (Institut de Radioprotection et the Sûreté Nucléaire) estimates that there are approx. 6000 fuel assemblies in the interim storage facility pool. The radioactive material of these fuel assemblies there has been decaying for longer than that of the fuel assemblies in the fuel pools of the 6 units and therefore produces less decay heat. There is no information available about the cooling status.

As at 18-03-2011, 6:00 h CET, NISA states that the interim storage pool is completely filled with water. TEPCO confirms on 18-03-2011, 10:00 h that the water level in the interim storage pool is ensured. The interim storage pool is yet to be closely inspected.

The dry-storage facility was subjected to a visual inspection on 17-03-2011. This revealed no deviations from normal conditions. An inspection of the dry-storage facility is being prepared.

NISA reports that the water temperature in the interim storage pool is 55 °C (as at: 18-03-2011, 11:19 h).

Cooling of the jointly used interim storage facility by means of water cannon was begun on 21-03-2011 at around 10:37 h.

## **2.2 Fukushima Daini**

A small fire in the auxiliary building of Unit 1 was extinguished within 2 hours (source: European Clearinghouse).

Initially, residual-heat removal from the pressure suppression pools of Units 1, 2 and 4 was not possible. In Units 1, 2 and 4, the pressure suppression pool temperature of 100°C was exceeded. There is no such information about Unit 3. There are reports that Unit 3 reached a cold subcritical condition on 12-03-2011.

Coolant levels in the reactor pressure vessels of the four units did not drop. Electricity supply from an external grid is available in these units.

According to TEPCO, containment venting was being prepared for all 4 units. It was, however, not carried out.

Following repairs of the auxiliary service water pumps that had been inundated by sea water, all units reached cold subcritical conditions on 14-3-2011.

According to information by the operator, the residual-heat removal system was turned off for approx. 1 hour on 15-03-2011. It was subsequently made operational again.

### ***INES classification by the authority***

The event in Unit 1 was classified on 12-03-2011 as INES 3.

The event in Unit 2 was classified on 18-03-2011 as INES 3.

The event in Unit 4 was classified by the authority on 18-03-2011 as INES 3.

## **2.3 Onagawa and Tokai**

According to current information, the Onagawa and Tokai sites have no acute safety-related problems. At the Onagawa plant, a fire in the turbine building was detected and extinguished. All three units at Onagawa are in shutdown condition and cold. The plant is currently being inspected.

According to media reports, two diesel generators failed at the Tokai plant, with one diesel generator remaining operable. Of two pumps provided for cooling, one was not available. TEPCO (17-03-2011, 16:00 h) reports that an external grid supply was established on 13-03-2011. Core cooling has been in operation since then.

### 3 Radiological situation

#### 3.1 Radiological situation at the Daiichi and Daini sites

On 12-03-2011 between 04:00 h and 04:40 h, the operator and the supervisory authority NISA reported an increase of the local dose rate in two locations near the plant gate of Daiichi from background values (approx. 70 nSv/h) to initially more than 10 times this level (approx. 0.9  $\mu$ Sv/h at 04:40 h) and to up to about 5  $\mu$ Sv/h at approx. 06:30 h. This increase could possibly be related to the beginning of containment venting at that point in time, although there is no corresponding confirmation.

According to further information by NISA, the local dose rate readings in the vicinity of Unit 1 of the Fukushima Daiichi plant increased during the course of containment venting until the explosion in the reactor building at 15:36 h (Japan local time) on 12-03-2011 to about 1000  $\mu$ Sv/h. Within approx. three hours after the explosion, the local dose rate readings in the vicinity of the plant dropped to ~70  $\mu$ Sv/h. According to the authority (quoted by the Kyodo news agency), local dose rates of more than 1200  $\mu$ Sv/h were measured again in the vicinity of Unit 1 at 11:13 h on 13-03-2011. At around 14:00 h, TEPCO recorded an increase of the measured values to up to 900  $\mu$ Sv/h. After that, the values dropped again to below 100  $\mu$ Sv/h. On 15-03-2011 at 10:20 h, local dose rates of 400000  $\mu$ Sv/h were measured in the vicinity of Unit 3, 100000  $\mu$ Sv/h in the vicinity of Unit 4, and 30000  $\mu$ Sv/h between Units 2 and 3.

Figure 1 shows the local dose rate measurements at the Fukushima I (Daiichi) site in different measuring locations for the period between 12-03-2011, 10:00 h and 21-03-2011, 21:00 h, most recently for the "main gate" measuring location.

The measured values show generally unsteady distributions with values between 60 nSv/h (background radiation) up to about 12000  $\mu$ Sv/h. Some of the maximum values can be correlated to confirmed measures at the plant (e.g. venting), especially the venting at Unit 2 on 14-03-2011 between 21:20 h and 23:00 h and the fire in the fuel pool in Unit 4 on 15-03-2011. The data relating to the fire affecting the fuel pool show an exponential decrease. This could be caused by short-lived radioactive materials deposited on the ground.

According to information by the operator, the measuring location MP 1 was shifted to the position of MP 2 on 13-03-2010 at around 20:10 h. This is near Unit 1. In this loca-

tion, values between 400 and 500  $\mu\text{Sv/h}$  are measured. Since 14-03-2011, approx. 15:30 h, there have been no data from measuring locations MP3 and MP4. The local dose rates communicated by the authority (NISA) at the time of the explosion in Unit 1 are not contained in the data provided by the operator. On 15-03-2011 after approx. 6:20 h, the values measured at the measuring location at the main gate rise up to a maximum of approx. 12000  $\mu\text{Sv/h}$  at around 09:00 h. This rise is presumably linked to the fire in the fuel pool of Unit 4. The values drop again after 09:00 h. This decrease continues until 18:00 h, when a level of approx. 450  $\mu\text{Sv/h}$  is reached. The data provided by the operator for the measuring location at the main gate show renewed increases around 23:00 h to up to 8000  $\mu\text{Sv/h}$  at 23:00 h (15-03-2011) and around 11:00 h (16-03-2011), with a maximum of 10850  $\mu\text{Sv/h}$  at 12:30. The local dose rate decreases until 16-03-2011 15:50 h; further statements on the development of the local dose rate at the main gate are not possible due to the lack of data until 17-03-2011, 10:50 h. For the two communicated values on 17-03-2011 at 11:00 h and 11:10 h, the local dose rate is about 650  $\mu\text{Sv}$ .

Readings on 18-03-2011 at the "west gate" measuring location show constant local dose rate levels of up to about 260  $\mu\text{Sv/h}$  in the morning and in the evening between 20:10 h and 23:30 h within a range of 370 - 450  $\mu\text{Sv/h}$ . On 19-03-2011 between 08:00 h and 10:00 h, two short-term increases are noticeable to approx. 830  $\mu\text{Sv/h}$  and 660  $\mu\text{Sv/h}$ . By 11:30 h, the values have gone down to about 315  $\mu\text{Sv/h}$ . For the "main gate" measuring location, the data available for the period between 13:50 h (18-03-2011) and 1:40 h (19-03-2011) show a rise from about 3400  $\mu\text{Sv/h}$  to about 5000  $\mu\text{Sv/h}$ , dropping again later to 3200  $\mu\text{Sv/h}$ . The available data for 19-03-2011 as from 11:40 h start with an again increased value of about 4000  $\mu\text{Sv/h}$ , followed by a drop to about 2800  $\mu\text{Sv/h}$ . Reasons for the temporary increases at the two measuring locations are presently not known.

On 20-03-2011 and until the afternoon of 21-03-2011, readings from the Daiichi site were only available from the main gate and individually from the west gate. Since approx. 13:00 h on 20-03-2011, a rise of the local dose rate at the central building from approx. 2600  $\mu\text{Sv/h}$  to about 3300  $\mu\text{Sv/h}$  so far has been recorded, with a subsequent decrease in the dose rate down to values of around 2000  $\mu\text{Sv/h}$  at 16:30 h on 20-03-2011.

Apart from a measured value of about 1300  $\mu\text{Sv/h}$  for measuring location MP 7, which was not contained in the data available so far, readings as from 16:42 h on 21-03-2011

are only available from the main gate. With a first measured value of 1100  $\mu\text{Sv/h}$ , the local dose rate has changed by 17:40 h to about 500  $\mu\text{Sv/h}$ , followed by a renewed rise, with a maximum of about 1900  $\mu\text{Sv/h}$  at 18:30 h and a subsequent drop to values around 400  $\mu\text{Sv/h}$  at 21:00 h.

The fall in the local dose rate at the main gate also continued during the course of 22-03-2011 until approx. 13:00 h to about 260  $\mu\text{Sv/h}$ .

NISA has confirmed that caesium-137 and iodine-131 were detected in the vicinity of Unit 1 of the Fukushima Daiichi plant. GRS assumes that radioactive materials were released into the containment and were mainly retained there. The operator, too, confirmed in a press release on 18-03-2011 that radioactive materials (e.g. iodine) had been measured within the plant premises and that the measured activity levels were exceeding natural background radiation levels with time. Furthermore, caesium-137 and iodine-131 have in the meantime been measured as surface contamination in various different prefectures.

On 17-03-2011 at approx. 10:00 h, local dose rate measurements were carried out by a helicopter flying over the plant. At a height of about 300 m above ground (240 m above the roof level of the reactor units), a local dose rate of 4.13 mSv/h was measured; at approx. 100 m height above ground (40 m above roof level), the local dose rate was 87.7 mSv/h. The readings correlate with the hypothesis that the local dose rate is caused by the direct radiation emanating from the uncovered nuclear material. According to up-to-date media information, on 17-03-2011, there were four helicopters flight over the site at a height of less than 100 m above ground. Also on 17-03-2011 at around 10:00 h, the operator said that local dose rates of 400 mSv/h were measured on the landward side of Unit 3 and 100 mSv/h on the landward side of Unit 4. More recent measured values are not available at the moment.

At the Daini site, local dose rate measurements are available from 13-03-2011 in the morning until 21-03-2011, 21:00 h and are shown in Figure 2. Here, on 14-03-2011 from 22:00 h onwards, measuring location MP 4 records a rise of up to approx. 920  $\mu\text{Sv/h}$  at 03:10 h and 03:50 h on 15-03-2011, with a subsequent fall to levels of around 10  $\mu\text{Sv/h}$  until 18:00 h. The measured values of this peak between 03:10 h and 03:50 h were later (16-03-2011) revised downwards by the operator to approx. 92  $\mu\text{Sv/h}$ .

Since 16-03-2011 at around 02:10 h, a renewed rise has been recorded, with a maximum of 39  $\mu\text{Sv/h}$  at 02:20 h, followed by a fall to 18  $\mu\text{Sv/h}$  at 09:00 h and a renewed maximum of 31  $\mu\text{Sv/h}$  at 11:10 h. The increased values are presumably linked to a transport of radioactive materials from Daiichi. On 20-03-2011, 19:00 h, the values lie again at around 11  $\mu\text{Sv/h}$ , following a short increase at 5:50 h to approx. 19  $\mu\text{Sv/h}$ . During the morning of 21-03-2011, the values increase again for a short while to approx. 28  $\mu\text{Sv/h}$  and subsequently fall during the further course again to around 12  $\mu\text{Sv/h}$  by 12:00 h on 22-03-2011.

### **3.2 Radiological situation in the vicinity**

There are different measured values available in the Fukushima prefecture. According to the "Disaster Provision Main Office", the values measured in the afternoon on 21-03-2011 lie between 0.5 and 11.5  $\mu\text{Sv/h}$ . Three values measured in the north-west on the border of the 30-km zone showed figures of between 45 and 110  $\mu\text{Sv/h}$  in the afternoon of 20-03-2011; in these measuring locations, values of up to 170  $\mu\text{Sv/h}$  had been measured on 17-03-2011.

In the neighbouring prefecture of Ibaraki, the national local dose rate measuring network registered increased local dose rate levels, presumably caused by the radioactive materials that deposited with the emissions on 15-03-2011 and 16-03-2011. Following a decrease in the local dose rate over the past couple of days, the dose values for the monitored measuring locations (Fig. 3) lie between 0.1  $\mu\text{Sv/h}$  and 0,6  $\mu\text{Sv/h}$  on 20-03-2011, 0:00 h. On 20-03-2011 between 11:00 h and 12:00 h, a rise in the local dose rate can be observed, followed by a renewed drop. In Horiguchi Hitachinaka City, the value was around 900 nSv/h. During the morning of 21-03-2011, the measured values increase markedly again with the arrival of an area of precipitation. Maximum levels that were reached were almost 3  $\mu\text{Sv/h}$  at the Momiyama Hokuta City station, about 140 km south of Fukushima Daiichi. Since approx. 10:00 h, the values at this station have been lying between 1100 nSv/h and 1150 nSv/h. The increase in the local dose rate in connection with the precipitation has been measurable as far away as in the Kanagawa prefecture to the south of Tokyo, most recently with values around 0.175  $\mu\text{Sv/h}$ .

In the early morning of 22-03-2011, a renewed rise in the local dose rate is measurable in the Ibaraki prefecture, with the following peaks: Onuma Hitachi approx. 1  $\mu\text{Sv/h}$  at around 7:00 h, in Horiguchi Hitachinaka 1.1  $\mu\text{Sv/h}$  at around 8:30 h, and in Momiya-

ma Hokota 1.3  $\mu\text{Sv/h}$  at around 15:50 h. These measured values are presently remaining constant or are dropping slightly.

Figure 3 shows a survey of the local dose rate measurements from different prefectures of the island of Honshu. Outside the provinces already mentioned, current readings are at background level. However, GRS disposes of no data from the Miyagi prefecture, which lies to the north of Fukushima and has been particularly heavily affected by the earthquake.

### **3.3 Meteorological situation**

According to the German Meteorological Service, a flow situation characterised by the passage of a weak low-pressure area with its centre to the southeast of the Japanese coast prevailed during the first half of the day of 15-03-2011, transporting the radioactive materials released with low winds in south-westerly direction along the coast. During the second half of the day, weather stations reported dominating weak circulating winds. During the night from 15-03-2011 to 16-03-2011, the wind freshened from north-easterly direction, so that at that time there was again a transport of the airborne materials released at the Fukushima site in easterly direction. Measuring data from the Ibaraki prefecture bordering on Fukushima in the south showed prevailing northerly to north-westerly winds until the afternoon of 17-03-2011, with wind speeds of between 3 and 7 m/s. On 18-03-2011, the stations of this region showed either weak winds from north-easterly directions or a somewhat stronger flow from south- to south-westerly directions. These observations also confirm reports by the German Meteorological Service. With the temporary change to southerly directions, a transport of potential releases from the plant into northern parts of the country was possible.

On 19-03-2011, high pressure was predominating in the region, with a general weak westerly flow that is apparently overlaid by local circulation patterns. For example, weather stations in the Ibaraki prefecture showed predominating wind directions around north-west with low wind speeds, which might be linked to the formation of an offshore-onshore circulation at night.

During the course of 20-03-2011, with the formation of a trough of low pressure, the wind directions predominating over Japan changed to north to north-east. Combined with an oscillating flow, a large area of precipitation passed over Honsho, reaching initially the south-westerly prefectures and in the early hours of the morning of 21-03-

2011 also the Fukushima and Ibaraki prefectures. In the afternoon, precipitation in these regions already abated.

For 22-03-2011 it is expected that due to the influence of high pressure from the west, the wind near the ground will change to north-westerly directions. Any radioactive particles will then be transported in the direction of the Pacific. It is expected that in the coming days the wind will change to south-west with a further trough of low pressure, meaning that radioactive particles would continue be transported in the direction of the Pacific.

### **3.4 Measures taken**

Within the evacuation radius of Daiichi (20 km) and of Daini (10 km), a total of 210,000 people have been evacuated.

Within a radius of 30 km around the Daiichi evacuation zone, the population was recommended to stay indoors. Also, according to the IAEA, a no-fly area was established in a radius of 30 km around the plant. The IAEA states furthermore that the Japanese coast guard ordered coastal waters to be cleared within a radius of 10 km around Daiichi and 3 km around Daini. According to the latest information, the zones up to 20 km were evacuated; for the wider 30-km zone, the population was instructed to stay indoors.

As a further measure, the local authorities were recommended on 16-03-2011 to instruct people coming from the 20-km evacuation zone to take iodine tablets with stable iodine in order to block the uptake of radioactive iodine.

### **3.5 Foodstuffs**

According to IAEA report of 19-03-2011, Japanese authorities measured radioactive iodine in foodstuffs (milk) in the Fukushima prefecture around the Daiichi plant and in vegetables in Ibaraki. The measurements were performed between 16 and 18-03-2011. Limit values were found to have been transgressed. In the raw milk dairy products up to 1510 Bq/kg were measured on 16-03-2011, which is five times the Japanese limit for putting such products into circulation. A ban on selling contaminated products was issued.

Furthermore, according to media reports of 20-03-2011 quoting the government spokesman, spinach contaminated with caesium-137 and iodine-131 above the permissible limits of 500 and 2000 Bq/kg, respectively, was found in the town of Hitachi in Ibaraki prefecture. Also, milk contaminated with iodine was found in a town 35 km to the north-west of Fukushima Daiichi. There have also been reports about contaminated drinking water in 4 towns, lying at 1- 2 % of the permissible limits.

Available data of 20-03-2011 that do, however, not consider the Miyagi and Fukushima provinces, show iodine-131 contamination in drinking water in nine provinces and caesium-137 contamination in drinking water in three provinces. For the Ibaraki province, the iodine-131 contamination is 3 - 4 % of the permissible value. In the Fukushima prefecture, media reports of 20-03-2011 say that maximum values of 10 % of the permissible value were measured. According to the Ministry of Health, one value above the permissible value was recorded on 19-03-2011.

According to media reports, the government has instructed the prefectures of Fukushima, Ibaraki, Tochigi and Gunma not to take any raw milk, spinach and another leaf vegetable (Kakina) out of the prefectures following the detection of individual samples that were contaminated with radioactive substances at levels above the permissible limit. According to a statement by government spokesman Edano on 20-03-2011, a report on the analysis of foodstuffs is being prepared that is to be published by the Ministry of Health later on 20-03-2011, but is not yet available to GRS.

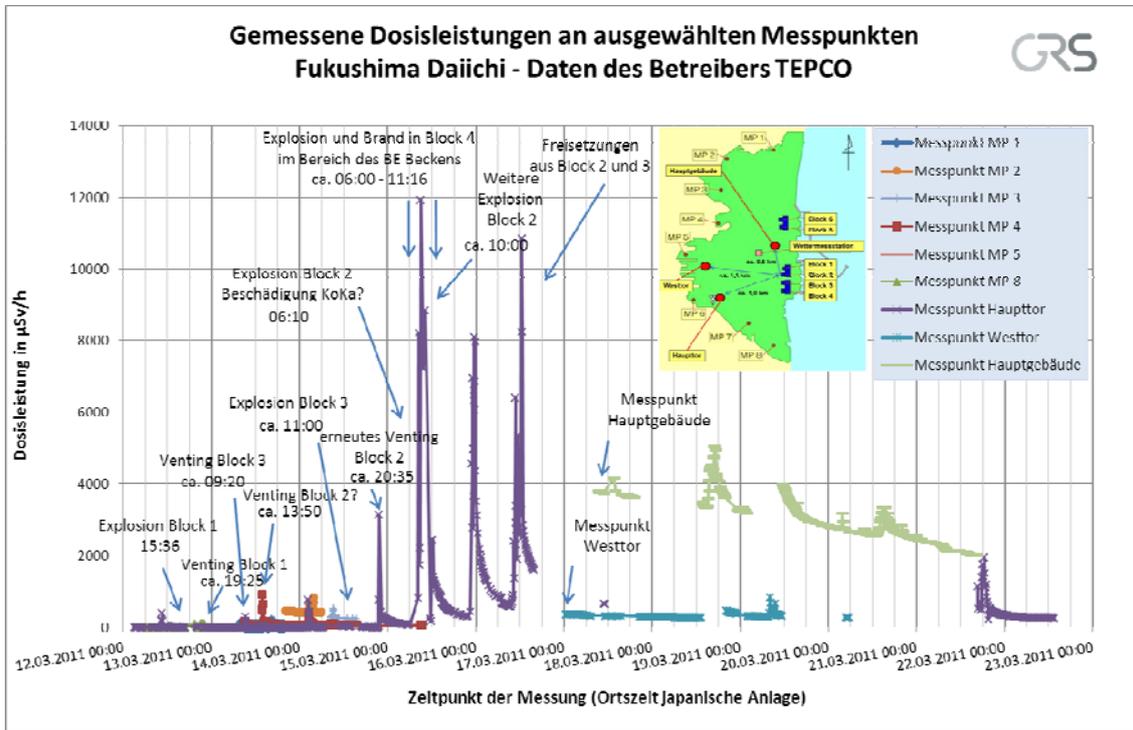


Figure 1 (all times local time)

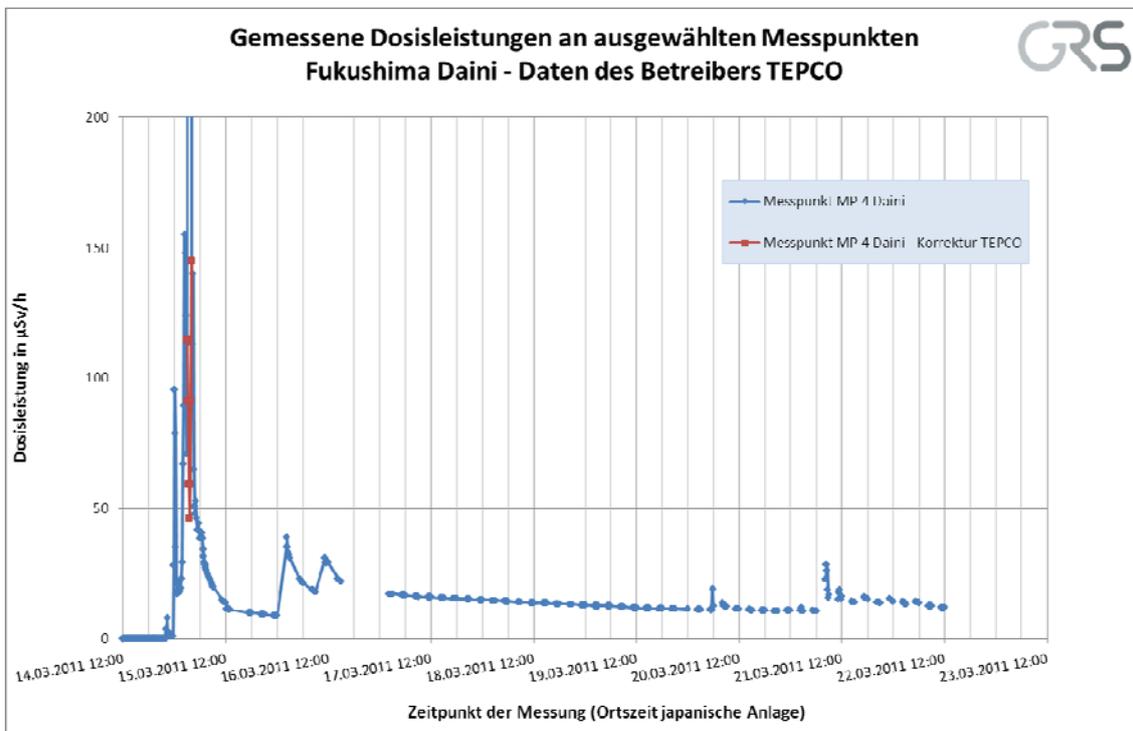


Figure 2 (all times local time)

Gemessene Ortsdosisleistung (ODL) in verschiedenen japanischen Präfekturen  
 Daten der japanischen nationalen Umgebungs-Radioaktivitätsüberwachung (SPEEDI)  
 Alle Zeitangaben in Ortszeit

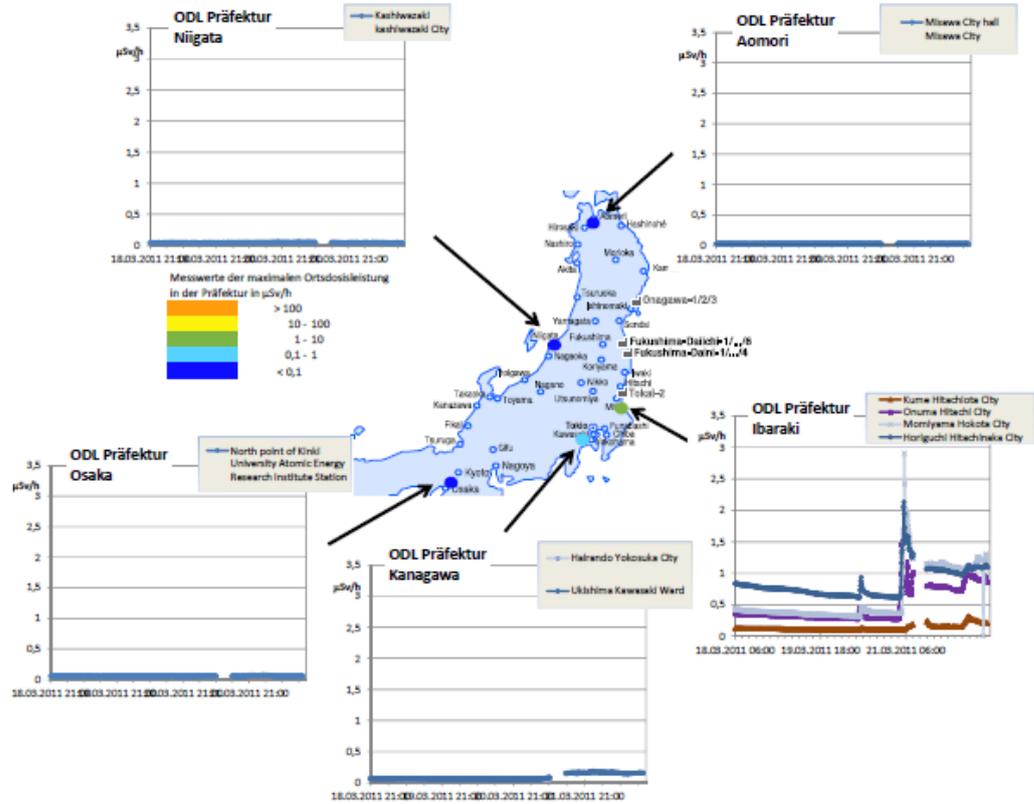


Figure 3 (all times local time)

#### 4 Brief overview of the current safety situation

Name	Power	Current status Confirmed: report by operator or NISA – unconfirmed: more detailed press report
Fukushima I (Daiichi 1)	460 MWe, 1380 MW <sub>therm</sub>	<p>- Condition of core and building structures: Core damage assumed, containment intact. Depressurisation of reactor carried out. Containment venting carried out. Hydrogen explosion on 12-03-2011 at 15:36 h. Severe structural damage to reactor building. According to TBS (Japanese TV station), presumably 70% of fuel assemblies damaged.</p> <p>- Condition of feeding/injection: Electrical power supply via mobile generators. Flooding of reactor with sea water. Sea water injection into containment via pipes of fire water system since 13-03-2011, 11:55 h (temporarily interrupted on 14-03-2011 at 1:10 due to water shortage in the sea water pool).</p> <p>- Important plant parameters (time of measurement always 21-03-2011, 14:25 h): Reactor pressure : 0.299 MPa (measuring location A), 0.272 MPa (measuring location B) [absolute pressures] Water level in the reactor: 1750 mm/1750 mm below upper core edge (measuring location A and measuring location B) Containment pressure: 0.16 MPa Pressure suppression pool: pressure 0.155 MPa, water temperature unknown</p> <p>- Information on fuel pool: Asahi with reference to TEPCO: - 292 fuel assemblies (1 core consisting of 400 fuel assemblies (source: TEPCO)) - Heat output: approx. 60 kW - Volume 1020 m<sup>3</sup> No information available on the condition of the fuel assemblies in the fuel pool.</p>

Fukushima I (Daiichi 2)	784 MWe, 2381 MW <sub>therm</sub>	<p>- Condition of core and building structures: 5 % core damage assumed. According to information by NISA, an evaluation by TEPCO on 14-03-2011 at 22:14 h shows core damage to be "less than 5%", according to Kyodo on 15-03-2011, TEPCO reports that approx. 33% of the fuel assemblies are damaged. Containment damaged (pressure suppression pool). Depressurisation of reactor carried out. Containment venting carried out. Hydrogen explosion on 15-03-2011 at 6:20 h. Structural damage to reactor building.</p> <p>- Condition of feeding/injection: Electrical power supply via mobile generators. Sea water injection into containment via pipes of fire water system since 14-03-2011, 22:50 h.</p> <p>- Important plant parameters (time of measurement always 21-03-2011, 14:25 h): Reactor pressure: 0.078 MPa (measuring location A), 0.076 MPa (measuring location B) [absolute pressures] Water level in the reactor: 1350 mm below upper core edge (measuring location A, measuring location B not available) Containment pressure: 0.120 MPa Pressure suppression pool: pressure below measuring range, water temperature unknown</p> <p>- Information on fuel pool: Asahi with reference to TEPCO: - 587 fuel assemblies (1 core consisting of 548 fuel assemblies (source: TEPCO)) - Heat output: approx. 400 kW - Volume 1425 m<sup>2</sup> - No information available on the condition of the fuel assemblies in the fuel pool. - Temperature 50 °C</p>
Fukushima I (Daiichi 3)	784 MWe, 2381 MW <sub>therm</sub>	<p>- Condition of core and building structures: Core damage assumed. Depressurisation of reactor carried out. Containment venting carried out. Hydrogen explosion on 14-03-2011 at 11:00 h. Severe structural damage to reactor building. Containment presumably damaged. White smoke or vapour visible since 16-03-2011, 11:45 h.</p> <p>- Condition of feeding/injection: Electrical power supply via mobile generators. Flooding with sea water. Freshwater injection into the containment</p>

		<p>via pipes of fire water system since 13-03-2011, 11:55 h. Since 13:12 h on 13-03-2011, sea water has been injected (temporarily interrupted on 14-03-2011 from 1:10 h until 3:20 h due to water shortage in the sea water pool).</p> <p>- Important plant parameters (time of measurement always 21-03-2011, 14:55 h):  Reactor pressure: 0.013 MPa (measuring location A), 0.146 MPa (measuring location B) [absolute pressures]  Water level in the reactor: 1550 mm (measuring location A) and 2025 mm (measuring location B), respectively, below upper core edge  Containment pressure: 0.110 MPa  Pressure suppression pool: pressure below measuring range, water temperature unknown</p> <p>- Information on fuel pool:  Asahi with reference to TEPCO:  - 514 fuel assemblies (1 core consisting of 548 fuel assemblies (source: TEPCO))  - Heat output: approx. 200 kW  - Volume 1425 m<sup>2</sup>  - Suspected fuel assembly damage</p>
Fukushima I (Daiichi 4) shut down before earthquake	784 MWe, 2381 MW <sub>therm</sub>	<p>Unit was shut down before the earthquake. Core had been fully unloaded from the reactor. Hydrogen explosion in the reactor building (fuel pool). Damage to the reactor building (15-03-2011 at 6:40 h) First fire in reactor building on 15-03-2011 at 9:38 h, ending at 11:00 h. Second fire on 15-03-2011 at 5:45 h, no longer visible from the plant premises at 6:15. According to press reports, the pool could not yet be refilled again. Attempts to do so by means of helicopter and fire engines.</p> <p>- Information on fuel pool:  Asahi with reference to TEPCO:  - 1331 fuel assemblies (IRSN reports 1500 fuel assemblies) (1 core consisting of 548 fuel assemblies (source: TEPCO))  - Heat output: approx. 2000 kW  - Volume 1425 m<sup>2</sup>  - Suspected fuel assembly damage</p>
Fukushima I (Daiichi 5)	784 MWe, 2381	<p>Unit was shut down before the earthquake, according to information by ENSI on 03-01-2011. Core in the reactor. Water level in fuel pool sinking, temperature rising.</p>

	$MW_{\text{therm}}$	<p>Since 20-03-2011, 14:30 in cold shutdown condition.</p> <ul style="list-style-type: none"> <li>- Important plant parameters (measuring time always 21-03-2011, 17:00 h):</li> </ul> <p>Reactor pressure: 0.108 MPa [absolute pressure]  Water level in the reactor: 2069 mm above upper core edge  Containment pressure: unknown  Pressure suppression pool water temperature unknown  Pressure suppression pool pressure: unknown  Emergency power supply from Unit 6 as of 19-03-2011, 4:22 h.</p> <ul style="list-style-type: none"> <li>- Information on fuel pool:</li> </ul> <p>Residual-heat removal system in operation again on 19-03-2011, 5:00 h.  Temperature on 21-03-2011 at 17:00 h: 42.3 °C</p> <p>Asahi with reference to TEPCO:</p> <ul style="list-style-type: none"> <li>- 946 fuel assemblies (1 core consisting of 548 fuel assemblies (source: TEPCO))</li> <li>- Heat output: approx. 700 kW</li> <li>- Volume 1425 m<sup>2</sup></li> <li>- No fuel assembly damage</li> </ul>
Fukushima I (Daiichi 6)	1100 MWe, 3293 $MW_{\text{therm}}$	<p>Unit was shut down before the earthquake, according to information by ENSI on 12-08-2010. Core in the reactor.  Water level in fuel pool sinking, temperature rising.  Since 20-03-2011, 14:30 in cold shutdown condition.</p> <ul style="list-style-type: none"> <li>- Important plant parameters (measuring time always 21-03-2011, 17:00 h):</li> </ul> <p>Reactor pressure: 0.104 MPa [absolute pressure]  Water level in the reactor: 1560 mm above upper core edge  Containment pressure: unknown  Pressure suppression pool water temperature: unknown  Pressure suppression pool pressure: unknown</p> <ul style="list-style-type: none"> <li>- Information on fuel pool:</li> </ul> <p>Temperature on 21-03-2011 at 17:00 h: 36.5 °C</p> <p>Asahi with reference to TEPCO:</p> <ul style="list-style-type: none"> <li>- 876 fuel assemblies (1 core consisting of 548 fuel assemblies (source: TEPCO))</li> </ul>

		<ul style="list-style-type: none"> <li>- Heat output: approx. 600 kW</li> <li>- Volume 1497 m<sup>3</sup></li> <li>- No fuel assembly damage</li> </ul>
Fukushima II (Daini 1)	1100 MWe, 3293 MW <sub>therm</sub>	<p>No containment venting. External electricity supply, plant state subcritical cold since 14-03-2011.</p> <p>Reactor pressure: 0.15 MPa [absolute pressure]</p> <p>Reactor water temperature: 33.2 °C</p> <p>Water level in the reactor: 8.196 m above upper core edge</p> <p>Pressure suppression pool water temperature: 25 °C</p> <p>Pressure suppression pool pressure: 127 kPa</p> <p>(time of each measurement 21-03-2011, 18:00 h)</p>
Fukushima II (Daini 2)	1100 MWe, 3293 MW <sub>therm</sub>	<p>No containment venting. External electricity supply, plant state subcritical cold since 14-03-2011.</p> <p>Reactor pressure: 0.12 MPa [absolute pressure]</p> <p>Reactor water temperature: 29.5 °C</p> <p>Water level in the reactor: 10.246 m above upper core edge</p> <p>Pressure suppression pool water temperature: 24 °C</p> <p>Pressure suppression pool pressure: 107 kPa</p> <p>(time of each measurement 21-03-2011, 18:00 h)</p>
Fukushima II (Daini 3)	1100 MWe, 3293 MW <sub>therm</sub>	<p>No containment venting. External electricity supply, plant state subcritical cold since 12-03-2011.</p> <p>Reactor pressure: 0.12 MPa [absolute pressure]</p> <p>Reactor water temperature: 34.5 °C</p> <p>Water level in the reactor: 8.169 m above upper core edge</p> <p>Pressure suppression pool water temperature: 26 °C</p> <p>Pressure suppression pool pressure: 104 kPa</p> <p>(time of each measurement 21-03-2011, 18:00 h)</p>
Fukushima II (Daini 4)	1100 MWe, 3293 MW <sub>therm</sub>	<p>No containment venting. External electricity supply, plant state subcritical cold since 15-03-2011.</p> <p>Reactor pressure: 0.15 MPa [absolute pressure]</p> <p>Reactor water temperature: 31.5 °C</p> <p>Water level in the reactor: 8.785 m above upper core edge</p>

		Pressure suppression pool water temperature: 29 °C Pressure suppression pool pressure: 112 kPa (time of each measurement 21-03-2011, 18:00 h)
Onagawa 1	524 MWe	All 3 units are in cold shutdown (below 100 °C) condition. The plant is currently being inspected.
Onagawa 2	825 MWe	
Onagawa 3	825 MWe	
Tokai 2	1100 MWe, 3293 MW <sub>therm</sub>	Plant in safe cold shutdown condition.

MWe: electrical power, MW<sub>therm</sub>: thermal power

GRS, mat, buu 22-03-2011, 10:30 h