Lessons Learned from Fukushima

2012 ISOE Asian ALARA Symposium

Tokyo

September 24, 2012

IAEA,OECD/NEA ISOE Committee 7th Chairman

EG on Severe Accident Management (SAM) Chairman

Wataru MIZUMACHI

Contents

1.North East Japan Earthquake and Tsunami

4th Largest Earthquake in the World

At 14.46 Magnitude 9.0 Earthquake

14.51 Largest Tsunami (39.8m height)

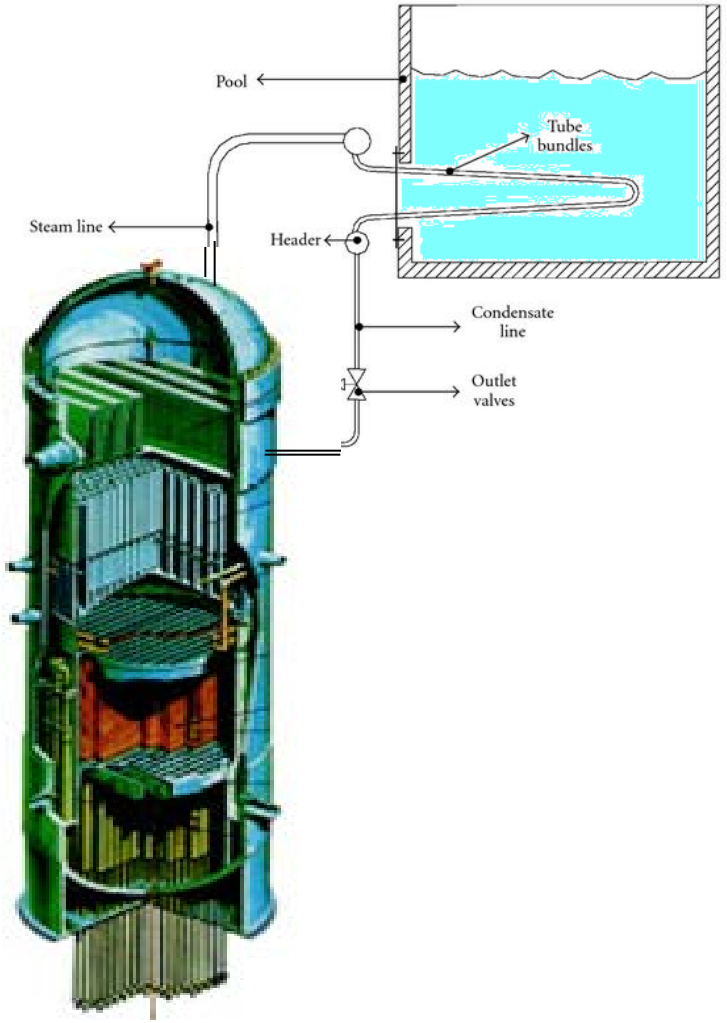
133 feet high : ten story building

So far , ～20 thousands people were killed.

～300 billion US Dollar damage is estimated.

No one has been killed by the radiation at Fukushima

Isolation Condenser



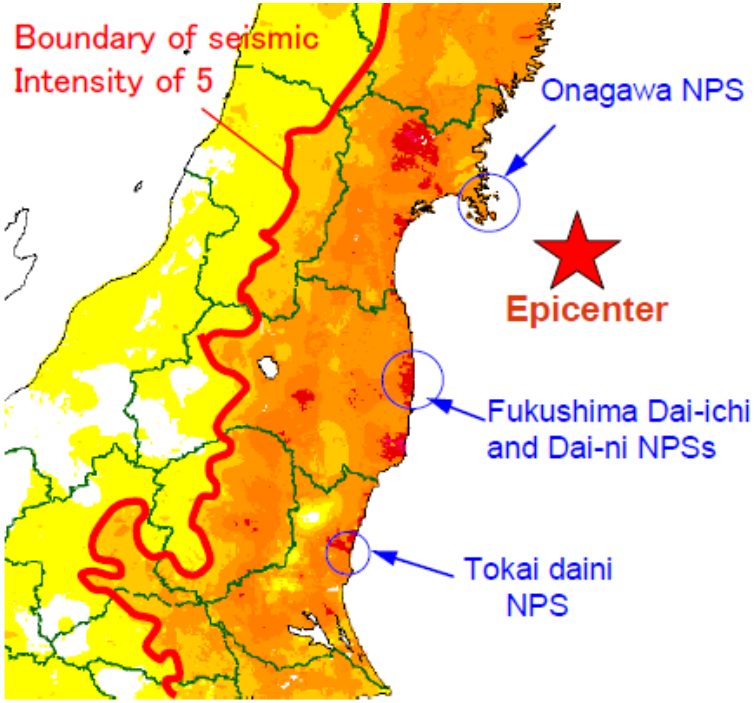
Passive and Simple Core Cooling System

by Natural Circulation

2. Fukushima Dai-ichi NPS Accident

2011 off the Pacific coast of Tohoku Earthquake

- Occurred 14:46 March 11, 2011
- Magnitude:9.0 Mw
- Epicenter location: 38º 10''N and 142º 86''E, and 23.7km in depth



Reference: JMA Release [Online]. http://www.jma.go.jp/jma/index.html
Partially modified by JNES.

Source: Fire and Disaster Management Agency

- East coast of northern area in the main island of Japan is seriously damaged
- As of August 11, 15,810 people are dead and 4,613 people are missing according to the Fire and Disaster Management Agency

Onagawa NPS was safe

- Unit-1 is 524 MW BWR,Unit-2 and3 are 825 MW BWR
- One civil engineer insisted the ground level of Reactor Building should be above 14m from Pacific Ocean considering the past Jorgan Tsunami.
- Onagawa people are mainly fishermen. Hundreds of them were killed by Tsunami.
- 360 fishermen climbed up to Onagawa NPS to escape from Tsunami. The Site manager accepted them to the sport gym next to R/B where they stayed 3 months supported by the emergency foods and so on.
- JSME will give the awards to him on Nov 2 this year.

List of earthquakes in Japan

From Wikipedia, the free encyclopedia

This is a **list of earthquakes in Japan** with a magnitude of 7.0 or above or which caused significant damage or casualties. As indicated below, magnitude is measured on the Richter magnitude scale (M_L) or the moment magnitude scale (M_w), or the surface wave magnitude scale (M_s) for very old earthquakes. The present list is not exhaustive and reliable and precise magnitude data is scarce for earthquakes that occurred prior to the development of modern measuring instruments.

This list is incomplete; you can help by expanding it (http://en.wikipedia.org/w/index.php?title=List_of_earthquakes_in_Japan&action=edit).

～BC 200 Year

Yayoi Earthquake

Date	Magnitude	Name of quake	Japanese name	Rōmaj
November 29, 684	8.0–8.4 (unknown scale)	Hakuko Nankai earthquake	白鳳南海地震	Hakuk Nankai
June 5, 745	7.9 M_s	occurred at Minoh		
July13, 869	8.3 M	869 Sanriku earthquake and tsunami	貞観三陸地震	Jōgan s jishin

56th Emperor Seiwa

Present Emperor is 125th.

All victims by the Tsunami have no responsibilities.

I have all responsibility because the god punished my activities as the emperor.

Do not take any tax from these areas attacked by the tsunami.

I will pray at Ise Temple and the officers should go there and help

all victims.

Clean up the mass of rubble.

858～876 as Emperor

Jorkan Earthquake and Tsunami attacked the same area in 869.

Summary of Fukushima Dai-ichi NPS

Items	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6
BWR type	BWR-3	BWR-4	BWR-4	BWR-4	BWR-4	BWR-5
PCV Model	Mark-1	Mark-1	Mark-1	Mark-1	Mark-1	Mark-2
Electric Output (MW_e)	460	784	784	784	784	1100
Max. pressure of RPV	8.24MPa	8.24MPa	8.24MPa	8.24MPa	8.62MPa	8.62MPa
Max. Temp of the RPV	300°C	300°C	300°C	300°C	302°C	302°C
Max. Pressure of the CV	0.43MPa	0.38MPa	0.38MPa	0.38MPa	0.38MPa	0.28MPa
Max. Temp of the CV	140°C	140°C	140°C	140°C	138°C	171°C(D/W) 105°C(S/C)
Commercial Operation	1971,3	1974,7	1976,3	1978,10	1978,4	1979,10
Number of DG	2	2 *	2	2 *	2	3*
Electric Grid	275kV x 4				500kV x 2	
Plant Status on Mar. 11	In Operation	In Operation	In Operation	Refueling Outage	Refueling Outage	Refueling Outage

* One Emergency DG is Air-Cooled

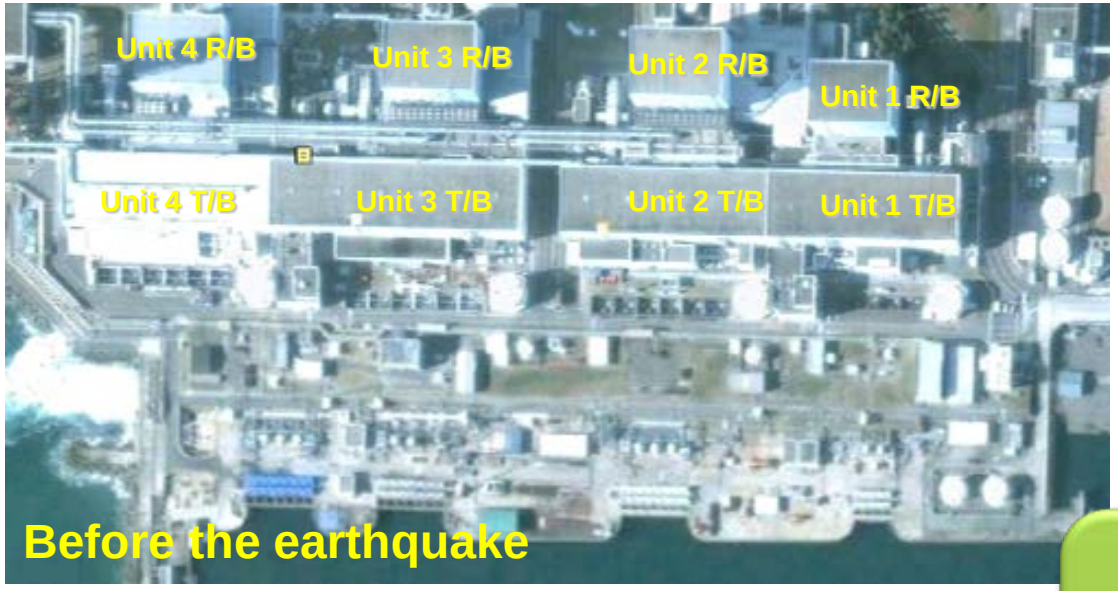
Source: Application document of license for establishment of NPS

Collapsed Tower

- **Damage of external power supply systems of the Fukushima Dai-ichi and Dai-ni NPSs**

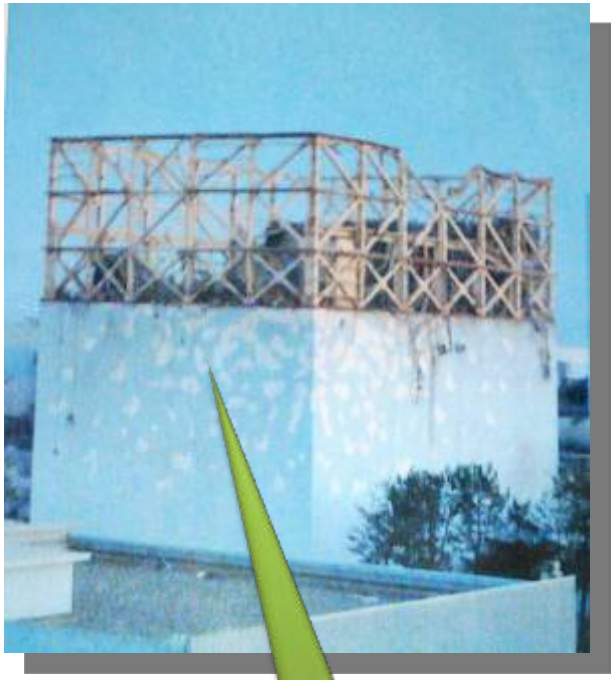
Tsunami getting over seawall

Satellite view of Fukushima Dai-ichi NPS



Source: Google Earth

Damage of reactor buildings



Unit 1

Unit 3

Unit 4

3.Memorial International Security Exhibition and Seminar on Sep 11 in 2012 at Philadelphia

A lot of people gathered there

- There were 20,000 people gathered for the security exhibition and 2.500 people for the security seminar at Philadelphia Convention Center.

- Dr ElBaradei, Nobel Piece Prize Winner and I made the presentations on Sept 11th.

ElBaradei Calls for Global Dialogue

- One of the most important elements of maintaining any close relationship is healthy, open communication.
- If you want Iran to change their behavior, then you better talk to them and the Islamic world.
- Addressing the root of the problem would be finding out if and why Iran would feel like it would need nuclear weapons in the first place.
- US and Russia have 19,000 nuclear weapons which can break the world 10 times. Crazy!

Lessons Learned from Fukushima

58th ASIS International Symposium

Pennsylvania Convention Center

September 11, 2012

IAEA,OECD/NEA ISOE Committee 7th Chairman

Severe Accident Management (SAM) Chairman

Wataru MIZUMACHI

4. Recent Situation of Fukushima

Current status of Fukushima NPPs

- Reactors: A condition equivalent to Cold Shutdown

☐Temperature of RPV bottom is, in general, below 100℃.

☐Release of radioactive materials from PCV is under control and public radiation exposure by additional release is being significantly held down.
(Not exceed 1 mSv/y at the site boundary as a target.)

☐Mid-term Safety of Circulating Water Injection Cooling System

- Spent Fuel Pools: More stable cooling

☐Circulating Cooling System by installation of heat exchanger

- Radioactive Contaminated Water: Reduction of total amount

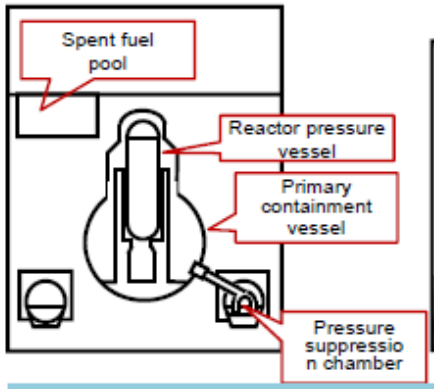
☐Full-fledged processing facilities

☐Desalination processing (reuse)

☐Storage

☐Mitigation of contamination in the ocean

Current Status of Fukushima Dai-ichi NPP



Unit 1

TEPCO

Unit 2

Ministry of Defense

Unit 3

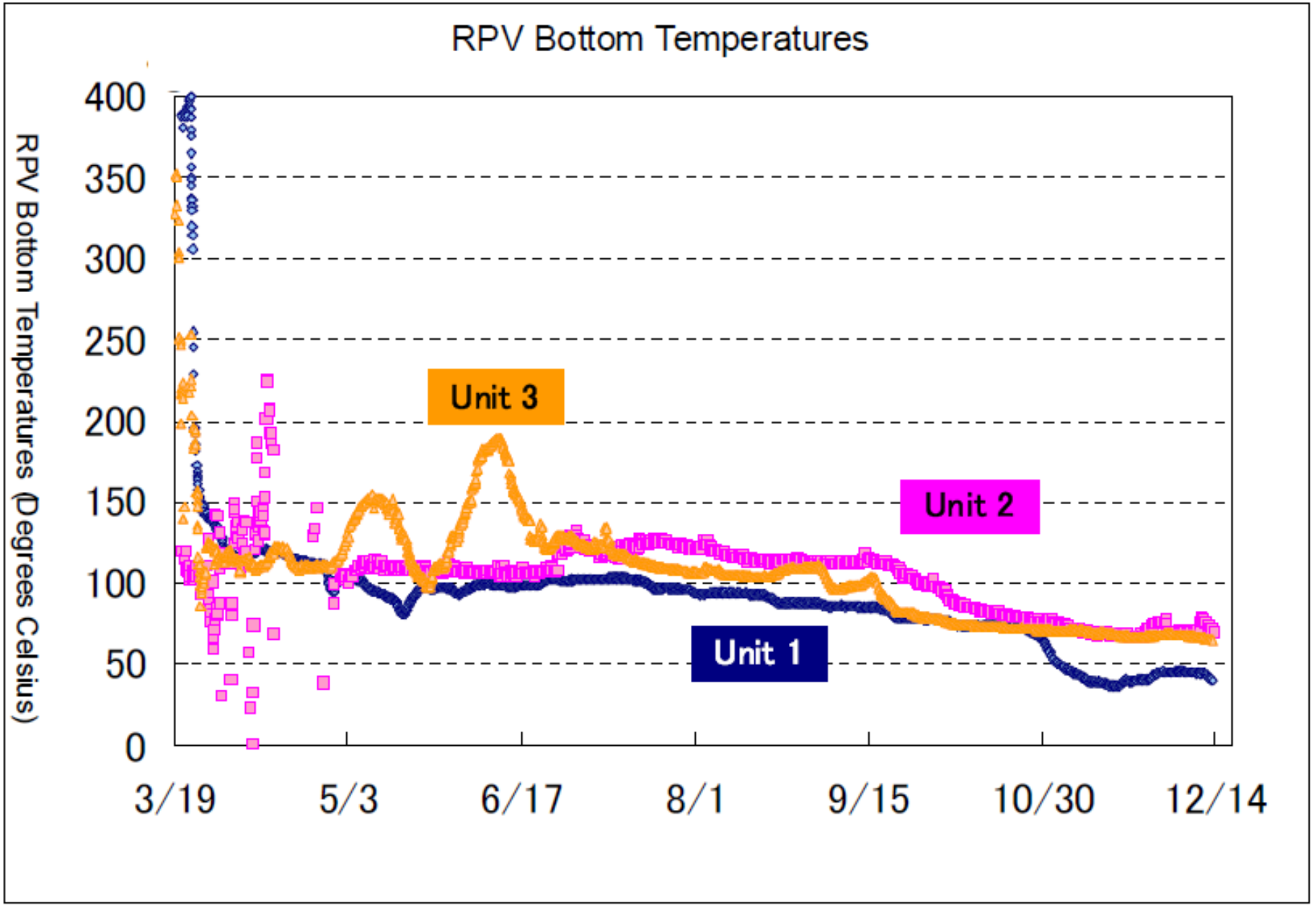
Air Photo Service

Unit 4

Air Photo Service

Reactor Pressure vessel Temperature at reactor vessel bottom*	Circulating water injection cooling 24.3°C	Circulating water injection cooling 47.1°C	Circulating water injection cooling 51.4°C	No fuel
Primary Containment vessel Temperature of air in PCV*	Nitrogen injection 25.4°C	Nitrogen injection 54.3°C	Nitrogen injection 44.4°C	—
Fuel pool Temperature of pool water*	Circulation cooling 26.5°C	Circulation cooling 14.2°C	Circulation cooling 14.4°C	Circulation cooling 26°C
Highly-contaminated water in R/B and T/B**	14,100 m^3	22,000m^3	23,800 m^3	18,300 m^3

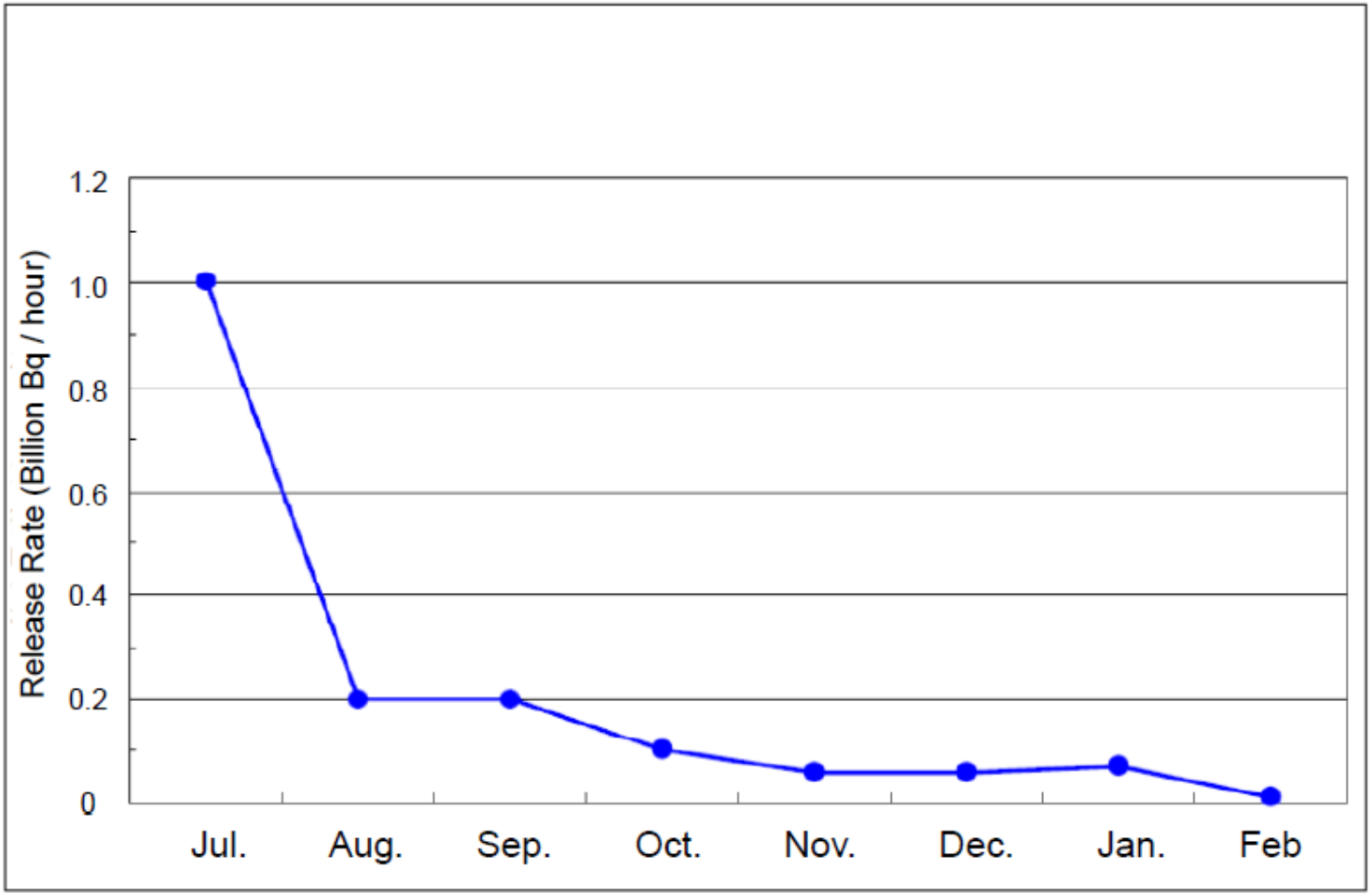
As of Feb 21, 2012


RPV Bottom Temperatures
RPV Bottom Temperatures (Degrees Celsius)
400
350
300
250
200
150
100
50
0
3/19
5/3
6/17
8/1
9/15
10/30
12/14
Unit 3
Unit 2
Unit 1


ANN
NEWS
2号機
格納容器

Release Rate of Radioactive Materials from PCVs of Units 1-3

- Current total release rate of Cesium 134 and 137 from PCVs of Units1-3 is estimated to be approx. 0.01 billion Bq/h at the maximum. (1/77,000,000 of early stages of the accident)

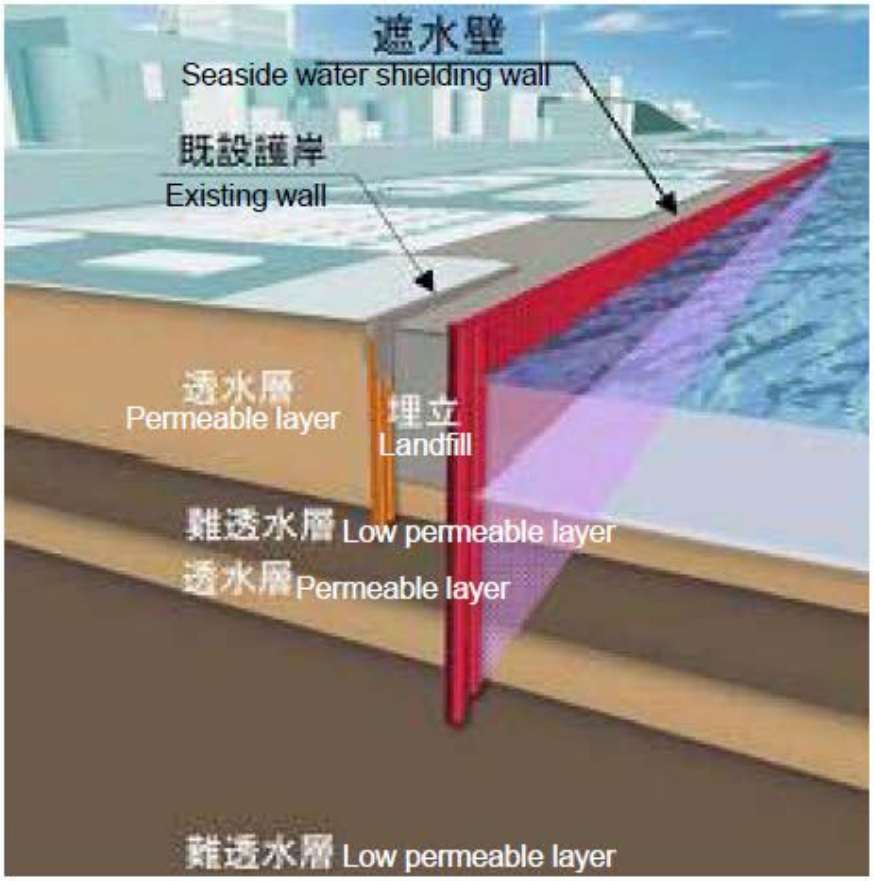


Construction of Water Shielding Wall

- A measure to prevent contamination of the ocean via the underground water.

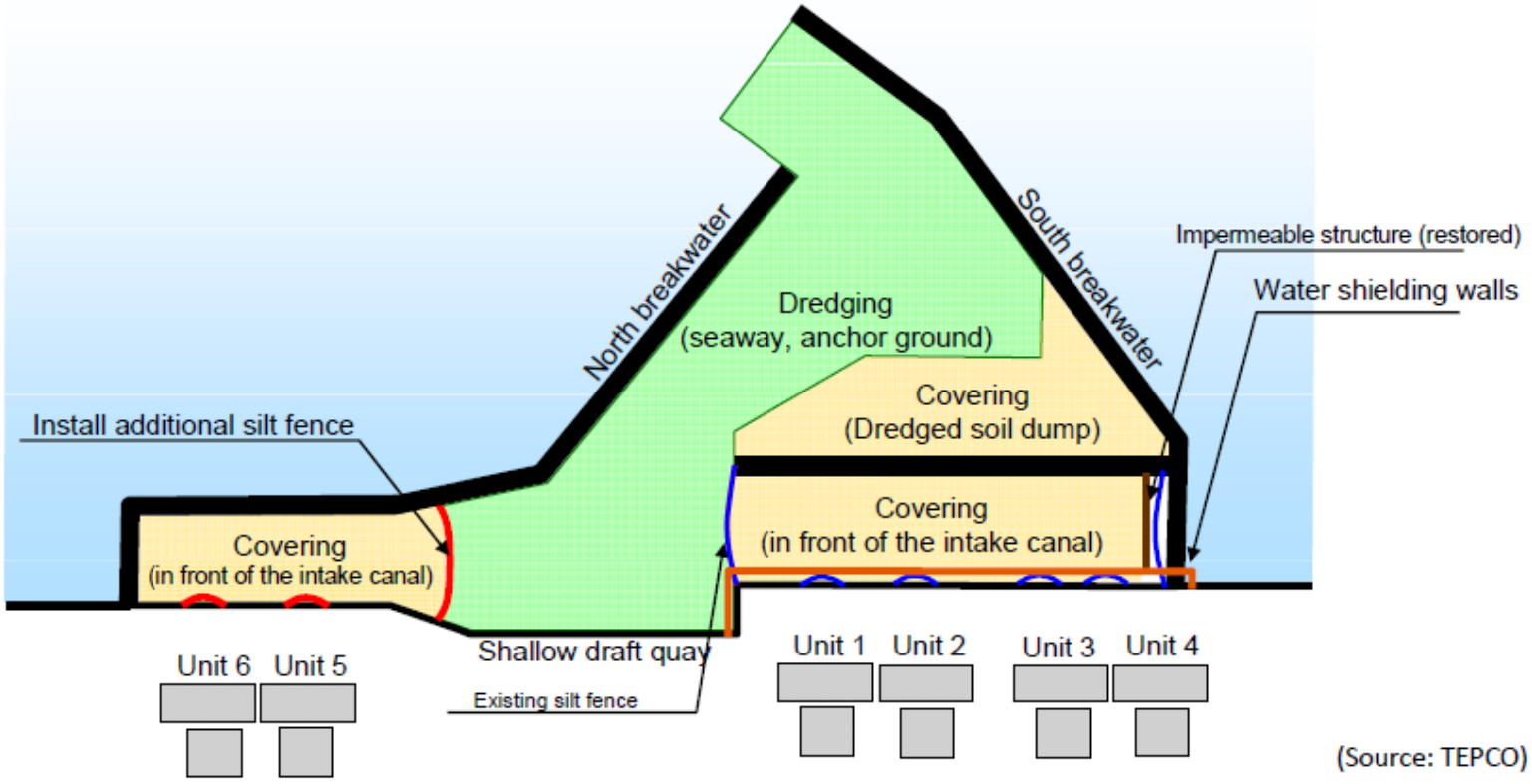
Image of water shielding walls

Cross-section view



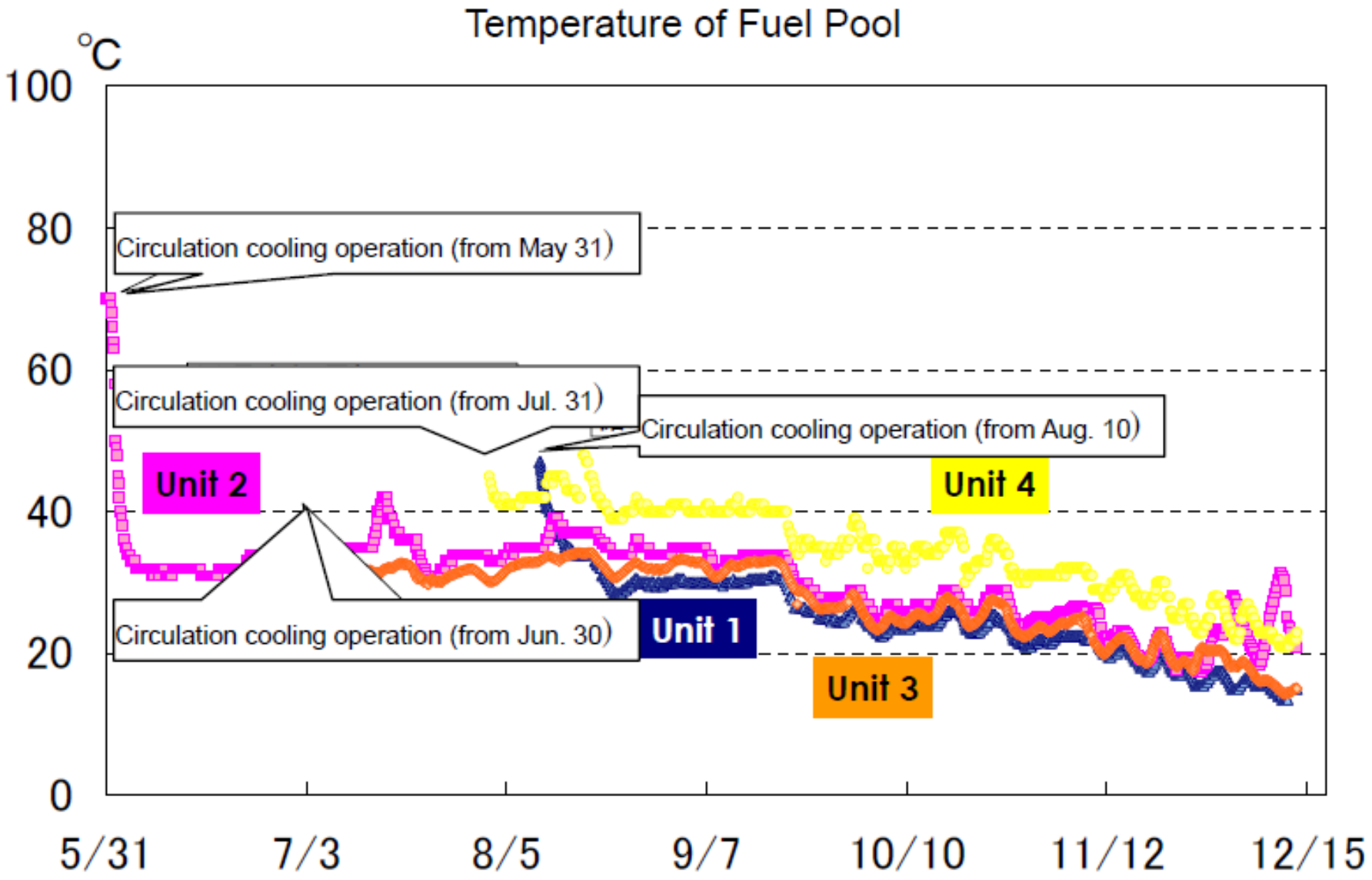
Start of Marine Soil Covering Construction at Inside Port

- High contaminated radioactive materials were detected from marine soil sampled at inside of the port
- To prevent contamination of the ocean outside of the port, marine soil in front of the intake canal is planned to be covered with solidified soil.



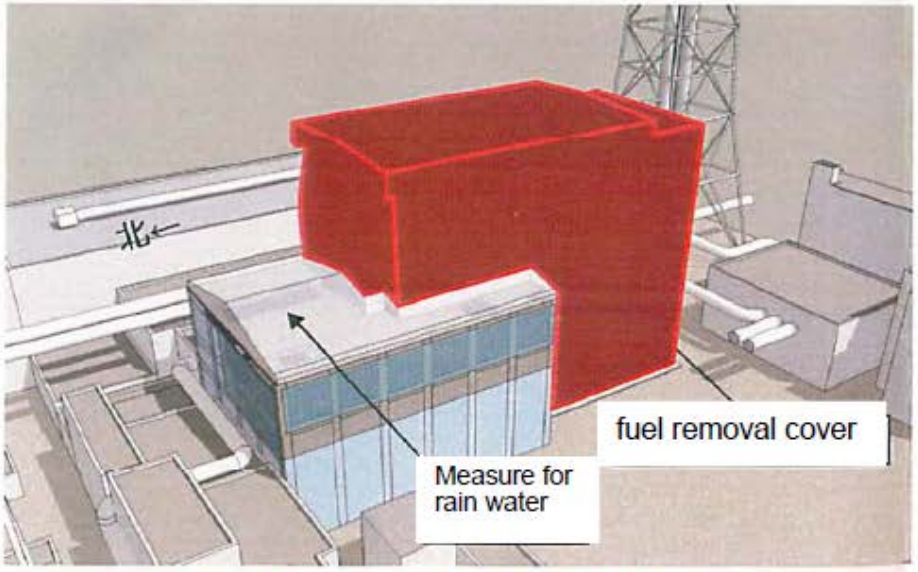
(Source: TEPCO)

Inside the Unit 4's Spent Fuel Pool

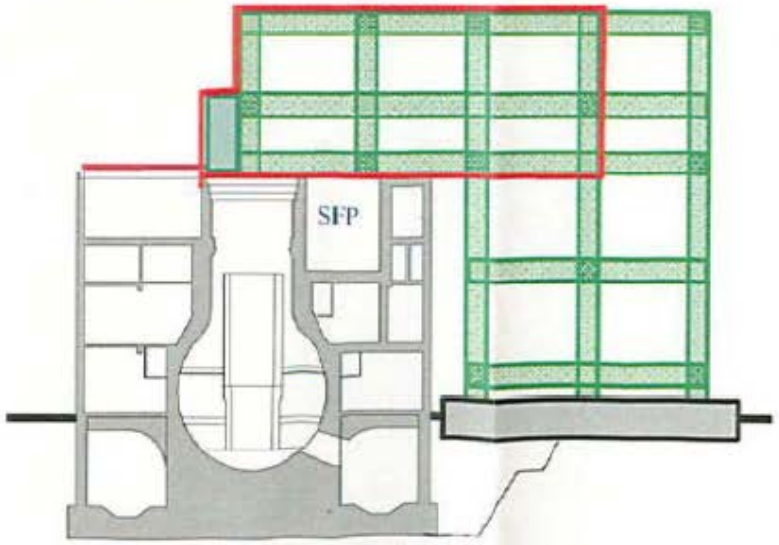

Temperature of Fuel Pool
℃
100
80
60
40
20
0
Circulation cooling operation (from May 31)
Circulation cooling operation (from Jul. 31)
Circulation cooling operation (from Aug. 10)
Circulation cooling operation (from Jun. 30)
Unit 2
Unit 4
Unit 1
Unit 3
5/31
7/3
8/5
9/7
10/10
11/12
12/15

Prepare for Fuel Removal from SFP of Unit 4

- Fuel removal are planned to be initiated in autumn 2013.
- Currently Rubble is being removed to prepare for the relevant works.
- Construction of covering structure will be initiated in spring 2013.

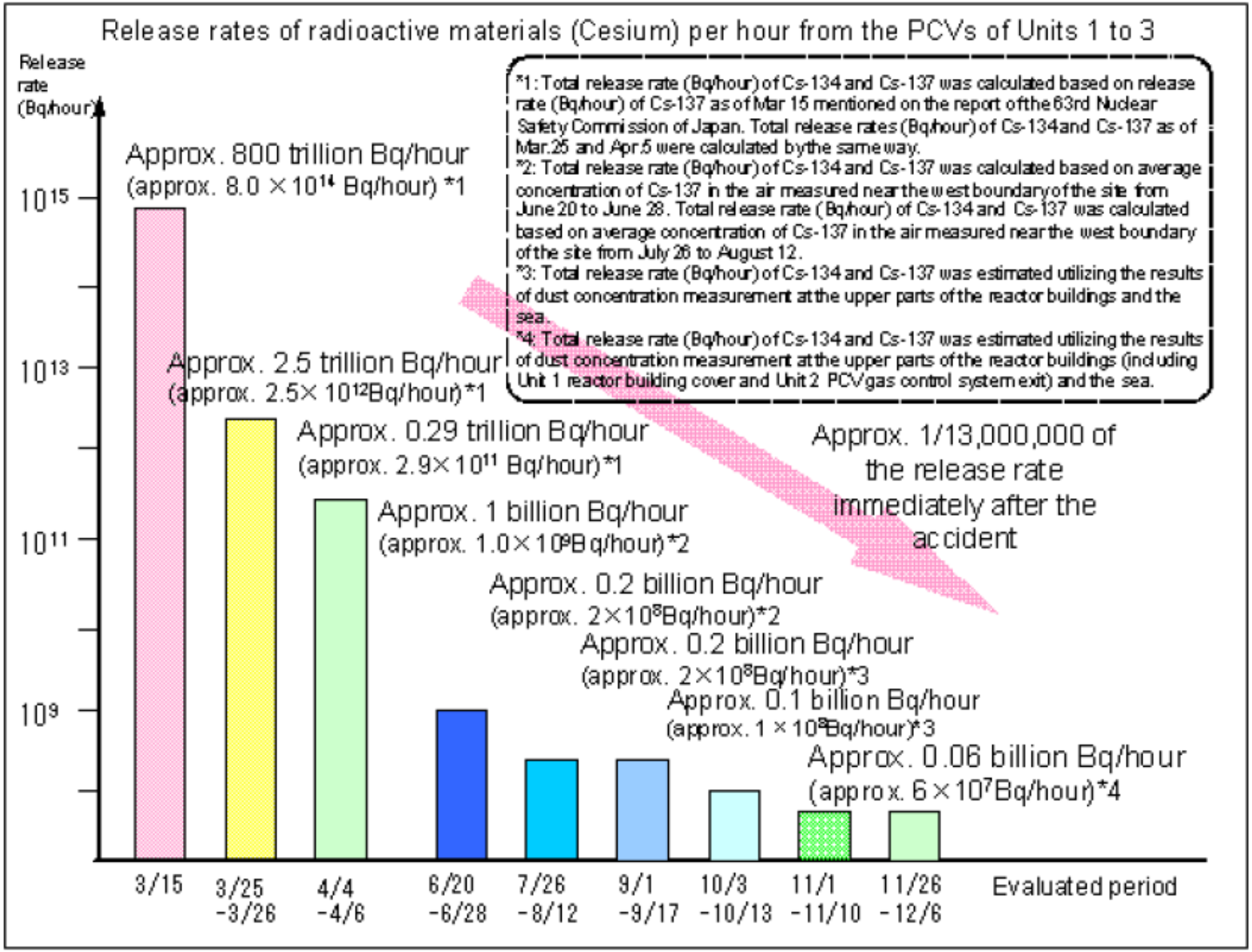


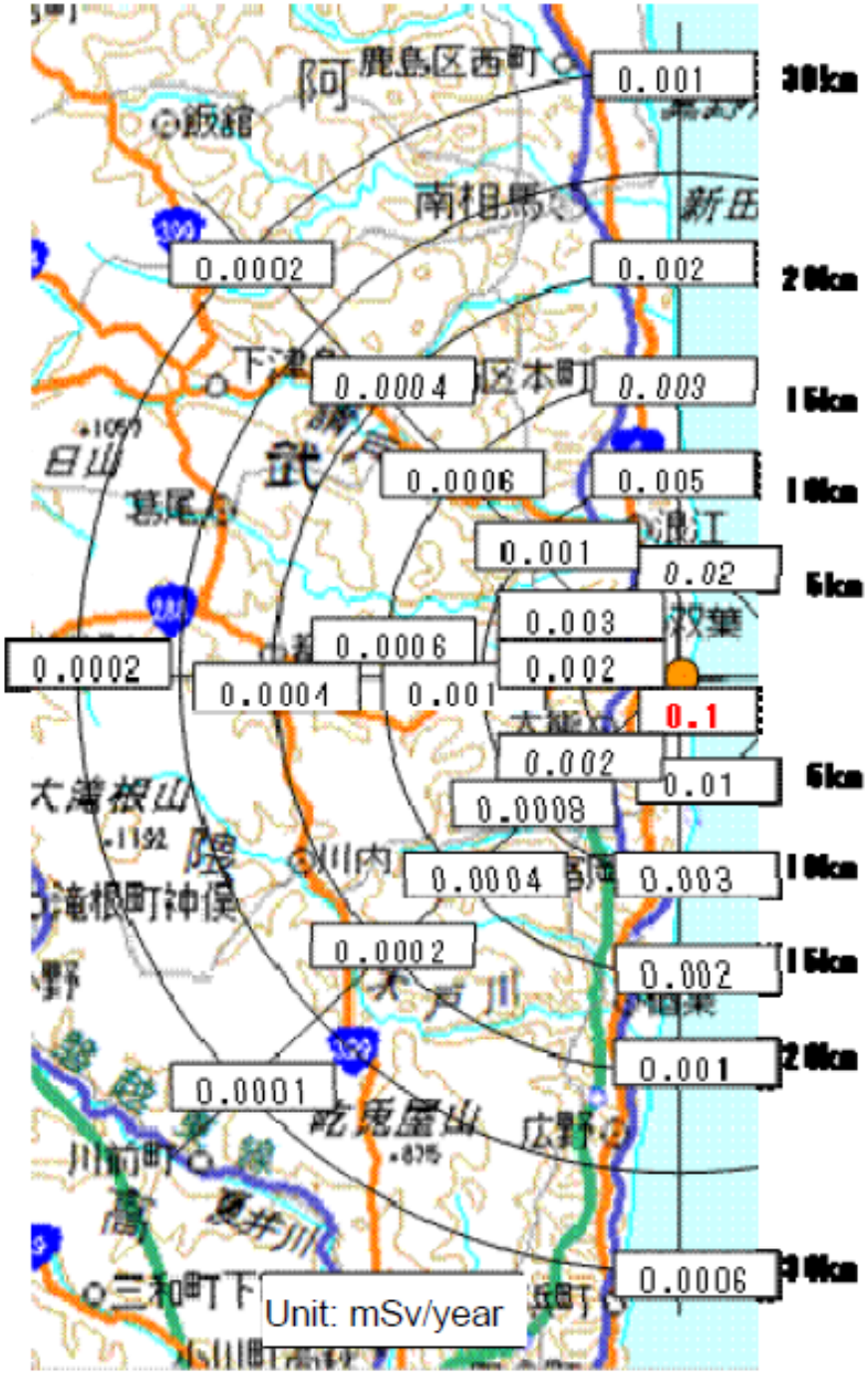
Building image of fuel removal cover



Cross-section diagram

(Source: TEPCO)


Release rates of radioactive materials (Cesium) per hour from the PCVs of Units 1 to 3
Release rate (Bq/hour)
10^{15}
10^{13}
10^{11}
10^{9}
Approx. 800 trillion Bq/hour
(approx. 8.0 × 10^{14} Bq/hour) *1
Approx. 2.5 trillion Bq/hour
(approx. 2.5× 10^{12}Bq/hour)*1
Approx. 0.29 trillion Bq/hour
(approx. 2.9× 10^{11} Bq/hour)*1
Approx. 1 billion Bq/hour
(approx. 1.0× 10^{9}Bq/hour)*2
Approx. 0.2 billion Bq/hour
(approx. 2× 10^{8}Bq/hour)*2
Approx. 0.2 billion Bq/hour
(approx. 2× 10^{8}Bq/hour)*3
Approx. 0.1 billion Bq/hour
(approx. 1 × 10^{8}Bq/hour)*3
Approx. 0.06 billion Bq/hour
(approx. 6× 10^{7}Bq/hour)*4
*1: Total release rate (Bq/hour) of Cs-134 and Cs-137 was calculated based on release rate (Bq/hour) of Cs-137 as of Mar 15 mentioned on the report of the 63rd Nuclear Safety Commission of Japan. Total release rates (Bq/hour) of Cs-134 and Cs-137 as of Mar.25 and Apr.5 were calculated by the same way.
*2: Total release rate (Bq/hour) of Cs-134 and Cs-137 was calculated based on average concentration of Cs-137 in the air measured near the west boundary of the site from June 20 to June 28. Total release rate (Bq/hour) of Cs-134 and Cs-137 was calculated based on average concentration of Cs-137 in the air measured near the west boundary of the site from July 26 to August 12.
*3: Total release rate (Bq/hour) of Cs-134 and Cs-137 was estimated utilizing the results of dust concentration measurement at the upper parts of the reactor buildings and the sea.
*4: Total release rate (Bq/hour) of Cs-134 and Cs-137 was estimated utilizing the results of dust concentration measurement at the upper parts of the reactor buildings (including Unit 1 reactor building cover and Unit 2 PCV gas control system exit) and the sea.
Approx. 1/13,000,000 of the release rate immediately after the accident
3/15
3/25 -3/26
4/4 -4/6
6/20 -6/28
7/26 -8/12
9/1 -9/17
10/3 -10/13
11/1 -11/10
11/26 -12/6
Evaluated period

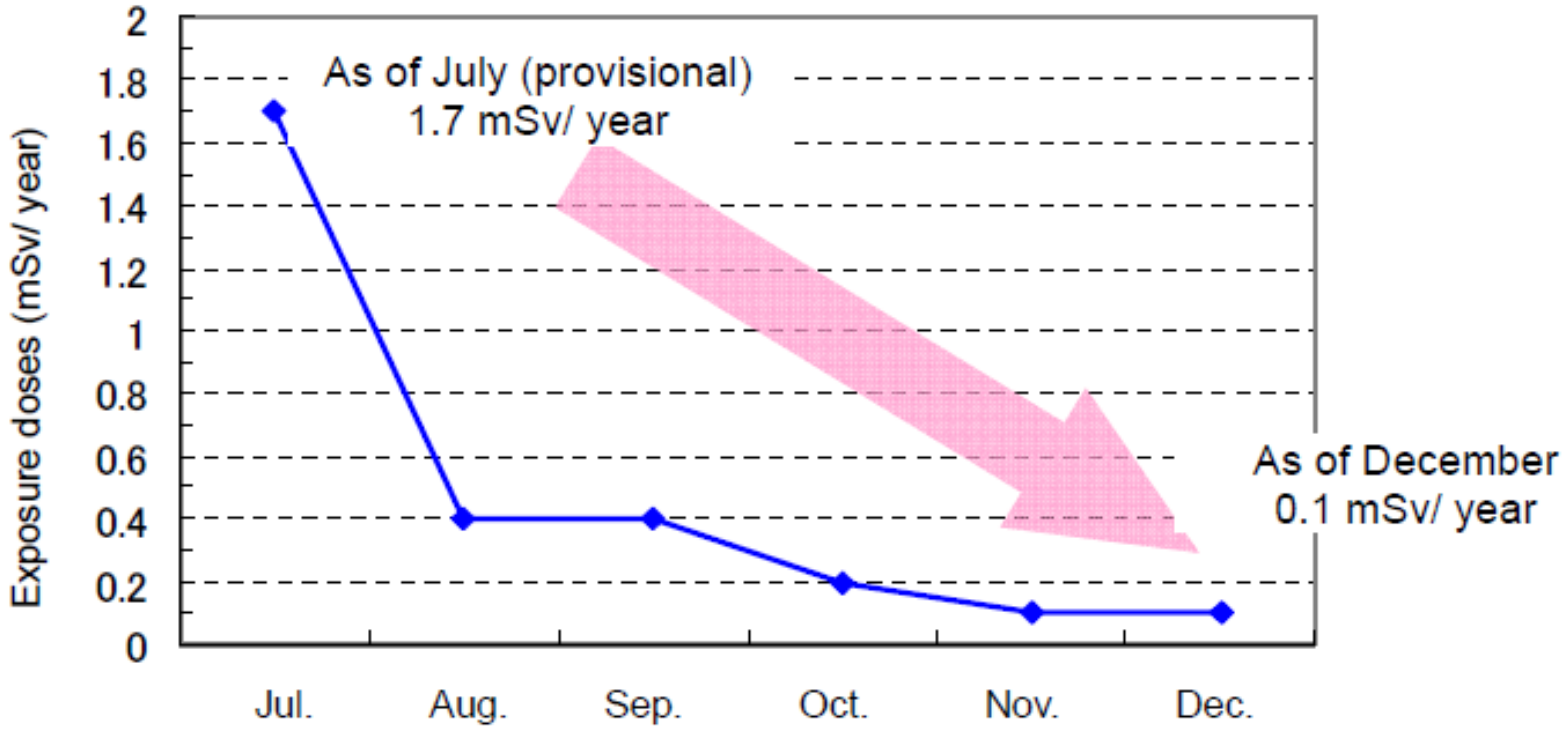

0.001
0.0002
0.002
0.0004
0.003
0.0006
0.005
0.001
0.02
0.003
0.0006
0.0002
0.002
0.0004
0.001
0.1
0.002
0.01
0.0008
0.0004
0.003
0.0002
0.002
0.001
0.0001
0.0006
Unit: mSv/year

Before and after the debris removal (upper: before, lower: after)

Debris storage area (Left: Containers storing debris, Right: Storage tent)

Exposure doses in case the release rate from the PCVs of Units 1 to 3 at the time of the evaluation continues for one year (mSv/year)

(Excluding the effect of the already released radioactive materials)



Protected Areas

March 12-15 **April 12** **Present**

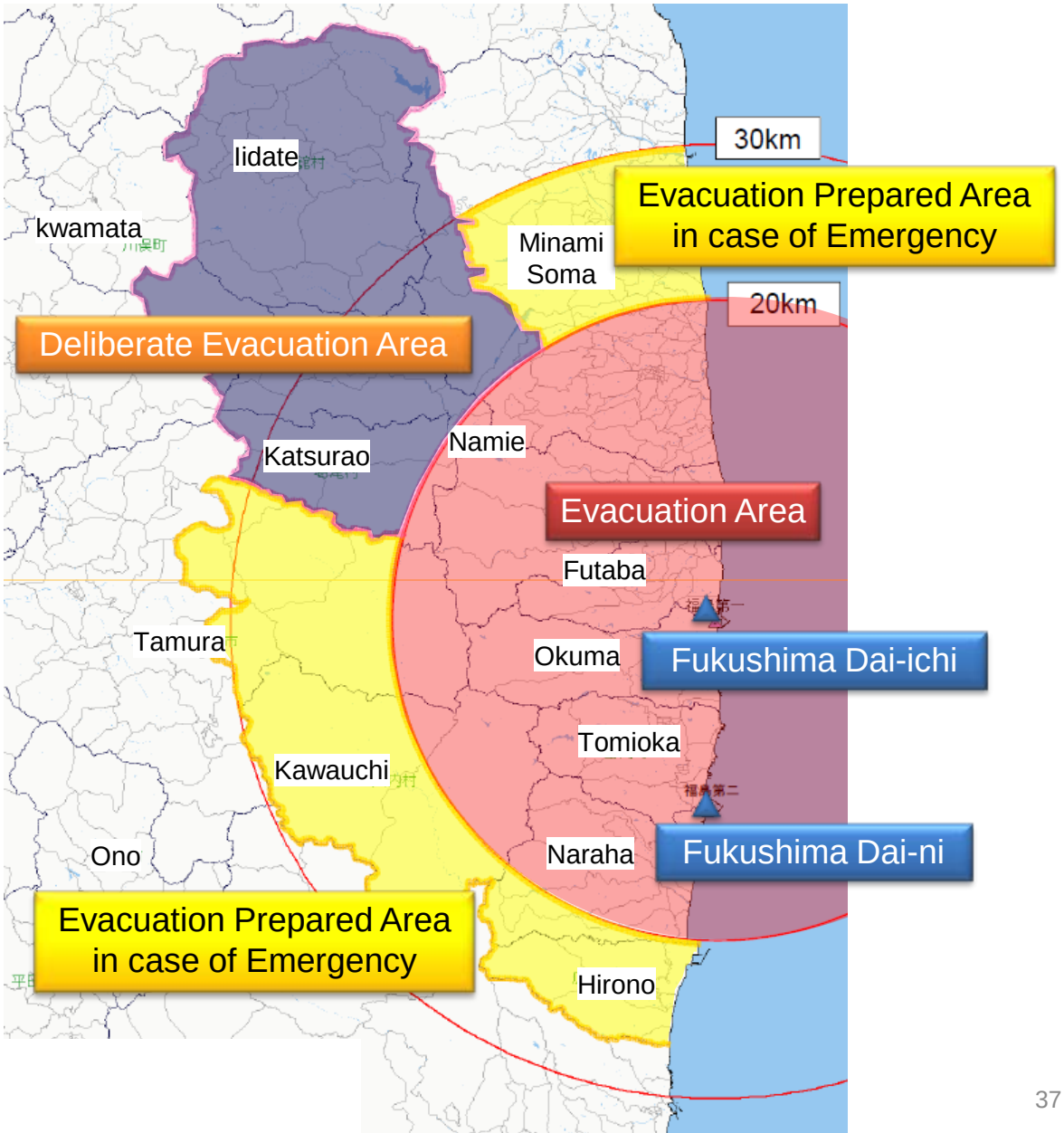
Evacuation Area

In-house evacuation area (20~30 km radius)

Evacuation Prepared Area in case of Emergency

Area where radioactive materials to be accumulated at high levels

Deliberate Evacuation Area

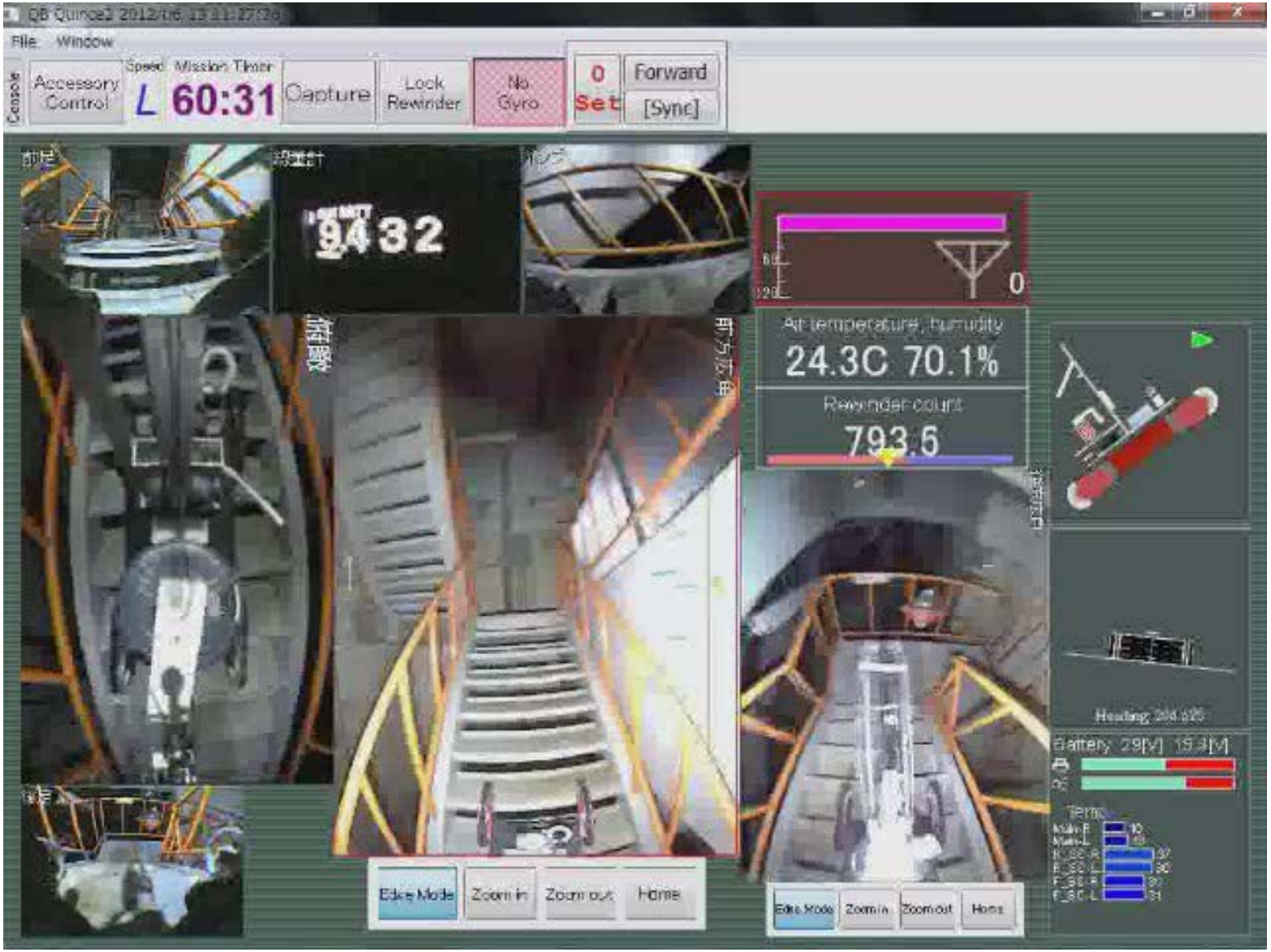


In-house evacuation area excluding deliberate evacuation area was renamed as evacuation prepared area in case of emergency.
Deliberate evacuation area needed to establish for specific areas beyond 20km radius where radioactive materials are to be accumulated at high levels.

1F4 PCV Head Removal

1F4 Spent Fuels Removal from Spent fuel Pool

1F2 Inside Reactor Building

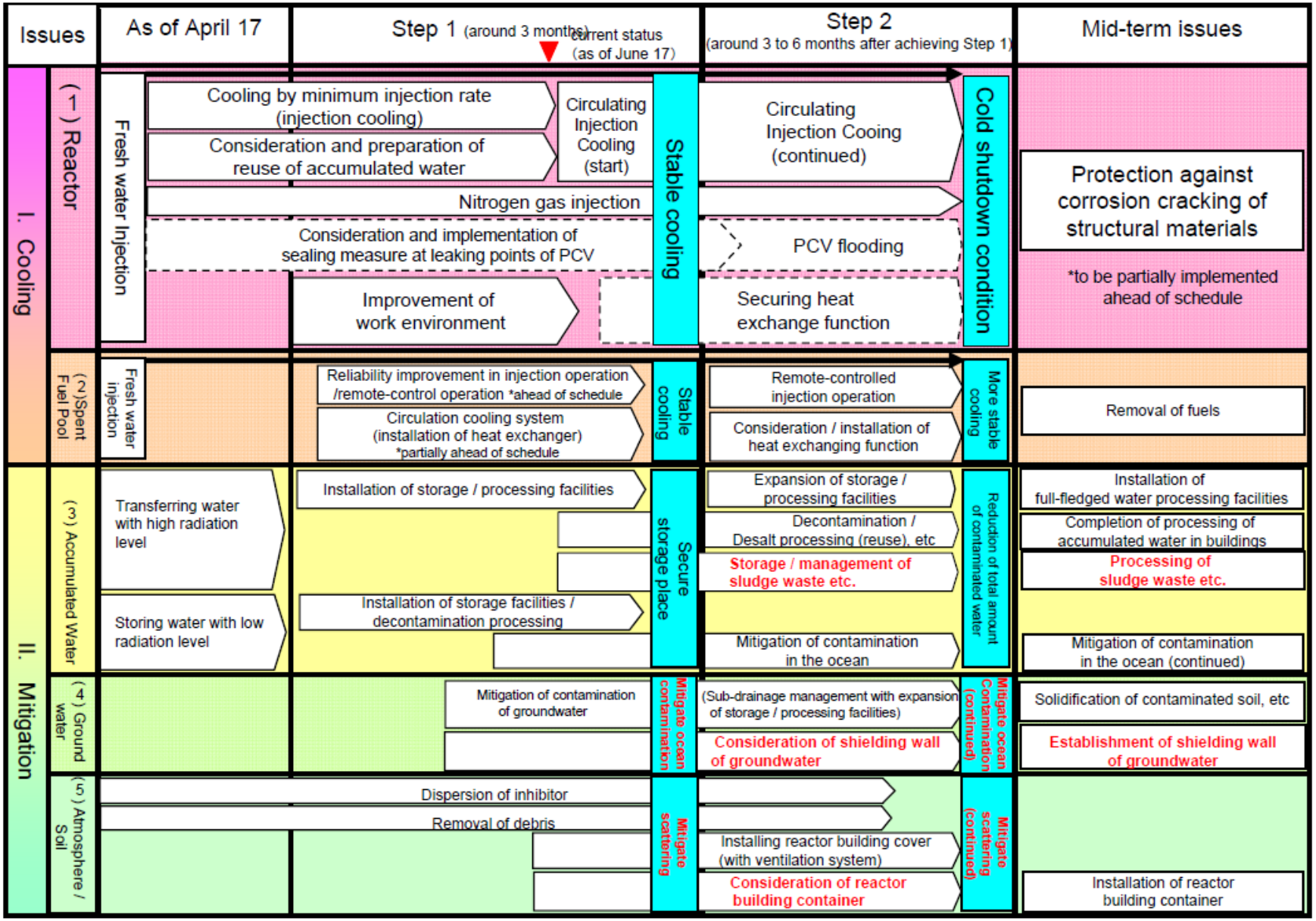

File Window
Console
Accessory Control
Speed Mission Timer
L 60:31
Capture
Lock Rewinder
No Gyro
0
Set
Forward
[Sync]
9432
0
Air temperature, humidity
24.3C 70.1%
Rewinder count
793.6
Edge Mode
Zoom in
Zoom out
Home
Edge Mode
Zoom in
Zoom out
Home
Battery 29[V] 15.3[M]
Temp

1F3 Above Operating Floor of R/B

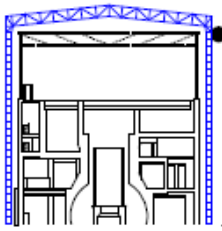
5. Future Efforts to Settle the Situation

Efforts to restore the Accident

Red colored: newly added to the previous version, Blue colored: modified from the previous version



Overview of Major Countermeasures in the Power Station as of June 17



Red colored: newly added to the previous version

piping

pumps

heat exchangers, water processing facilities

Reactor building cover (5, 50, 54, 55)

Full-fledged container (50, 56)

Cooling of spent fuel pool by external water injection (18, 22, 28)

Sampling of steam/pool water and measurement of radioactive materials (19)

Circulation cooling of spent fuel pool (23, 24, 25, 27)

Storage / management of sludge waste etc. (81)

Storage/process of low radiation-level water (33, 35, 40, 46)

Storage: tanks, megafloats, barges
Process: decontamination by zeolite

Lower the amount of steam generated (4)
Maintain and enhance countermeasures in Step 1 if needed (17)

Processing high radiation-level water (31,34,38,41,43,44)

Nitrogen gas injection (2, 11, 15)

Reactor Building

Tank

Water processing facility (Decontamination and desalt processing)

PCV venting (with filtration) (10)

Primary Containment Vessel (PCV)

Cooling at minimum water injection rate (7,12,14)
Reuse of processed water (45)
(Implement circulation cooling system)

Storage of high radiation-level water (30, 32, 37, 39, 42)

Flooding up to top of active fuel (3, 9)

Reactor Pressure Vessel (RPV)

Turbine Building

Steam Turbine

Heat Exchanger

Additionally-installed Tank

Centralized Waste Processing Building

Installation of heat exchangers (13)

Condenser

Injection of fresh water with pumps (1)

Suppression Chamber

Dispersion of inhibitor (47, 48, 52)
Removal of debris (49, 53)
Consideration of countermeasures for contaminated soil (51)

Processing of sub-drainage water after being pumped up (36)

Sealing the leakage location (6, 16)

Prevent contamination of groundwater (66,67); Consideration of shielding wall of groundwater(68)

Seismic assessment (20),Continued monitoring (21),
(Unit 4) Installation of supporting structure under the bottom of spent fuel pool (26)

Preventive measures against leakage of high radiation-level water (29)
Prevent contamination in the ocean (64)
Isolation of high-level radioactive water (65)

Improvement of life/work environment of workers(74,75); improvement of site environment(76)

Install various interconnecting lines of offsite power(8); enhance countermeasures against tsunami (69,70); planning of reinforcement work of each Unit (71); various countermeasures of radiation shielding (72,73)

Continue/Enhance monitoring (55~62), Consideration of necessary measures to reduce radiation dose (63)

Enhancement of radiation control (77,78); Enhancement of medical system (79,80)

Main points of Roadmap

Issues		Main points
I. Cooling	Reactor	• Nitrogen gas injection (Step I) • Circulation cooling system in which contaminated water accumulated in buildings is reused for reactor cooling (Step I, II)
	Spent fuel pool	• Circulation cooling system (Step I)
II. Mitigation	Accumulated water	• Installation of storage/processing facilities (Step I)
	Ground water	• Mitigation of contaminated ground water (Step I, II)
	Atmosphere /Soil	• Dispersion of inhibitor (Step I, II) • Removal of debris (Step I, II)

6. Responses at Other Nuclear Power Stations

Responses at other Nuclear Power Stations

1. Emergency Safety Measures

- NISA instructed all electric power companies to implement emergency safety measures. (30 March)
- Based on the report from each electric utilities, NISA has confirmed that emergency safety measures had been appropriately implemented.(6 May)

2. Additional Emergency Safety Measures

- NISA and other relevant ministries are to improve and strengthen the emergency safety measures based on lessons learned from the accidents which are stated in the Government report to IAEA. (7 June)

3. Hamaoka NPS shutdown

- The government requested Chubu Electric Power Company to halt the operation of all units of Hamaoka NPS due to high possibility of large-scale tsunami resulting from the envisioned earthquake. (6 May)

4. Stress test

- The government announced to hold the stress test on NPPs. (6 July)

Outline of Emergency Safety Measures

Phase	Emergency Safety Measures	
	Short Term	Mid Term
Expected Time to Completion	Done	One to three years
Goals (Desired Level / Extent)	Preventing fuel damage and spent fuel damage even if (1)AC power supplies, (2)seawater cooling functions and (3)spent-fuel storage pool cooling functions are all lost.	Enhancing reliability of emergency safety measures (short term) (Securing/speeding up achievement of cold shutdown; measures against tsunami)
Examples of Specific Measures	【Securing Equipment】 ● Deploying power generator vehicles (to support cooling reactors and spent fuel pools) ● Deploying fire engines (to supply cooling water) ● Deploying fire hoses (to secure water supply routes from freshwater tanks, seawater pits, etc.) 【Preparing Procedural Manuals, Etc.】 ● Preparing procedural manuals for emergency responses utilizing the above-mentioned equipment 【Training to Respond】 ● Implementing training for emergency responses based on the procedural manuals 【Measures Against Flooding】 ● Measures to prevent flooding at reactor buildings assuming approx. 15-meter-high tsunami	【Measures Against Assumed approx.15-Meter Tsunami】 ●Building seawalls ●Installing water-tight doors 【Measures to Secure/Speed Up Achievement of Cold Shutdown】 ●Installation of air-cooled diesel power generators ●Securing back-up electric motors for seawater pumps ●Actions needed for other necessary equipment

Series of Events and Countermeasures in case of tsunami, for BWR

Fuel Pool

Reactor Containment

Emergency
Diesel Power
Generator

External Power Supply

DC Power Supply
(Battery)

Reactor
Pressure Vessel

Alternative Water Injection

Reactor Core
Isolation
Cooling System

Emergency Reactor
Cooling System

Pressure Suppression Chamber
Cooling Pump

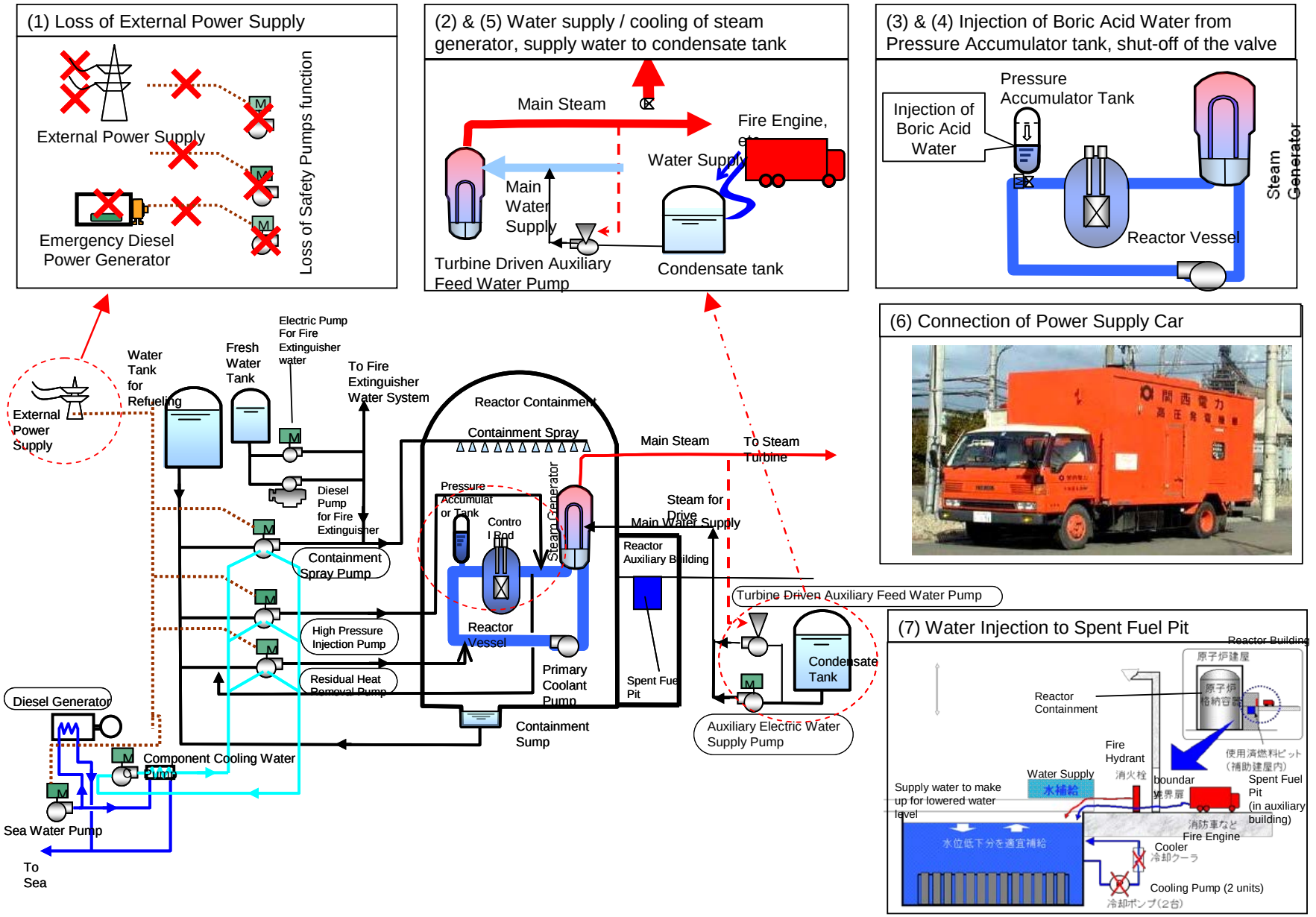
Ventilation
Stack

Sea Water Pump

Pressure Suppression Chamber

Pressure Suppression Chamber

Series of Events and Countermeasures in case of tsunami, for PWR



7. Nuclear Renaissance After Fukushima

Nuclear Renaissance After Fukushima

- Withdrawal from Nuke
  - Germany by 2022
  - Spain, Switzerland Gradually
- Delay of New Construction
  - USA, France,（Japan : Chaos）
- Promotion of New Construction
  - China, Korea, India, Russia, Finland, UAE
- New Comer to Nuke
  - Vietnam, Indonesia, Turkey, Poland, Jordan,
  - Saudi-Arabia, Belarus

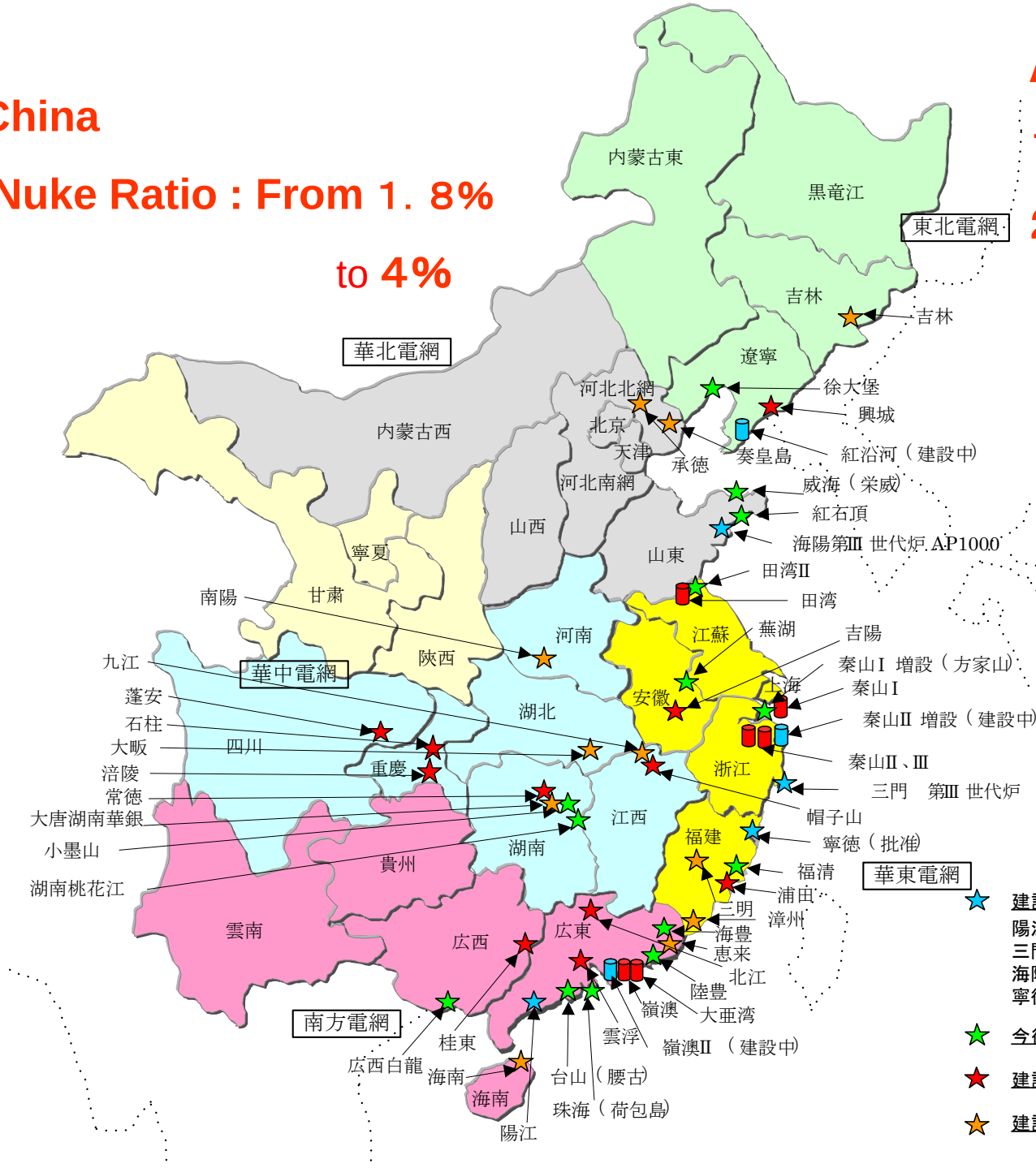
China

Nuke Ratio : From 1．8% to 4%

As of 2012

15 NPPs : Operating

27 NPPS :Under Construction



運転中　6サイト・11基　8,998MWe

秦山Ⅰ：1号機　（PWR　310MWe）
秦山Ⅱ：1, 2号機（PWR　各650MWe）
秦山Ⅲ：1, 2号機（CANDU　各720MWe）
大亜湾：1, 2号機（PWR　各984MWe）
嶺澳Ⅰ：1, 2号機（PWR　各990MWe）
田湾Ⅰ：1, 2号機（VVER-1000　各1,000MWe）

建設中　3サイト・8基　7,300MWe

秦山Ⅱ：3, 4号機（PWR　各650MWe）
嶺澳Ⅱ：1, 2号機（PWR　各1,000MWe）
紅沿河：1～4号機（PWR　各1,000MWe）

建設開始確実　4サイト・10基　10,320MWe

陽江：CPR1000　1,080MWe　4基
三門：AP-1000　1,000MWe　2基
海陽：AP-1000　1,000MWe　2基
寧徳：PWR　1,000MWe　2基

今後建設可能性が高いプロジェクト　13サイト

建設可能性はあるが未だ検討中のプロジェクト　12サイト

建設提案あるも建設可能性が低いプロジェクト　11サイト

Dubai　14 NPPs are planned by 2022（$ 100 Billion）

Dubai
Tower
828m
Hotel,
Mansion
Office
Dubai

7 Star Hotel on the Island（321m）

8.New Regulatory Body

NRA (Nuclear Regulation Authority) started Sept 19 last week

- Prime Minister instead of Japan' Parliaments assigned 5 commissioners.
- Mr. Tanaka ,First Chairman said

1. NRA will revise nuclear safety guide within this year including the severe accident management and countermeasure which was not included in the current one.
2. Early next year they will check all NPSs by the new one for the restart.

- Annual Budget is 630 Million Dollar
- Man Power : 480

Structure and functions of the NRA

For administrative purpose, the Nuclear Regulation Authority (NRA) is placed under the Ministry of the Environment (MOE).
However, independent personnel control from MOE is secured.
In the future independent budget will be secured.

NRA consists of :

- Commission

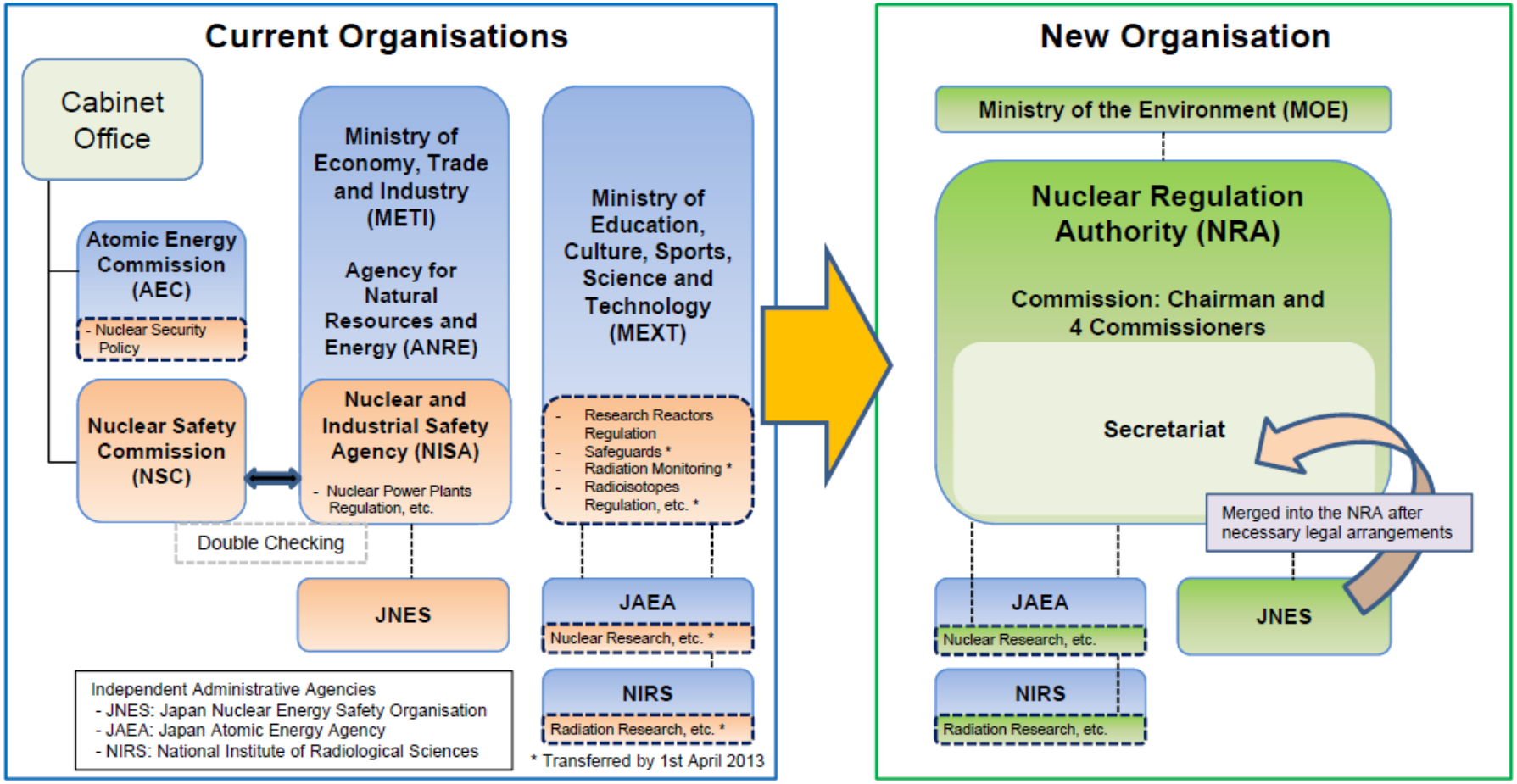
  One chairman and 4 commissioners are appointed by the Prime Minister after the approval of the National Parliament.

- Secretariat

  The NRA has a comprehensive function of nuclear regulation.

  - Nuclear Safety (from METI, MEXT and MLIT)
  - Nuclear Security (from METI, MEXT and AEC)
  - Nuclear Safeguards (from MEXT)
  - Radiation Monitoring (from MEXT)
  - Radioisotopes Regulation (from MEXT)

Independence: Separate nuclear regulation function and nuclear promotion function and establish the "Nuclear Regulation Authority (NRA)", as an independent commission body affiliated to the MOE. Chairman and Commissioners are appointed by the Prime Minister after the approval of the National Diet.
Integration: Integrate nuclear regulation functions, namely, nuclear safety, security, safeguards, radiation monitoring and radioisotopes regulation, into the NRA.



9.Conclusion on Nuclear Renaissance

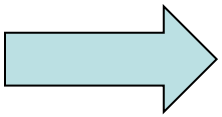
1. Before Fukushima accident, 438 new NPSs will be expected to start operation by 2025.
2. After Fukushima, Germany, Italy, Switzerland, Spain will quit the new construction of NPSs.
3. USA and Japan will delay the new construction.
4. China,Korea,India,Finland,and the new countries like Vietnam and UAE will continue to construct NPSs.
5. For these countries, we have to improve the safety by lessons learned from Fukushima.

Conclusion on Fukushima Accident

1. There exist a lot of the high radioactive materials in the Nuclear Power Plants and we should not release these to the public.
2. Fukushima made the bad human and organizational mistakes.
3. We have to remember the basic safety philosophy of the nuke.
4. Although the severely strong earthquake attacked Fukushima, the plant was safely stopped and cooled the core and kept all radioactive materials inside.
5. Tsunami damaged everything.

Conclusion on Fukushima Accident (No 2)

6. There are two major mistakes in Fukushima. One is the organizational issue. IAEA clearly stated that the complicated structures and organizations can result in delay in urgent decision making. We have to learn from Security Society.
7. Second one is the hardware. In the case of severe accident, the water , the electricity and the instrumentaion are essential.
8. In the world, all utilities formed the new organizations for the severe accident and they have already added the core supply water, other electricity and so on ,and the safety grade of the all nuclear power plants improved so much.



We learned a lot from Fukushima. We have to operate the nuclear power plants safely to supply the good quality, large scale, economical, clean electricity to the public in the world.


Thank you for your attention
For more information, please visit:
www.isoe-network.net
www.nea.fr