The Fukushima Accident and Implications for Nuclear Energy Policy

November 25, 2011

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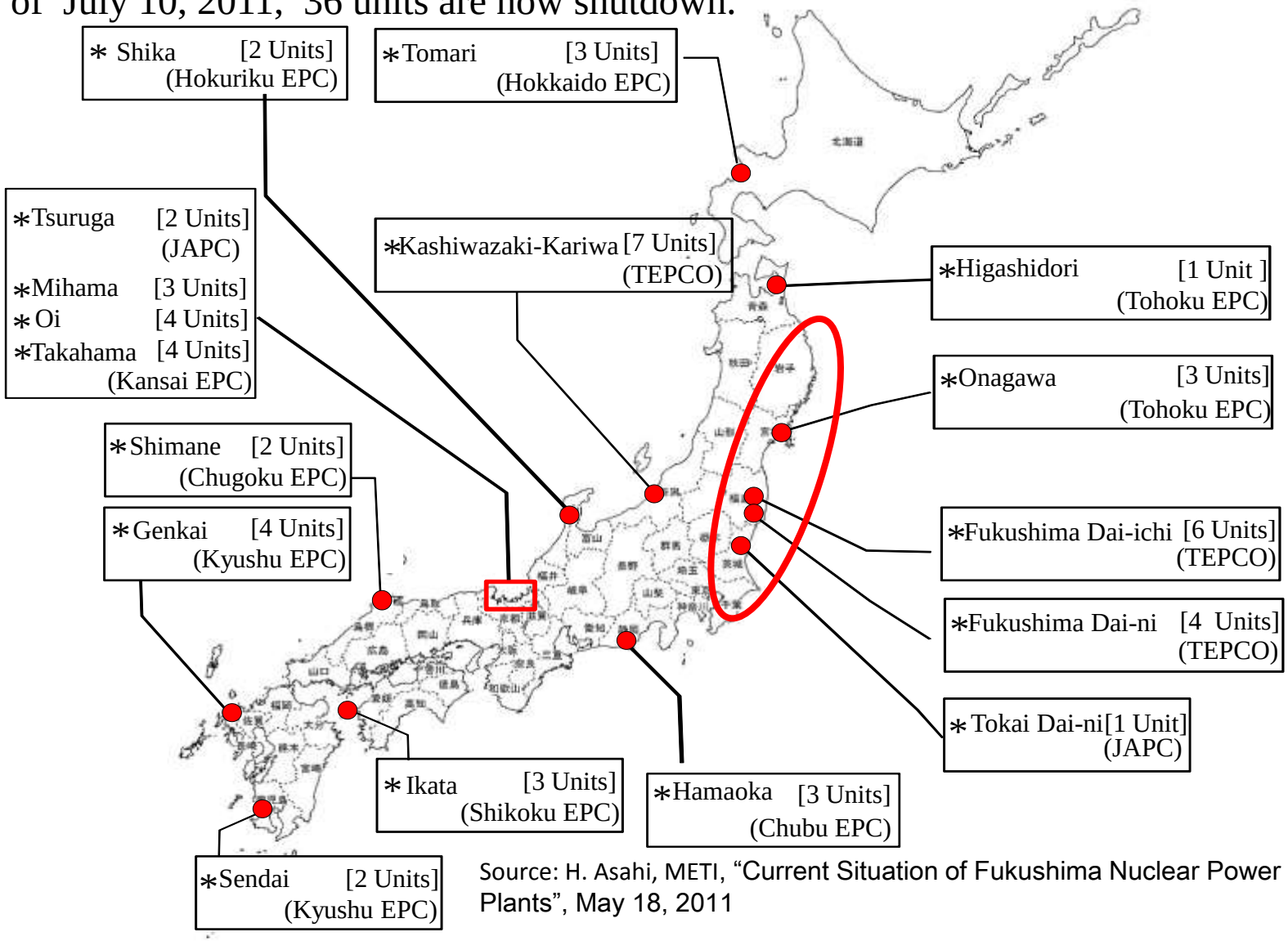
Note: The views expressed here are of my own and do not necessarily reflect those of the JAEC nor the government.

SUMMARY

- The 3/11 Fukushima nuclear accident triggered by the East Japan Great Earthquake and Tsunami has become one of the worst nuclear accident not only in Japan but also in the world, and not yet under control.
- In the short term, cold shutdown of the reactors, decontamination and recovery of life in Fukushima area, securing safety of existing reactors are the top priorities.
- For mid-long term, clean up the site is major challenge for us and it will probably take decades to do so.
- The government set up new policy making processes for wider public debate on future energy policy, while aiming at “reducing dependence on nuclear power.” Transparent national debate is essential for recovering public trust.
  - Atomic Energy Commission has restarted its deliberation process for Framework of Nuclear Energy Policy.

Location of Nuclear Power Stations in Japan

54 units (30 units of BWR and 24 units of PWR, total 49GW) in 17 sites
As of July 10, 2011, 36 units are now shutdown.



Source: H. Asahi, METI, "Current Situation of Fukushima Nuclear Power Plants", May 18, 2011

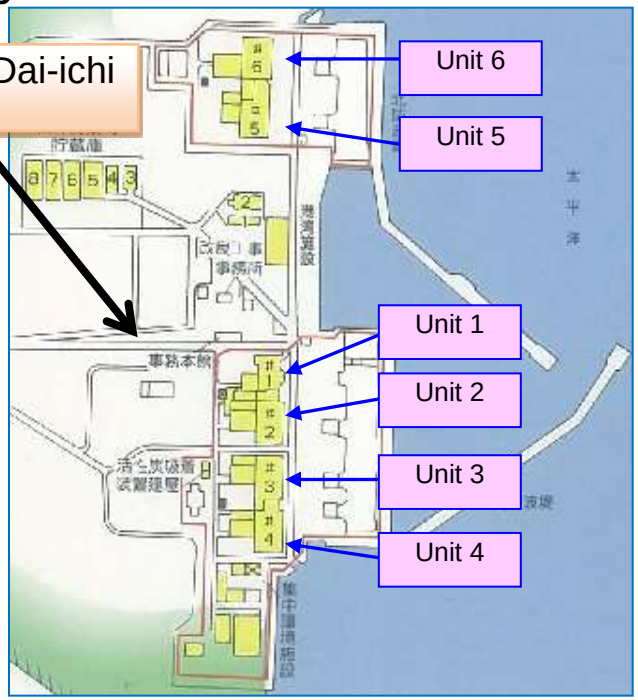
Location of NPSs within Fukushima

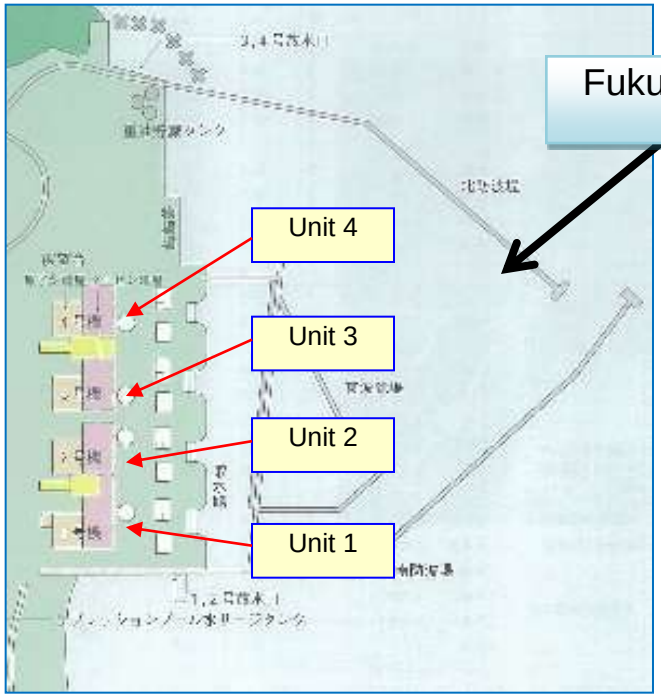
Fukushima Dai-ichi NPS

Fukushima Dai-ni NPS

Layouts of Fukushima Dai-ichi NPS and Fukushima Dai-ni NPS

Fukushima Dai-ichi NPS





Fukushima Dai-ni NPS

Loss of all power sources due to the Earthquake and Tsunami

Note:
- **All operating units when earthquake occurred were automatically shut down.**
- **Emergency D/Gs have worked properly until the Tsunami attack.**

① Loss of offsite power due to the earthquake

Grid Line

Tsunami (estimated more than 10m)

Turbine Building

Reactor Building

D/G

Elevation: about 10m

Seawater level

Seawater Pump

② D/G Inoperable due to Tsunami flood

①+② ⇒ Station Black Out

All Motor Operated pumps (including ECCS pumps) became inoperable

Source: Nuclear and Industry Safety Agency(NISA), April 4, 2011, at IAEA
http://www.nisa.meti.go.jp/english/files/en20110406-1-1.pdf

Fukushima Dai-ichi NPS Unit 1

(Status of the reactor core)

- 14:46 March 11: Loss of external power supply, Start-up of emergency diesel generators
- 14:52 March 11: Start-up of isolation condenser
- 15:37 March 11: Loss of all AC power
- 05:46 March 12: Start of fresh water injection from a fire extinguishing line

Water injection seemed to have stopped for 14 hours and 9 minutes.

- **around 17:00 March 11: The fuel was exposed, and the core melt started afterwards.**

Fukushima Dai-ichi NPS

(AC Power supply)

[External power supply] ➡ **[Emergency diesel generators]**

X	Yonomori -line No.1
X	Yonomori- line No.2
X	Okuma- line No.1
X	Okuma-line No.2
X	Okuma-line No.4
X	TEPCO nuclear line

earthquake

X	▭	(Unit 1)
X	▭	(Unit 1)
X	▭	(Unit 2)
X	▭	(Unit 2)
X	▭	(Unit 3)
X	▭	(Unit 3)
X	▭	(Unit 4)
X	▭	(Unit 5)
X	▭	(Unit 5)
X	▭	(Unit 6)
X	▭	(Unit 6)
O	▭	(Unit 6)

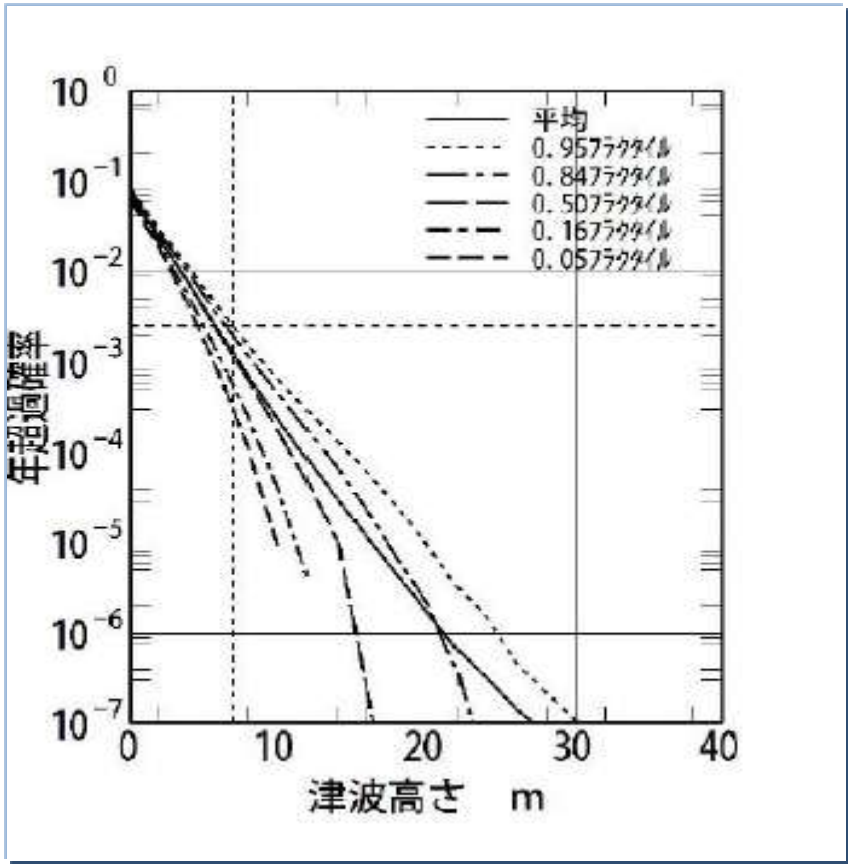
Tsunami

Safety Regulation on Sever Accident

- The Regulatory Guide for Reviewing Safety Design *does not take total AC power loss as a design basis event*.
  - *No particular considerations are necessary against a **long-term** total AC power loss*
  - the assumption of a total AC power loss is not necessary if the emergency AC power system is reliable enough
  - Loss of all seawater cooling system functions is not taken as a design basis event.
- Flammability Control System (FCS) is not aimed at preventing hydrogen combustion *inside the reactor building*
- In Japan, a civil standard on seismic PSA is also established, *while study of PSA related to other external events such as flooding has only started.*
- (Based on NSC decision in 1992).. licensees have taken *voluntary actions (not included in regulatory requirements),* such as measures to prevent accidents from becoming severe accidents

TEPCO Has Evaluated High-Tsunami

Tsunami Height Analysis（2010）



Tsunami Study has been reported to NISA

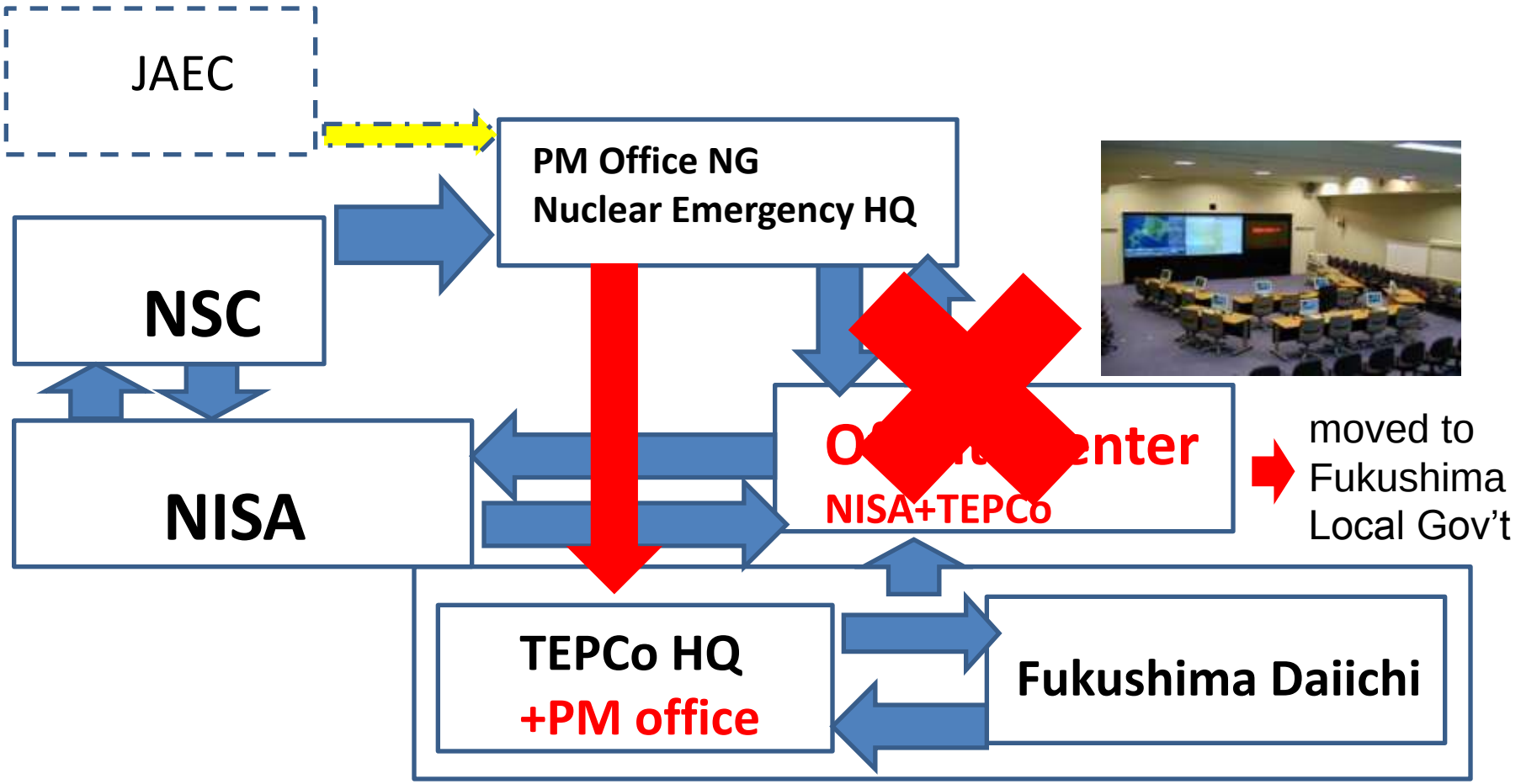
- 2008: TEPCO studied Jogan-Tsuhami
- June, 2009年: TEPCO asked civil engineering society to evaluate their analysis
- June 2009:TEPCO reported to NISA on preliminary results
- March 7, 2011: NISA was briefed on “possible 10m height tsunami at Fukushima.”

http://www.meti.go.jp/earthquake/nuclear/backdrop/20110911.html

Dry cask storage after 3.11 (@Fukushima)

http://www.tepco.co.jp/en/news/110311/images/110909_69.jpg

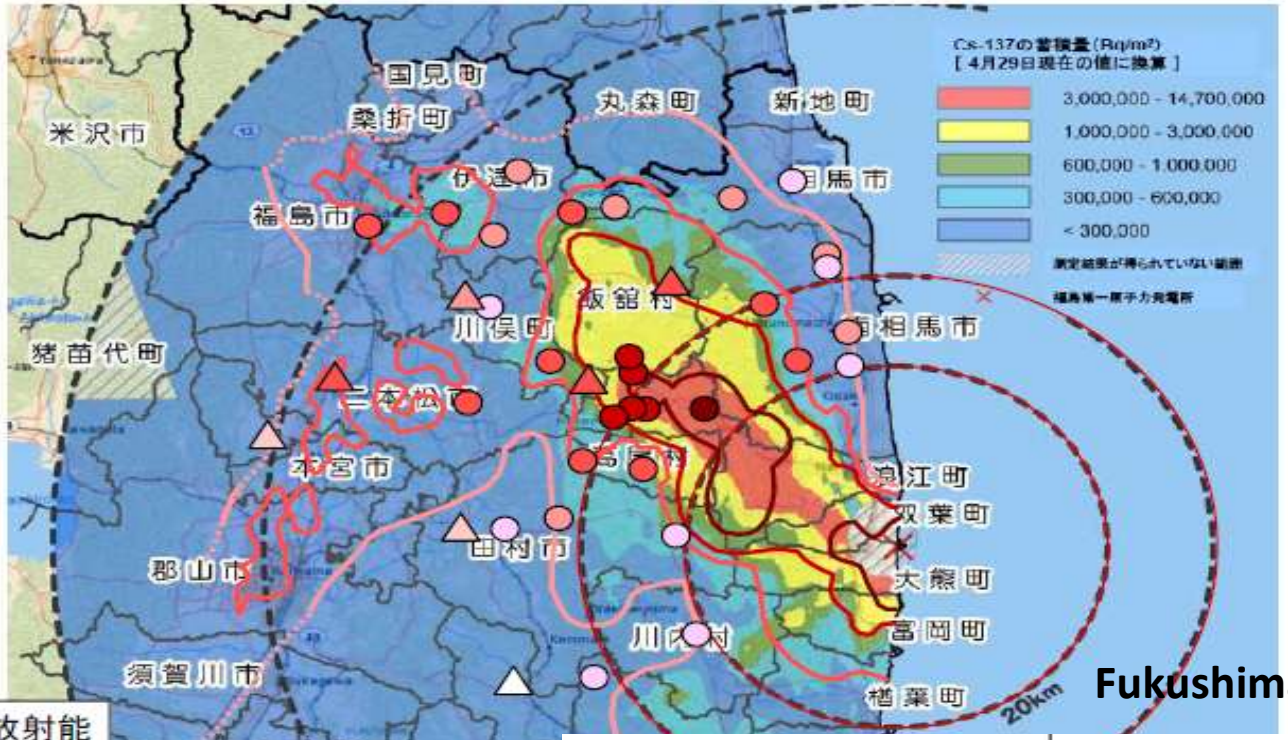
Nuclear Emergency: Institutional Arrangement under the Law*



*Act on Special Measures Concerning Nuclear Emergency Preparedness (ASMCNE)

Contamination Map by MEXT and DOE
(as of May 6, 2011)

5月6日公表文科省・米国DOE航空機モニタリング結果との重ね合わせ



Cs137放射能濃度

- 5000 kBq/m²以上
- 1480 kBq/m²以上
- 555 kBq/m²以上
- 185 kBq/m²以上
- 37 kBq/m²以上
- 37 kBq/m²以下

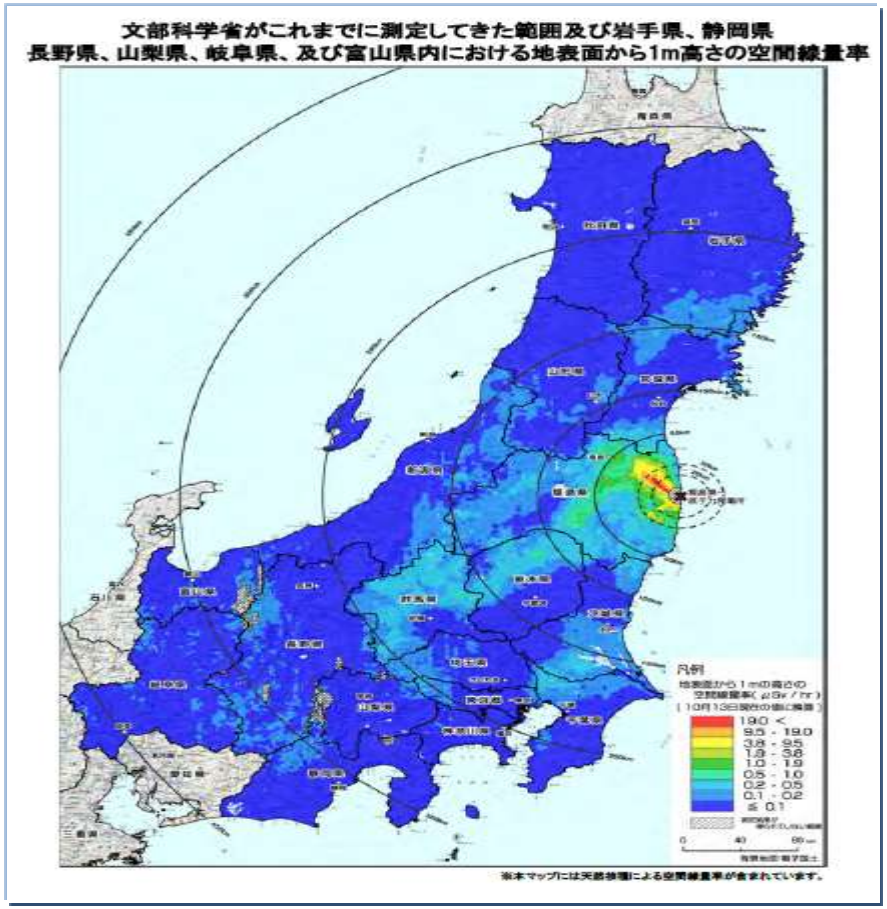
汚染レベル	今回の事故(注)	チェルノブイリ事故
555～1,480 kBq/m²の汚染地域	約 700 km²	約 7,200 km²
1,480 kBq/m²以上の汚染地域	約 600 km²	約 3,100 km²

Fukushima **Chernobyl**

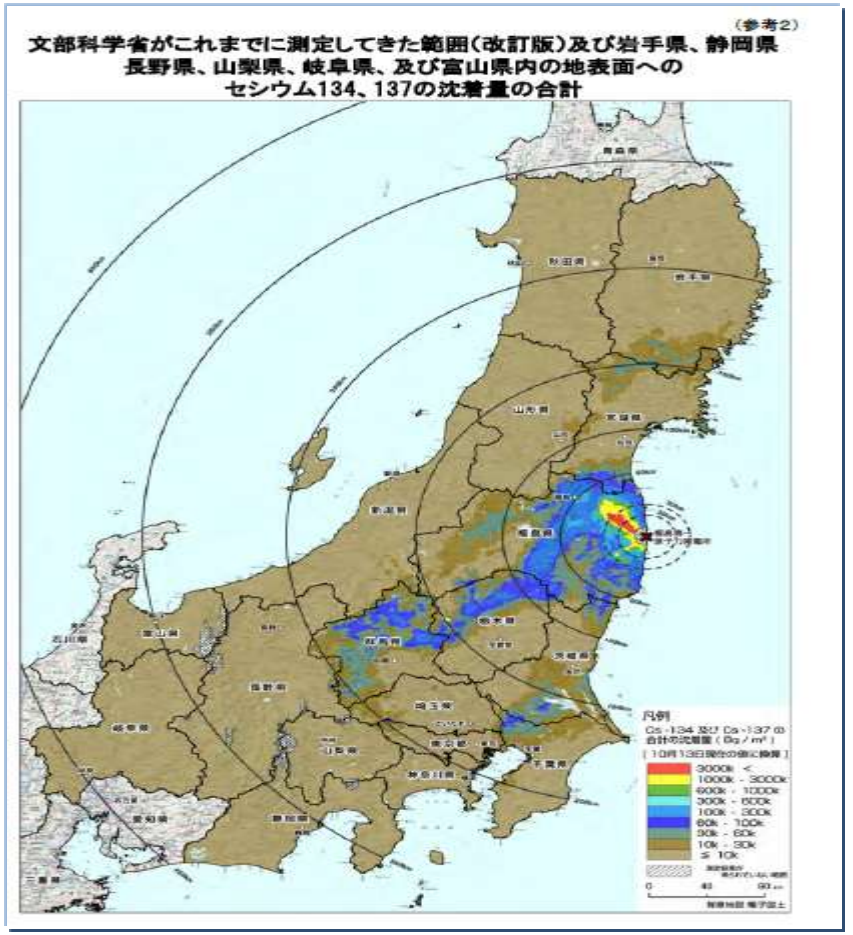
Source: T. Kawada, "Current Status of Soil Contamination and how to respond," Presentation at JapanAtomic Energy Commission Meeting, May 24, 2011
http://www.aec.go.jp/jicst/NC/iinkai/teirei/siryo2011/siryo16/siryo2.pdf

Cs 134, Cs 137 Concentration Maps

Air monitoring map

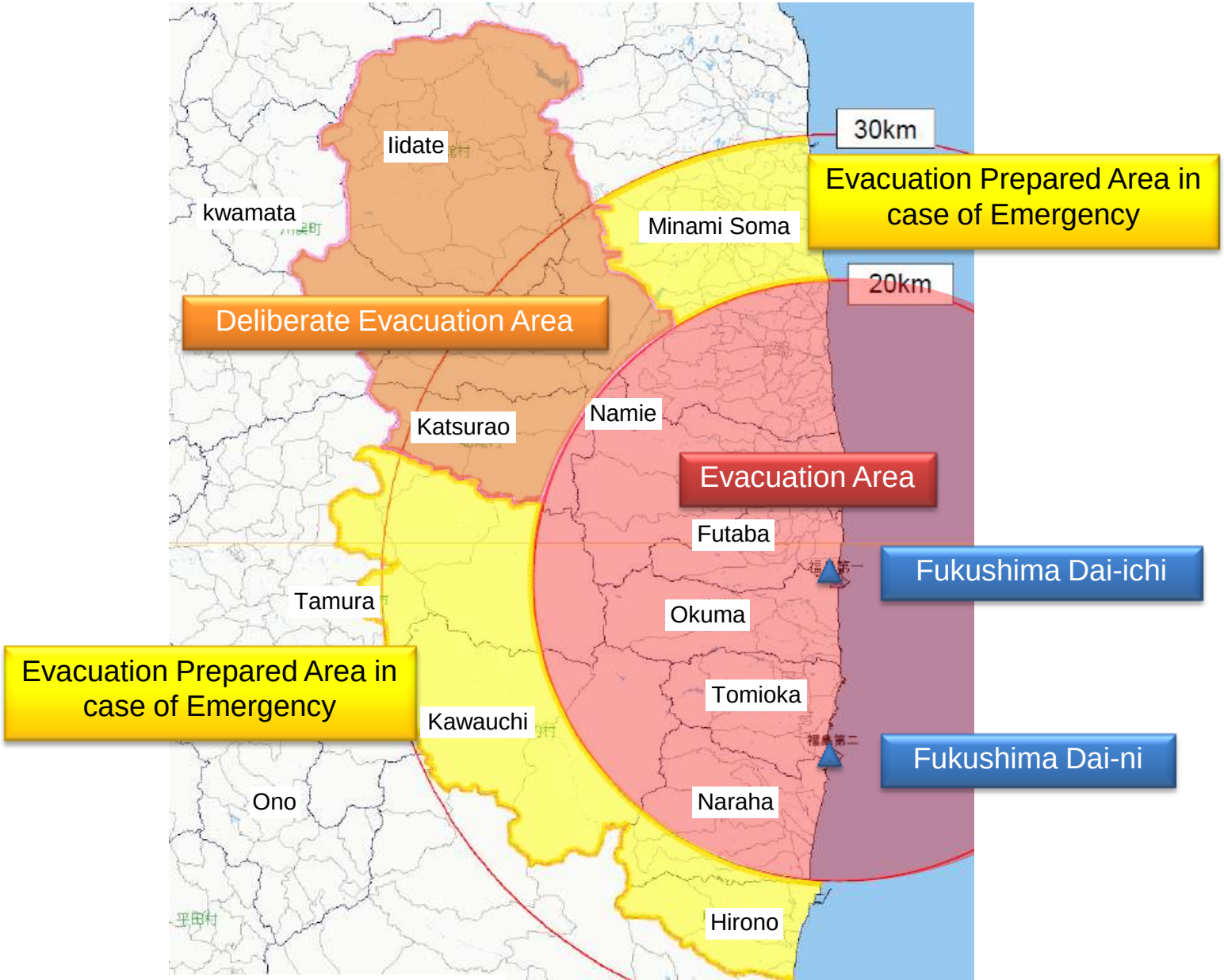


Ground concentration map

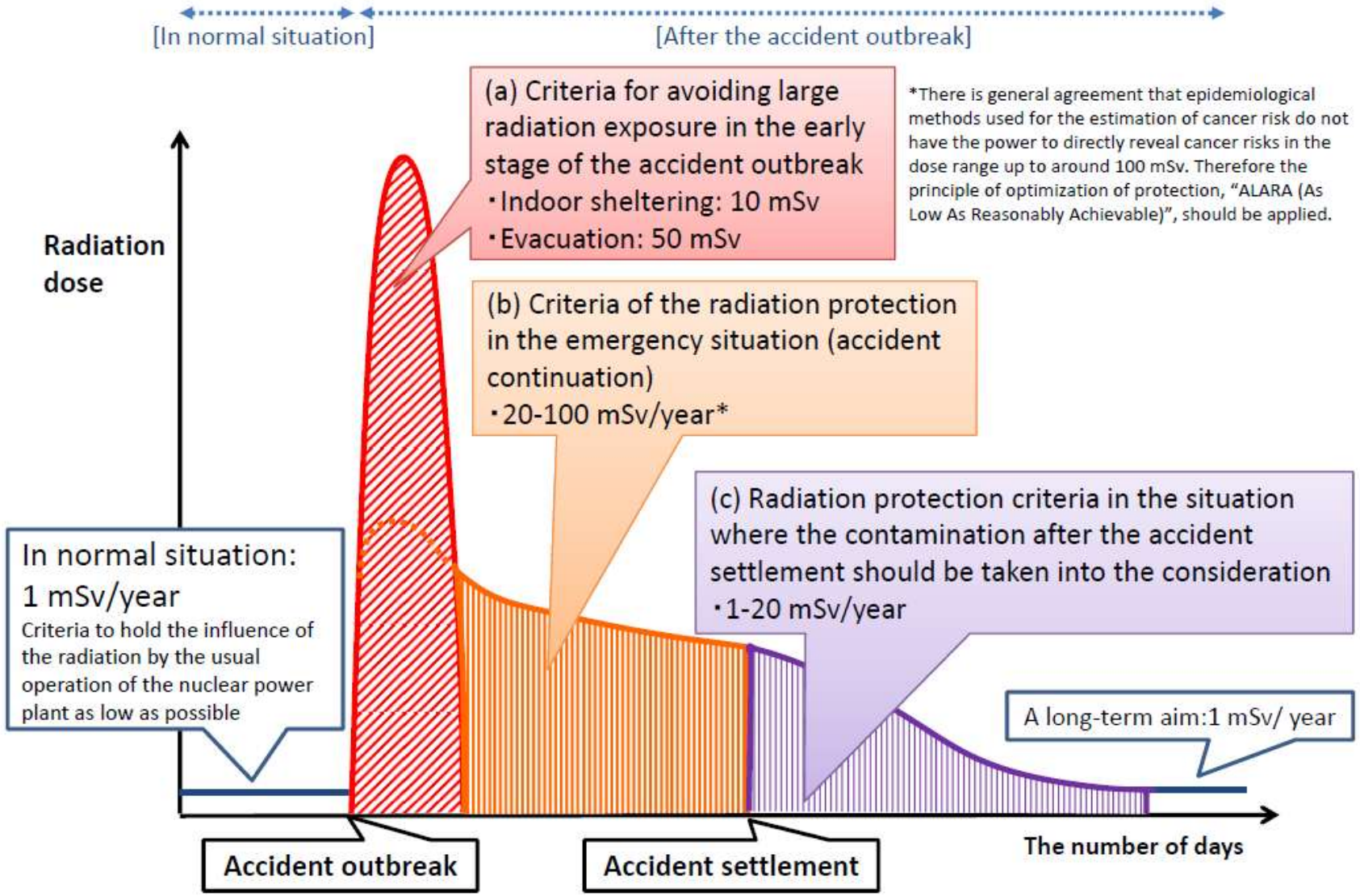


http://radioactivity.mext.go.jp/ja/1910/2011/11/1910_111112.pdf

Evacuation Areas



The idea of the criteria of the radiation dose for the radiation protection

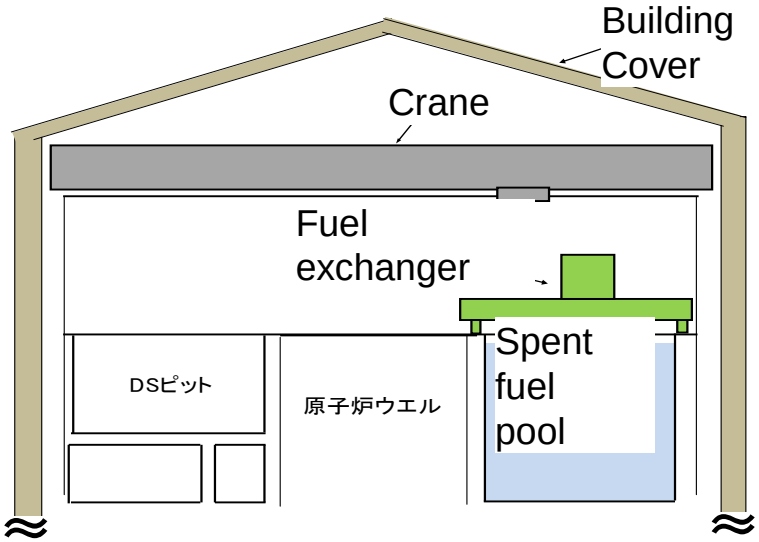


Removal of SF from SF pool

SF remain covered by water during and after the accident: sipping analysis suggests that SF is mostly intact, though some might be damaged by falling objects due to hydrogen explosion

1. Remove rubbles by crane

2. Install refueling machine & overhead crane



3. SF transfer by cask

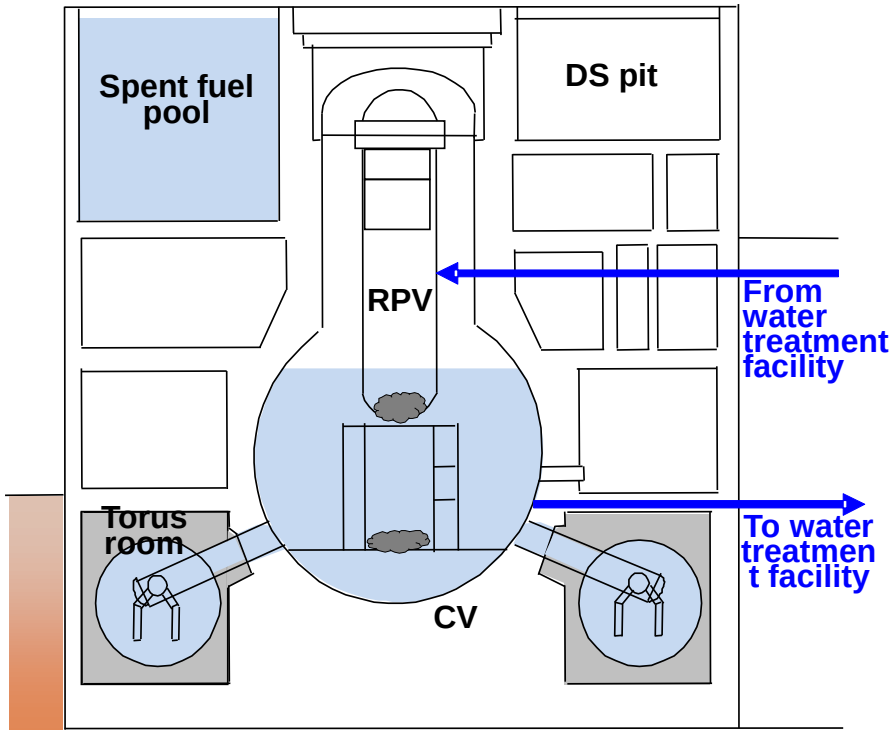
Removal of core debris

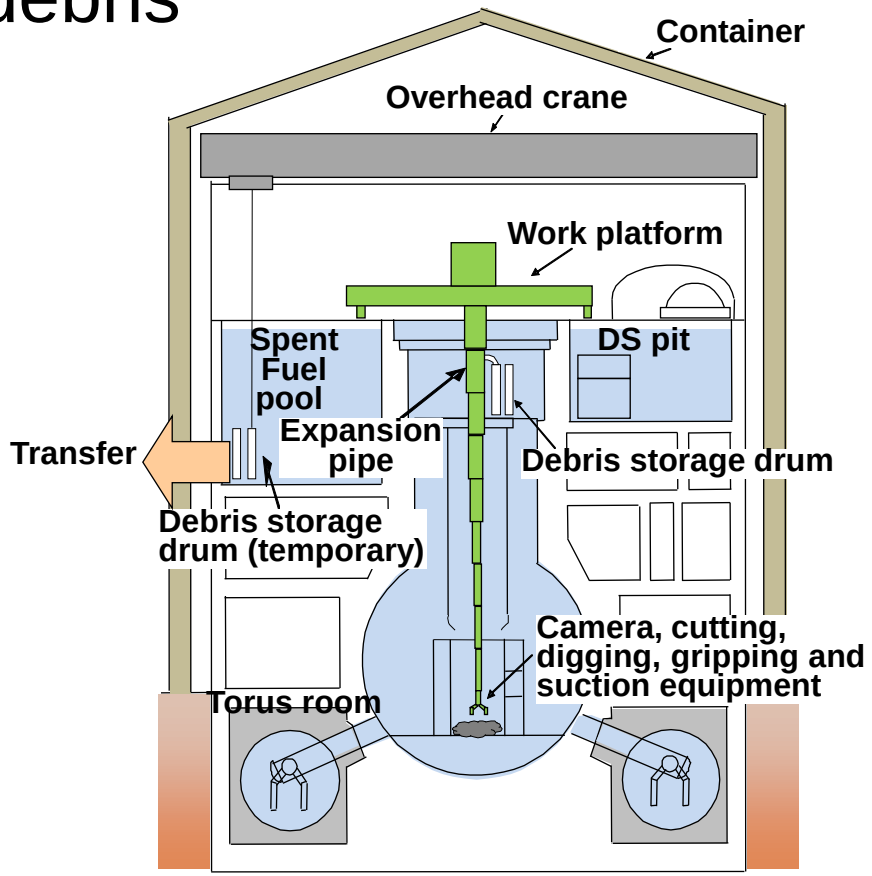
Decontamination (to reduce exposure)

→ Plugging the leaky holes

→ Flooding the containment

→ Removal of core debris





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 within this report. (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 within mid to long term countermeasures. (6 May)

Report of Japanese Government to the IAEA Ministerial Conference on Nuclear Safety (06/07/2011)

- 5 Categories 28 list of Lessons learned

1. Strengthen preventive measures against a severe accident
2. Enhancement of Responsive measures against a severe accident
3. Emergency responses to nuclear disaster accident
4. Robustness of the safety infrastructure established at the nuclear power station
5. Thoroughness in safety culture while summing up all the lessons.

Source: Nuclear Emergency Response Headquarters, Government of Japan,
”Report of Japanese Government to the IAEA Ministerial Conference on Nuclear Safety
-The Accident at TEPCO’s Fukushima Nuclear Power Stations -”, June 2011.
http://www.kantei.go.jp/foreign/kan/topics/201106/iaea_houkokusho_e.html

Establishment of New Nuclear Safety Agency:

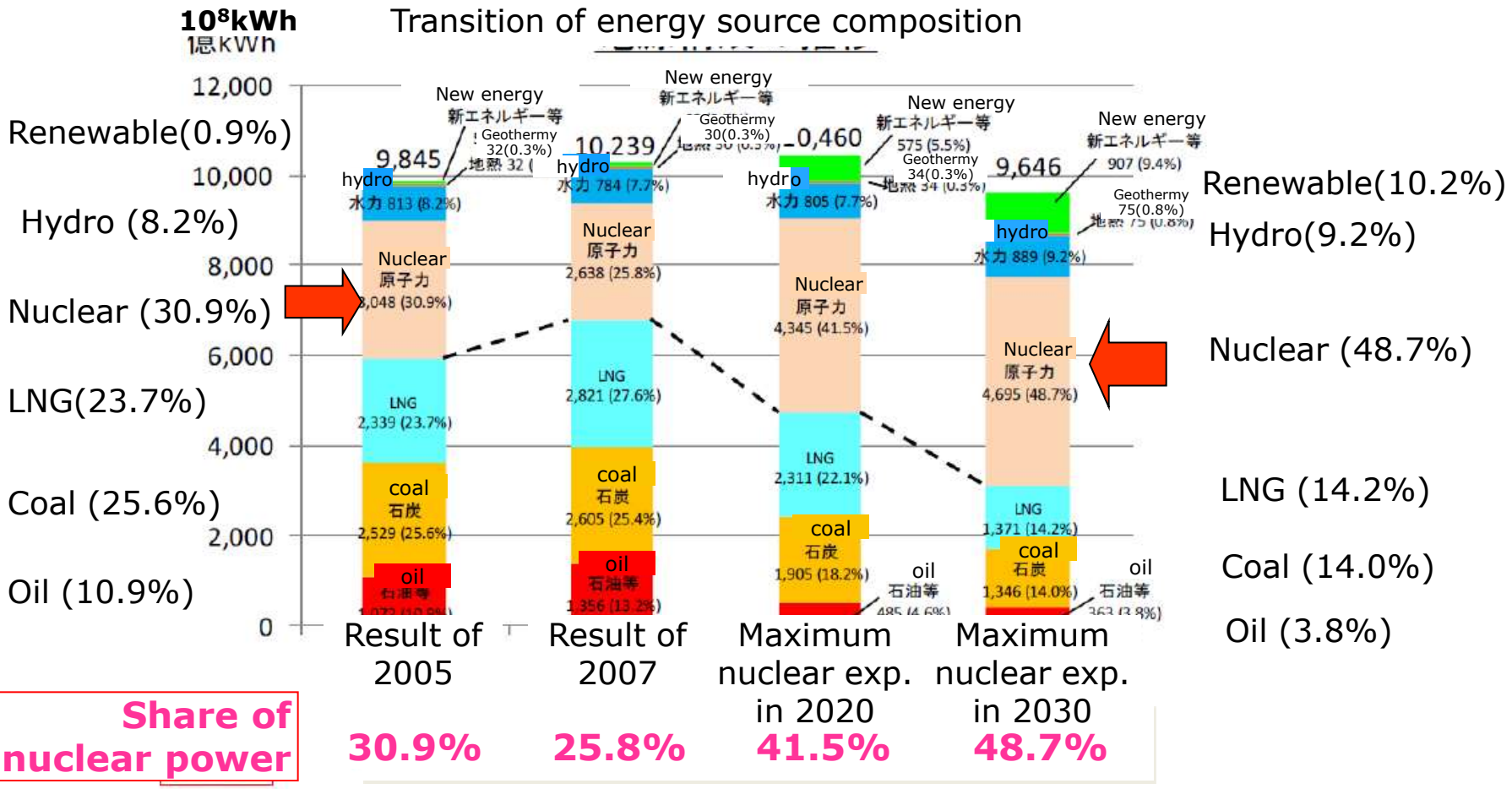
Additional Report to the IAEA by the Japanese Government (Sept. 15, 2011) :

"Basic Concept of Structural Reform of Nuclear Safety Regulations" at the Cabinet Meeting of August 15

- Launch of a new safety regulatory body, on the basis of the principle of "separating regulation from utilization," the nuclear safety regulatory divisions of NISA will be separated from the Ministry of Economy, Trade and Industry with a "*Nuclear Safety and Security Agency* (tentative name)" aimed to be established by April 2012 as an external agency of the Ministry of Environment by integrating into it the functions of the NSC.

http://www.kantei.go.jp/foreign/noda/topics/201109/201109_additional_report_all.pdf

Goal of Power Production Mix in 2030 (2010)



Source: Institute of Energy Economics, March 2010

More nuclear plants may face shutdown

All nuclear plants may face shutdown by May 2012

- Out of all 54 units: (as of Nov. 20, 2011)
  - 14 units are shutdown due to the Earthquake
  - 30 units are shutdown due to maintenance etc.
  - Only 10 units are now operating. All nuclear plants could be shutdown by May, 2012.
- The governor of Fukui said it will not approve the re-startup of nuclear reactors without new safety requirements. (May 20, 2011, Asahi)
- The governor of Hokkaido approved to restart the operation of Tomari #3. (Aug. 17, 2011)
- Scandals on public symposium have become political issues in Kyushu and Hokkaido.

Declining production of nuclear power

Capacity Factor

Nuclear Power Gen. (100MKwh

Source: Nikkei Shimbun, Aug. 23, 2011

PM Noda's Speech at UN High-level meeting on Nuclear Safety and Security (11/09/22)

- Japan will disclose to the international community all the information related to this accident, in both swift and accurate manner.
- Japan is determined to raise the safety of nuclear power generation to the highest level in the world.
- Japan stands ready to respond to the interest of countries seeking to use nuclear power generation.
- Japan will also participate actively in efforts to ensure nuclear security.
- Energy is the 'lifeblood' of the economy and serves as a foundation for the daily human lives.
- I should like to close my remarks by pledging that Japan, as the country in which this accident occurred, will dedicate itself to shouldering its responsibilities and taking action.

http://www.kantei.go.jp/foreign/noda/statement/201109/22speech_e.html

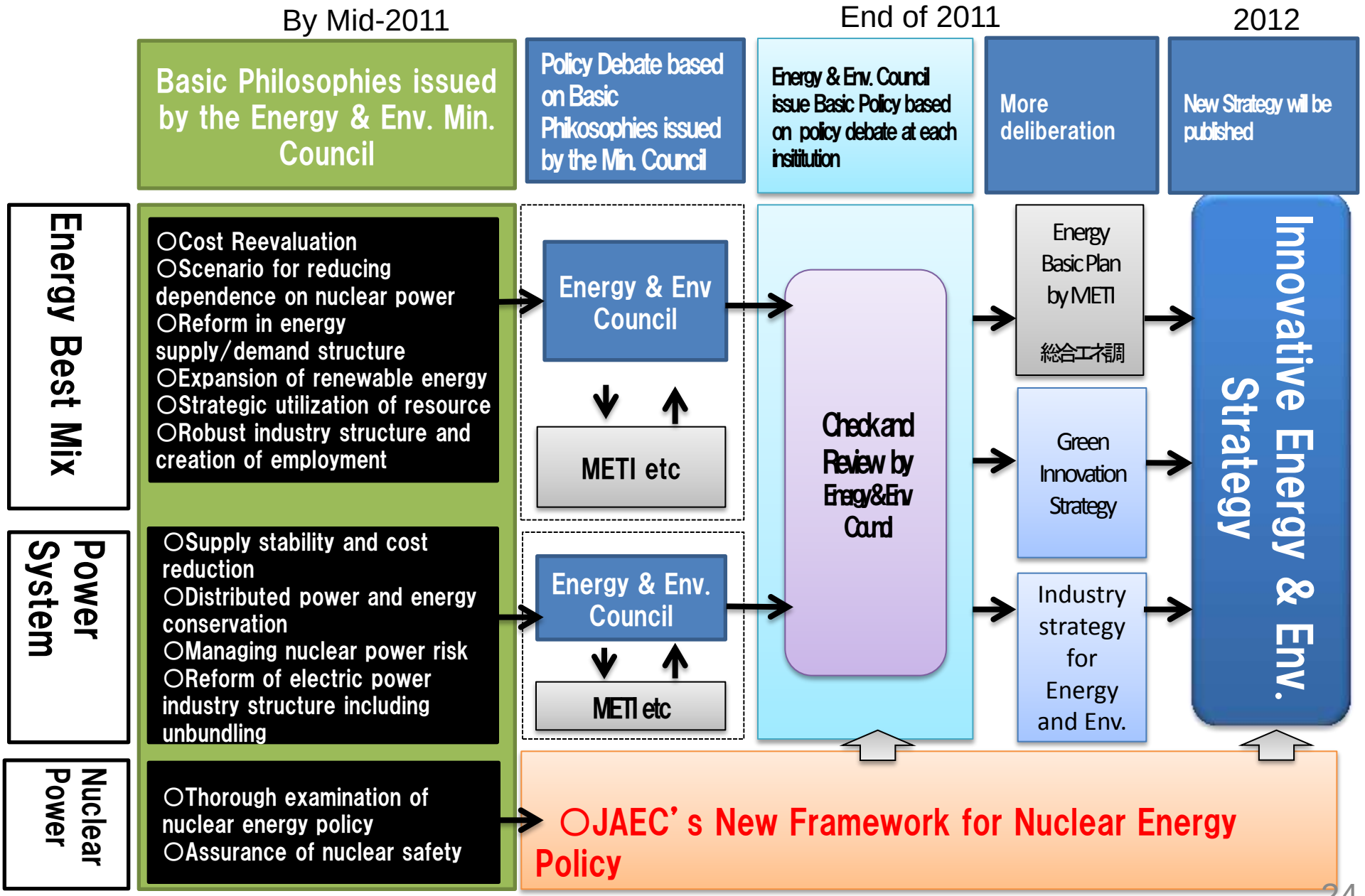
New Energy Policy: Three Philosophies (July 29, 2011) by Energy and Environment Min. Council

(1) Three principles toward new best energy mix (*reducing dependency on nuclear power*, strategic approach for energy security, *complete reevaluation of nuclear energy policy*)

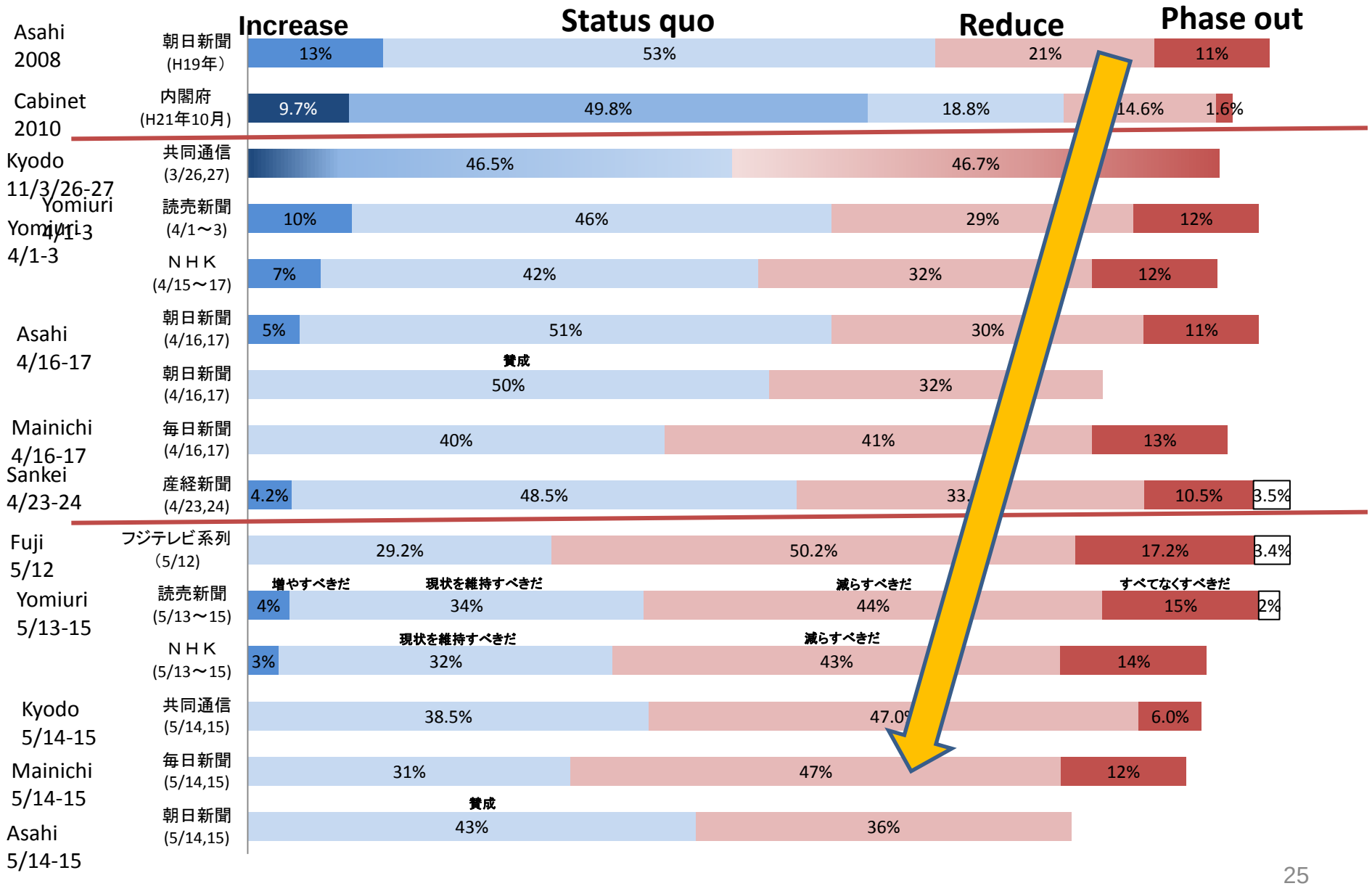
(2) Three principles toward new energy system (realization of distributed energy system, international contribution, multi-eyed approach)

(3) Three principles toward national consensus (*national debate in order to overcome "pro-" "anti-" conflict*, strategy based on objective data, dialogue with various sectors of the public).

6. Towards Innovative Energy and Environmental Strategy
—Structures for New Energy/Environmental Policy Making Processes—



Public Opinion Shifting to “reduce” and “phase out”



Japan Atomic Energy Commission (JAEC)

○The Role of Japan Atomic Energy Commission

The Japan Atomic Energy Commission is set up in the Cabinet Office and has five commissioners. Its mission is *to conduct planning, deliberations, and decision-making regarding basic policy for research, development, and utilization of nuclear energy, including the formulation of the Framework for Nuclear Energy Policy except matters related to nuclear safety*. When the JAEC deems it necessary as a part of its assigned mandate, *JAEC can recommend and demand reports of the head of relevant administrative organization through the Prime Minister*.

Members: 5 (appointed by the Prime Minister with the consent of the House of Representatives and House of Councilors)

Chairman
Dr. Shunsuke KONDO

Vice Chairman
Dr. Tatsujiro SUZUKI

Commissioner
Ms. Etsuko AKIBA

Commissioner
Dr. Mie OBA

Commissioner
Mr. Akira OMOTO

JAEC's Activities for Nuclear Energy Policy

- Restarted the deliberation process for new Framework for Nuclear Energy Policy (Sept. 27, 2011)
  - It was suspended after the 3/11 Fukushima accident
  - Members of the Committee have been changed slightly to reflect changing circumstances after the accident
  - Major issues: Safety, Cost, Nuclear Power and Fuel Cycle Options, Waste Management, International Perspectives, R&D planning, etc.
- Established Sub-Committee on Issues for Nuclear Power and Fuel Cycle Technology Technologies
  - 7 expert members (Chair: Tatsujiro Suzuki)
  - Identify options and criteria for evaluations
  - Identify key differences of cost estimates/evaluations over different options
  - Submit key findings to the JAEC (as necessary)

Table 2 Nuclear Fuel Cycle Cost of a Model Plant

Costs of Three Cycle Models (1) —Discount rate: 3%, 5%—

(yen/kWh)

Items	Discount rate: 3%			Discount rate: 5%		
	Reprocessing model	Direct disposal model	State-of-the-Art model	Reprocessing model	Direct disposal model	State-of-the-Art model
Uranium fuel	0.73	0.81	0.77	0.81	0.88	0.86
MOX fuel	0.15	–	0.07	0.14	–	0.04
(Total at the front end)	0.88	0.81	0.84	0.94	0.88	0.90
Reprocessing, etc.	1.03	-	0.46	1.04	-	0.30
Temporary storage	–	0.09	0.05	-	0.07	0.04
High-level radioactive waste disposal	0.08	–	0.04	0.05	–	0.01
Direct disposal	–	0.10–0.11	–	–	0.05–0.05	–
(Total at the back end)	1.11	0.19–0.21	0.55	1.08	0.12–0.12	0.36
Total	1.98	1.00–1.02	1.39	2.03	1.00–1.01	1.26

(Note) The total may not correspond to the sum of all the items due to rounding. (Sending end)

Table 3 Estimation of the Accident Risk Cost based on the Frequency of Occurrence of Damage

Accident Risk Cost of a Model Plant

Frequency of occurrence (/reactor year)	Accident risk cost of the model plant, by operation rate (yen/kWh)			Additional cost per increase in the amount of damage by 1 trillion yen (yen/kWh)		
	Utilization factor 60%	Utilization factor 70%	Utilization factor 80%	Utilization factor 60%	Utilization factor 70%	Utilization factor 80%
1.0×10^{-5} (IAEA safety goal for an early large release from an existing reactor)	0.008	0.007	0.006	0.002	0.001	0.001
3.5×10^{-4} (Frequency of severe accidents at commercial reactors around the world; equivalent to once every 57 years[1])	0.28	0.24	0.21	0.06	0.05	0.04
2.0×10^{-3} (Frequency of severe accidents at commercial reactors in Japan; equivalent to once every 10 years[1])	1.6	1.4	1.2	0.32	0.27	0.24

[1] Frequency of occurrence of accidents on the condition that 50 power reactors are in operation

Table 3 Estimation of the Accident Risk Cost in Reference to the Insurance Scheme

Estimation of the Accident Risk Cost under the U.S. Mutual Aid Scheme

- Amount of damage, including expenses for decommissioning reactors, as estimated by the Subcommittee in relation to the model plant: 4.9936 trillion yen
- Exclusively for the purpose of making estimation, the Subcommittee calculated the amount of damage as 5 trillion yen based on the assumption that there is a mutual assistance scheme for nuclear plant operators in reference to the Price-Anderson Act. As a result of sensitivity analysis, the estimated amount of damage nearly doubled to 10 trillion yen.

Amount of damage	Period of payment	Total nuclear power generation [1]	Accident risk cost
5 trillion yen	40 years	280.0 billion kWh	0.45 yen/kWh
10 trillion yen			0.89 yen/kWh

[1] Actual result in FY2010, Energy and Environment Council

  - The amount of damage could be further reduced if it is shared among nuclear plant operators around the world.

Report from the Advisory Committee on Nuclear Security, Japan Atomic Energy Commission (Sept. 5, 2011)

Lessons Learned from the Fukushima Accident

1) Strengthen Nuclear Security Measures

- Considering that accident, there is a clear necessity of stronger nuclear security measures for facilities and equipment

2) Strengthen measures against Internal Threats

- Control of entry and exit was clearly insufficient during the accident's initial period. Licensees should strengthen measures against internal threats, including thorough measures to prevent trespassing.

3) Strengthen Education and Training

- It is clearly important to provide emergency response training which hypothesizes very severe situations.

4) Strengthen Nuclear Security System

- In response during emergency, quick response under a clear chain of command is clearly important. Similar to ensuring safety, for ensuring nuclear security during emergencies, the government should allocation of roles in the government, clarify the chain of command, and arrange its approach to radiation safety in order.