Fukushima Status and Lessons

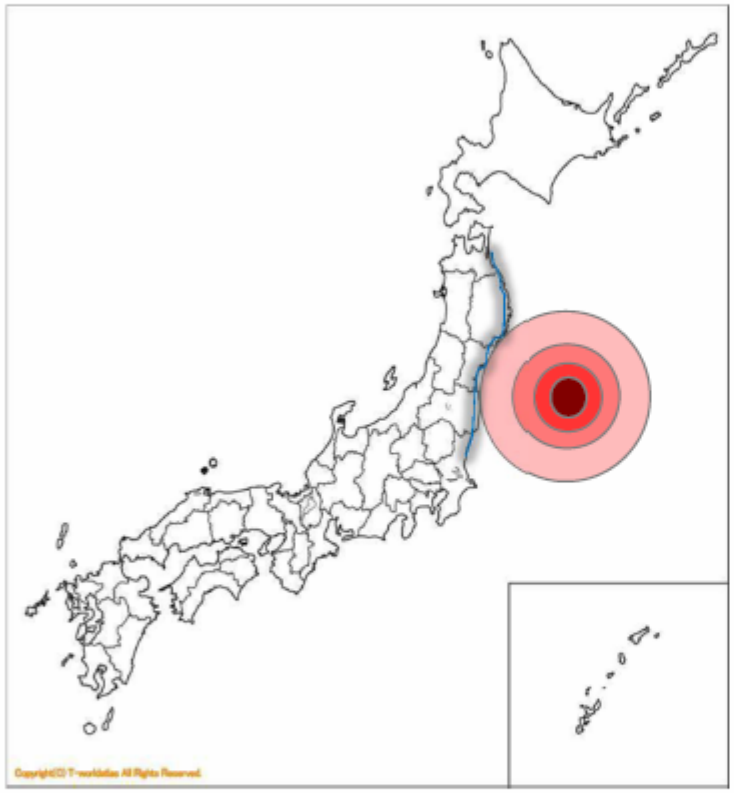
LAS/ANS Symposium on **Fukushima Outcomes: The impact on Latin American Nuclear Power Programs**

2 to 5 July 2012.

Rio de Janeiro – Brazil

Kazuaki Matsui/ IAE

Unprecedented challenge for Japan



The Great East Japan Earthquake

Earthquakes

Main shock

- Magnitude : 9.0 (Mar. 11th 2011)

Aftershocks

- Magnitude 7 or greater : 6 times
- Magnitude 6 or greater : 97 times
- Magnitude 5 or greater : 594 times
  (As of Feb 28th 2012)

Casualties

- **Dead : over 15,800**
- **Missing: over 3,200**
- **Injured: over 6,000** (As of Feb 21st 2012)

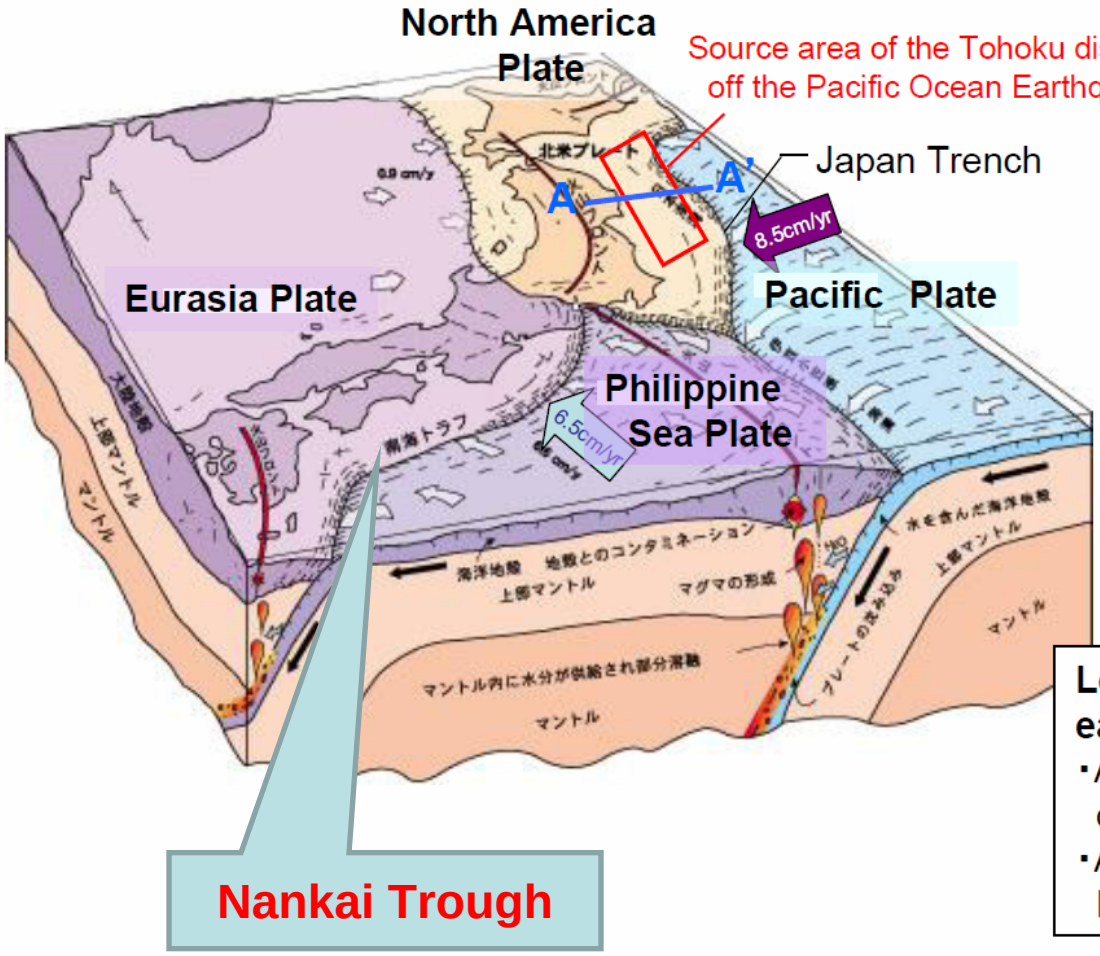
Evacuees

- **Over 342,000** (As of Feb 9th 2012)

Enormous earthquake, tsunami and nuclear accident

Source: Ministry of Economy, Trade and Industry

Plate Tectonics around Japan



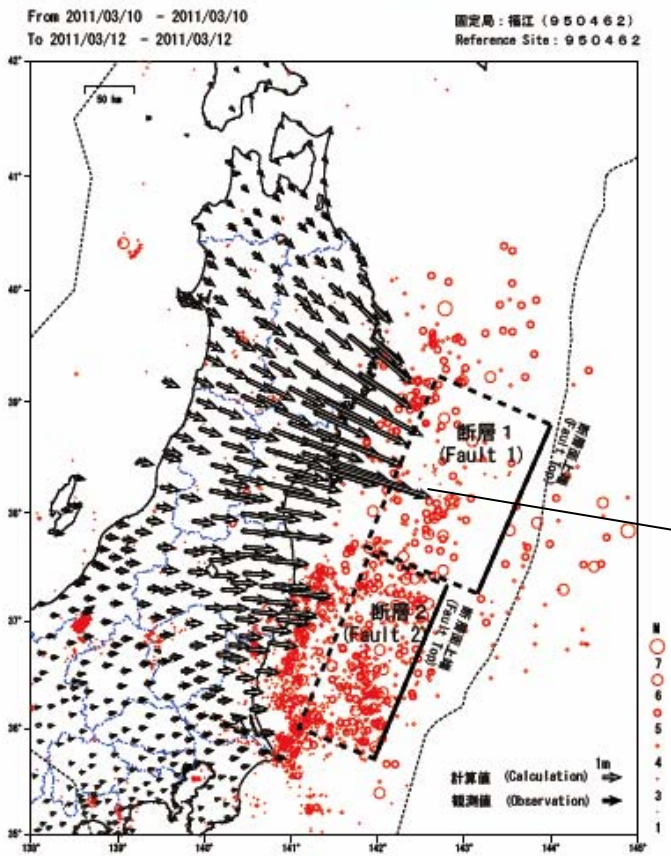
Plates structure around Japan
- Pacific Plate
- North America Plate
- Philippine Sea Plate
- Eurasia Plate

Plate Motion
- Pacific plate subducting under North America plate of 8.5 cm/yr in west direction
- Phillipine sea plate subducting under Eurasia plate of 6.5 cm/yr in north-west direction

Locations of principal interplate earthquakes
- Along Japan trench : Plate boundary of pacific plate and north America one
- Along Nankai trough: Plate boundary of Philippine sea plate and Eurasia one

The 2011 off the Pacific coast of Tohoku Earthquake on March 11, 2011: Fault Model By Geospatial Information Authority of Japan

1. Horizontal Displacement



星印は気象庁の震央（142.861°，38.104°）。
A Star indicates an epicenter released from JMA. (142.861°, 38.104°)
矩形断層二枚での推定結果。
Two rectangular faults with uniform slip are assumed.
西側に傾き下がる逆断層。モーメントマグニチュードは北側が8.8、南側が8.3。２つ合わせて8.9。
West-dipping reverse fault. Total moment magnitude: Mw8.9(Northern segment: Mw=8.8, Southern segment:Mw=8.3)
断層の長さは南北に約190kmの断層１と約190kmの断層２で合計約380km。
Total major rupture length: ~380 km (Fault Length: Northern segment ~190 km / Southern segment ~190 km)
赤丸は気象庁一元化震源（3/11-3/15）。
Red circles indicate epicenters determined by JMA. (3/11-3/15)

	緯度 Lat	経度 Lon	上端深さ Depth (Fault Top) km	長さ Length km	幅 Width km	走向 Strike	傾斜角 Dip	すべり角 Rake	すべり量 Slip m	Mw
断層１	38.80°	144.00°	5.1	186	129	203	16	101	24.7	8.8
断層２	37.33°	142.80°	17.0	194	88	203	15	83	6.1	8.3

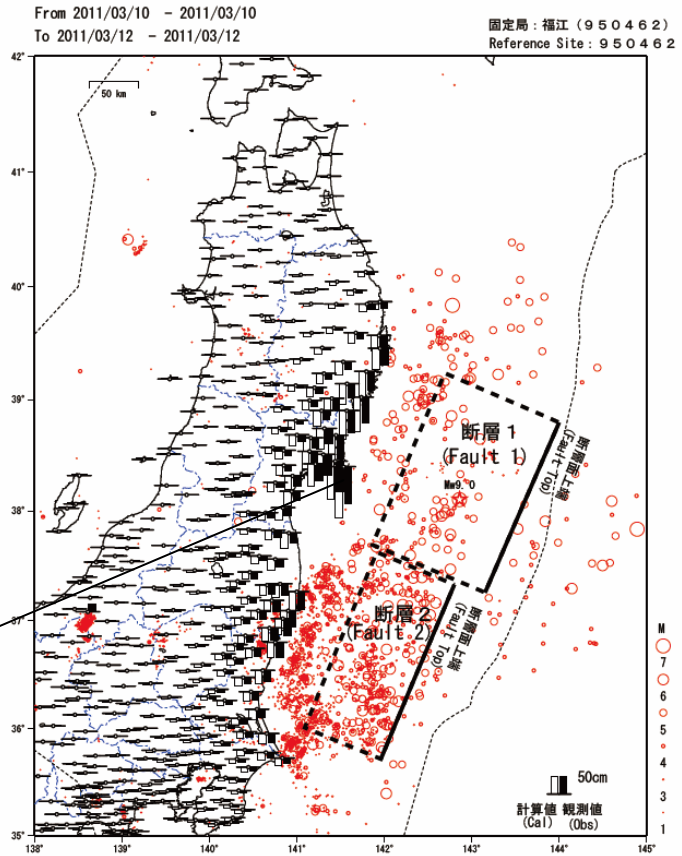
Lat=38.80 Lon=144.00 D=5.1km L=186.2km W=128.5km Strike=203deg Dip=16deg Rake=101deg Slip=24.69m Open=0.0m Mw=8.8
Lat=37.33 Lon=142.80 D=17.0km L=193.9km W=87.9km Strike=203deg Dip=15deg Rake=83deg Slip=6.12m Open=0.0m Mw=8.3

国土地理院資料
Geospatial Information Authority of Japan

5.3m

1.2m

2. Vertical Displacement



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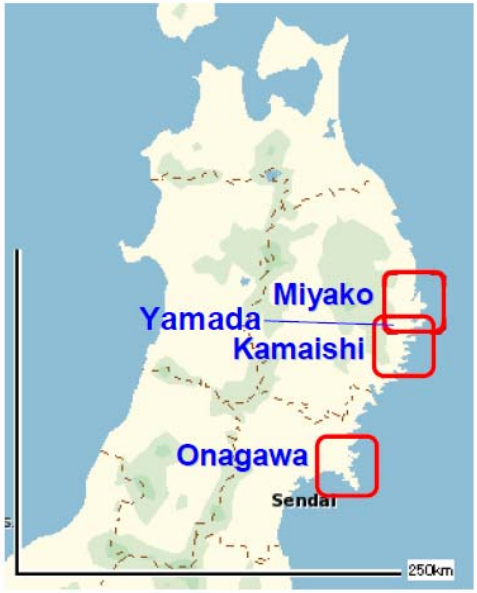
国土地理院資料
Geospatial Information Authority of Japan

Damages of Seawall and Harbor Installation

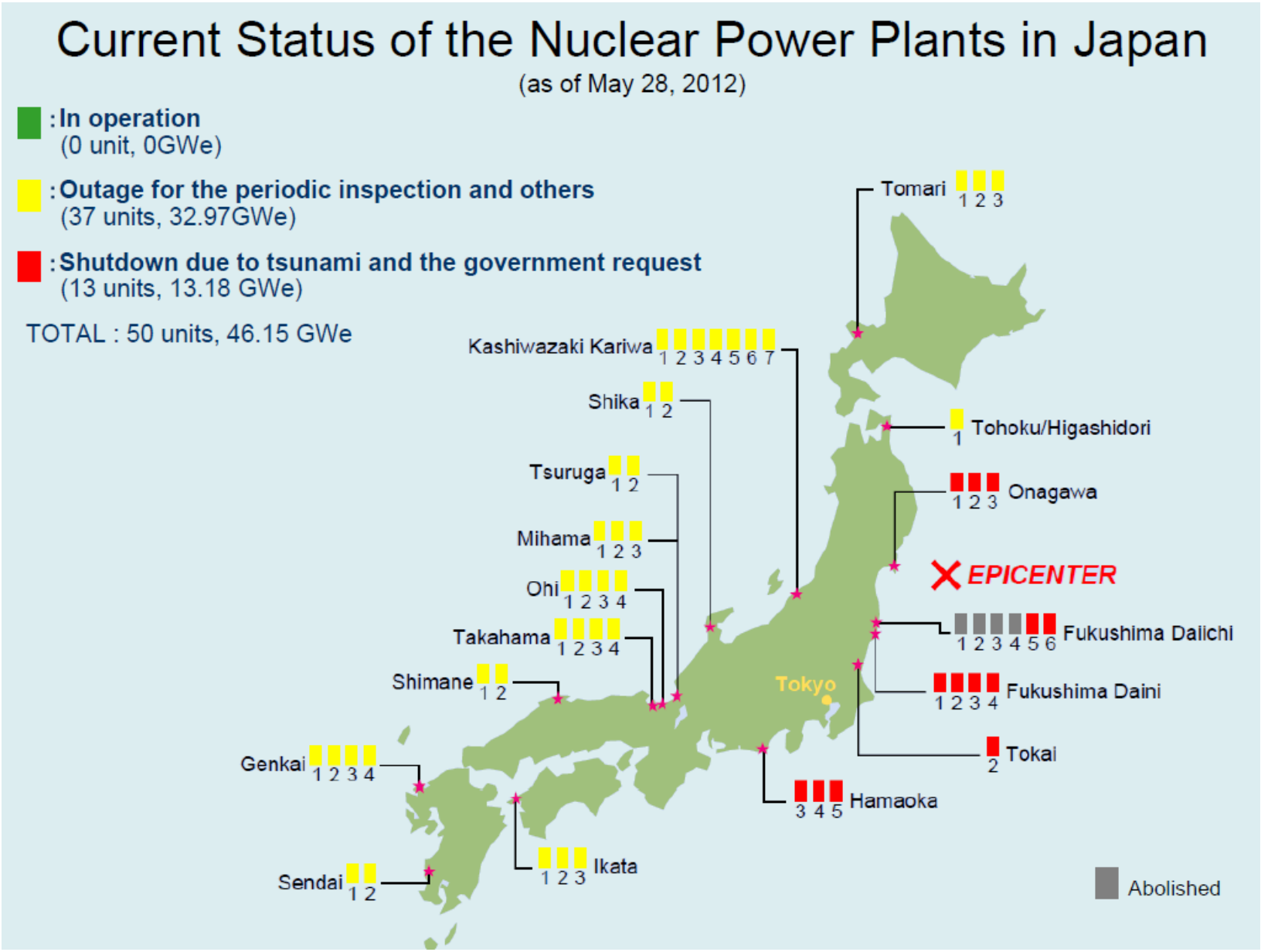


Destruction by tsunami scouring

Destruction by wave pressure

Current Status of the Nuclear Power Plants in Japan

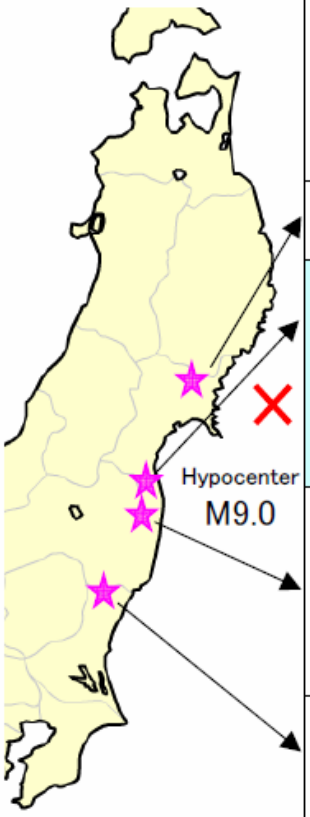
(as of May 28, 2012)



http://www.jaif.or.jp/english/news_images/pdf/ENGNEWS02_1332837013P.pdf

1. Fukushima Daiichi NPP Accident and Toward Decommissioning

Overview of the Accident (2/2)



○:Outage	Earthquake		Tsunami					Fuel Damage
	Power Supply (Off-Site Power/EDG)	Cooling Function: SWP	Tsunami Height (m)	NPP Altitude (m)	Power Supply: Off-site Power	Power Supply: EDG	Cooling Function: SWP	
Onagawa 1,②,3	○ (○/○)	○	13	13.8	○	○	○	Intact
Fukushima Dai-ichi 1,2,3,④ ⑤,⑥	○ (×/○)	○	15.5 (Submer-ged)	10 (Unit 1 to 4) 13 (Unit 5,6)	× (Tsunami)	**Unit 1 to 5** × Unit 6 ○	Unit 1 to 4 × Unit 5,6 ×→○ A few days later	Unit 1 to 3 (Damaged) Unit 4 to 6 (Intact)
Fukushima Dai-Ni 1,2,3,4	○ (○/○)	○	14.5 (Submer-ged)	12	○	Unit 1,2 × Unit 3,4 ○	Unit 1,2,4 ×→○ A few days later Unit 3 ○	Intact
Tokai Dai-ni 1	○ (×→○/○) A few days later	○	5.3	8	Earthquake ×→○ A few days later	○	○	Intact

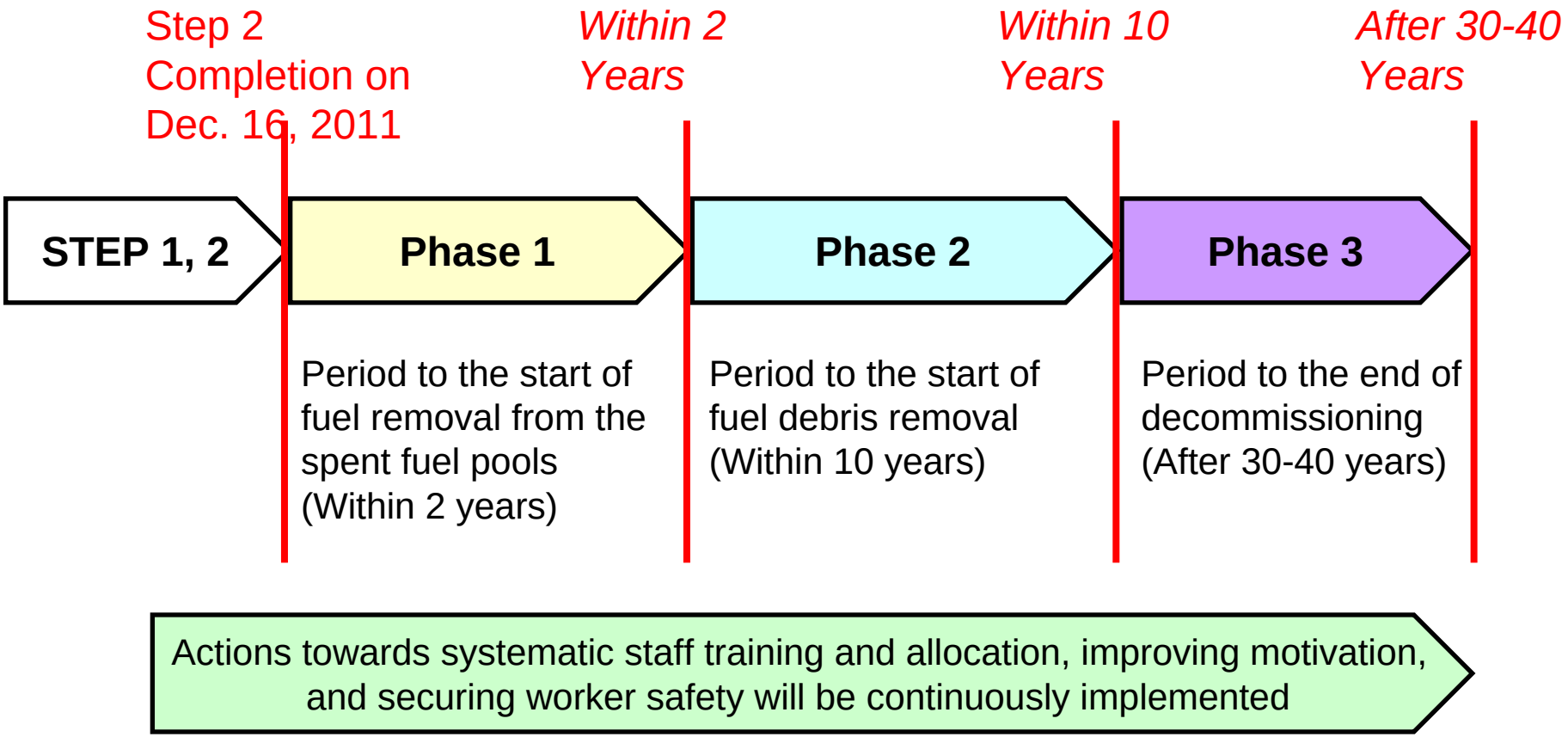
FEPC

Mid-to-Long-Term Decommissioning

- Fukushima Daiichi #1 to #4 decommissioning is much more complicated than the case of TMI-2
- Fuel in the Spent Fuel Pool is to start to be removed within 2,013, the next year
- Defueling from RPV is to start within 10 years.
- Defueling process may take over 20 to 25 years for completion
- Government supports with R&D have commenced for defueling and Fukushima Daiichi-Cleanup
- Flexible program management is must
- International supports and contribution to the activities would be appreciated.

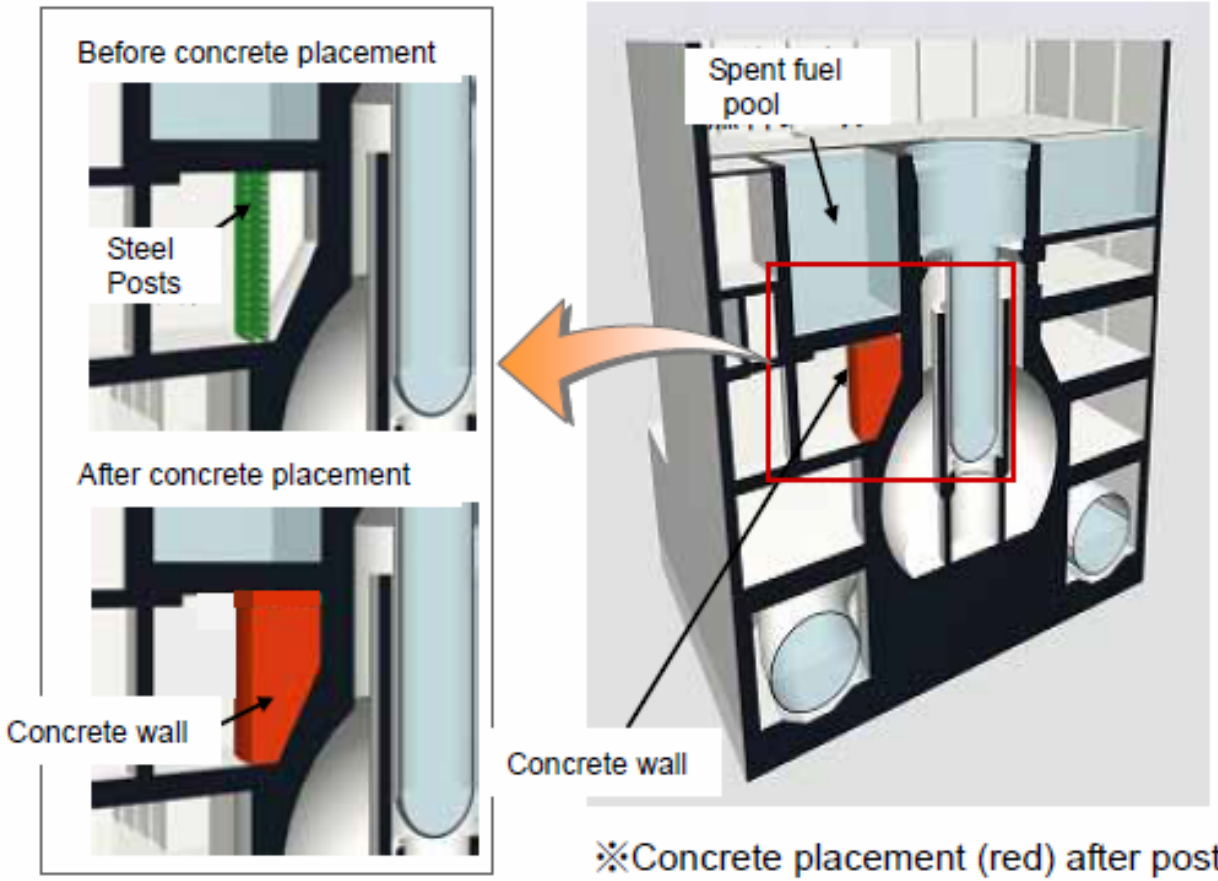
Mid-to-Long-Term Decommissioning Roadmap Outline

Mid-to-Long-Term Roadmap towards the Decommissioning of Fukushima Dai-ichi Nuclear Power Units 1-4



For more detail: http://www.meti.go.jp/english/earthquake/nuclear/decommissioning/index.html

Structural strength of #4 RB and SFP proved sufficient against another earthquake by analysis. In addition, 20% seismic safety margin increased by reinforcing the bottom of SFP



※Concrete placement (red) after posts installation (green)

http://www.tepco.co.jp/en/nu/fukushima-np/info/index-e.html

Photos by courtesy of TEPCO, June 12, 2012

1F-#4

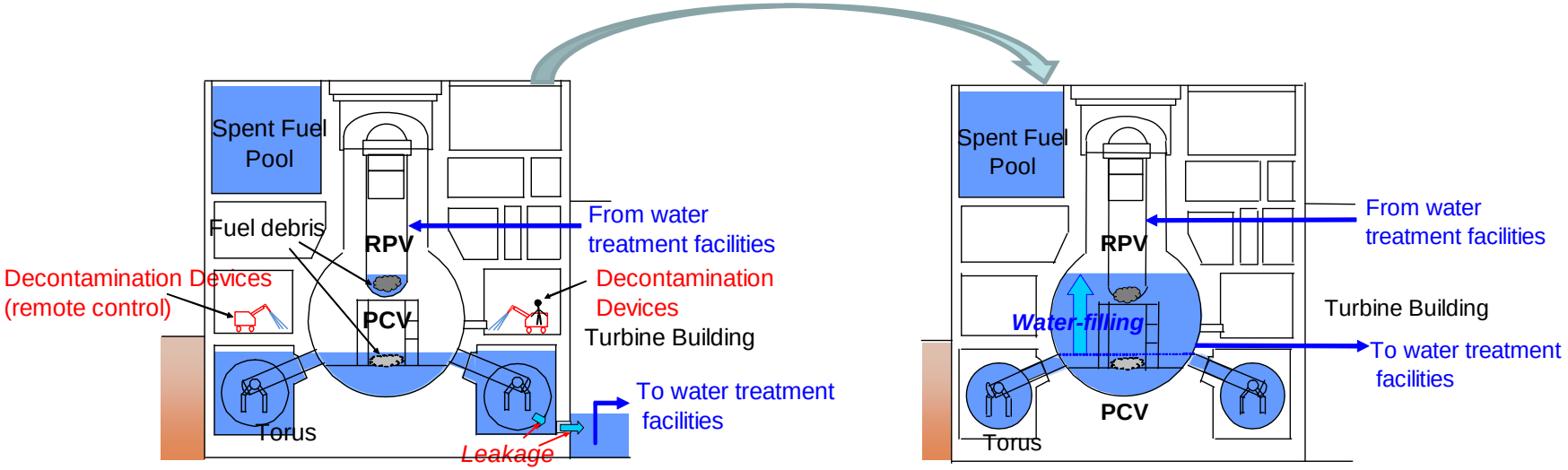
Top of SFP floor

1F-#4 operation

Look up SFP bottom

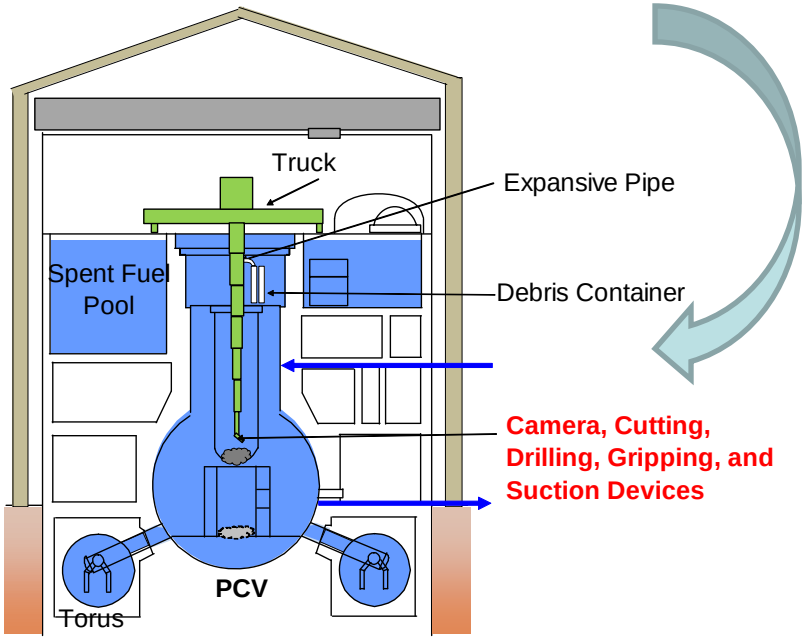
Check the concrete wall newly installed

Toward Fuel Debris Removal



Water levels at the bottoms of PCV #1, 2, 3

- #1; ~2 m
- #2; ~50 cm
- #3; ~5 m



3. Technological Knowledge about the Accident

- 5 categories, 30 countermeasures (in the interim report on Feb. 16, 2012)

External Power Supply Systems

On-site Power Supply Systems

Cooling Systems

Countermeasures for Containment Systems

Communication, Instrumentation and Control System, and Emergency Response Arrangement

- The presentation at IAEA International Experts' Meeting held on Mach 19-20, 2012 in Vienna

http://www.nisa.meti.go.jp/english/files/en20120321.pdf (Presentation material)

External Power Supply Systems (Reference)

Countermeasure 1 Improve reliability of external power supply system and grid

Countermeasure 2 Improve earthquake resistance of substation

Countermeasure 3 Improve earthquake resistance of switchyard

Countermeasure 4 Recover external power supply quickly

Nuclear and Industrial Safety Agency (NISA), IAEA/CSS 31, March 2012

On-site Power Supply Systems (Reference)

Countermeasure 5	Disperse On-site power equipment
Countermeasure 6	Enhance countermeasure for flooding
Countermeasure 7	Enhance diversity and redundancy of emergency AC power supply
Countermeasure 8	Enhance emergency DC power supply
Countermeasure 9	Prepare dedicated backup power supply
Countermeasure 10	Facilitate alternative power supply from outside
Countermeasure 11	Stock backup electrical equipment

Nuclear and Industrial Safety Agency (NISA), IAEA/CSS 31, March 2012

Cooling Systems (Reference)

Countermeasure 12 Improve the response capabilities for accidents

Countermeasure 13 Disperse the cooling water system and prevent flooding

Countermeasure 14 Enhance UHS at a time of accident

Countermeasure 15 Improve the maneuverability of isolation valves

Countermeasure 16 Enhance the alternative water injection functions

Countermeasure 17 Improve the reliability of cooling and injection system for spent fuel pool

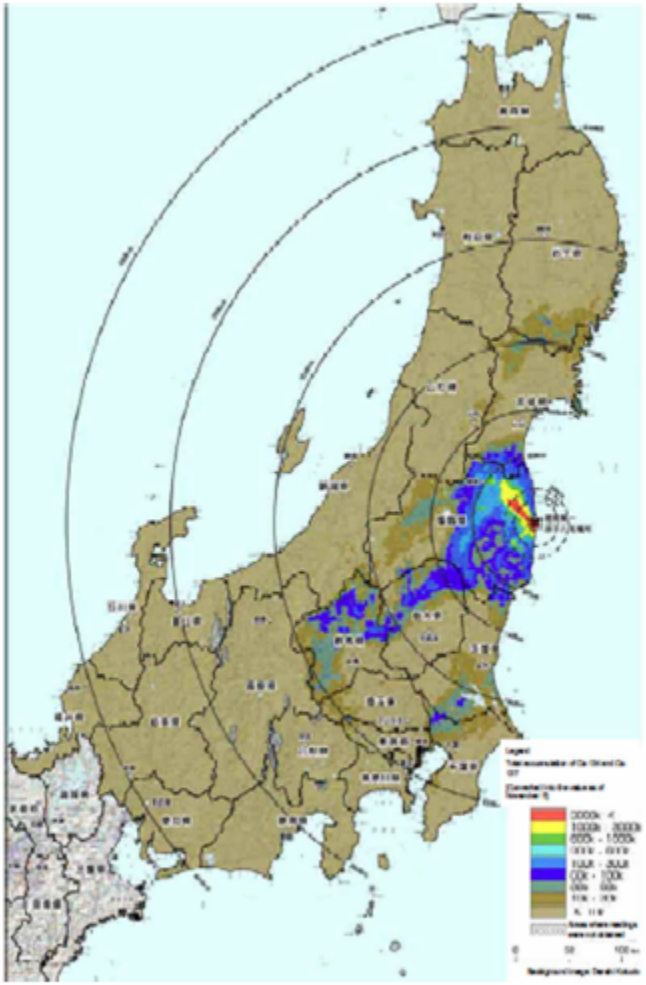
Containment Systems (Reference)

Countermeasure 18	Enhance diversity of PCV cooling system
Countermeasure 19	Prevention of the damaging of PCV top-head flange caused by overheating
Countermeasure 20	Proceed with low pressure injection process reliably
Countermeasure 21	Improve maneuverability of venting system
Countermeasure 22	*Mitigate the effect of radioactivity caused by venting*
Countermeasure 23	Ensure independency of vent system
Countermeasure 24	Prevent the Hydrogen explosion (control the gas concentration and the adequate release)

Communication, Instrumentation and Control System, and Emergency Response Arrangement (Reference)

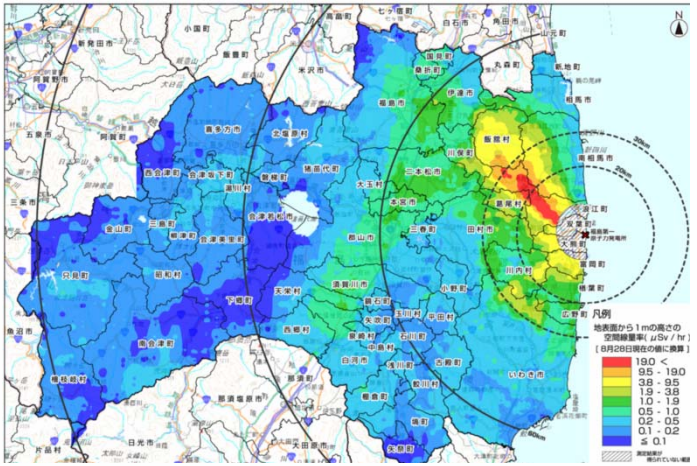
Countermeasure 25	*Prepare emergency command center*
Countermeasure 26	Secure the communication tools for accidents
Countermeasure 27	*Improve reliability of the measurement equipment for accidents*
Countermeasure 28	Enhance the monitoring functions for the plant conditions
Countermeasure 29	Enhance emergency monitoring functions
Countermeasure 30	Create the structure and conduct the training for the emergency response

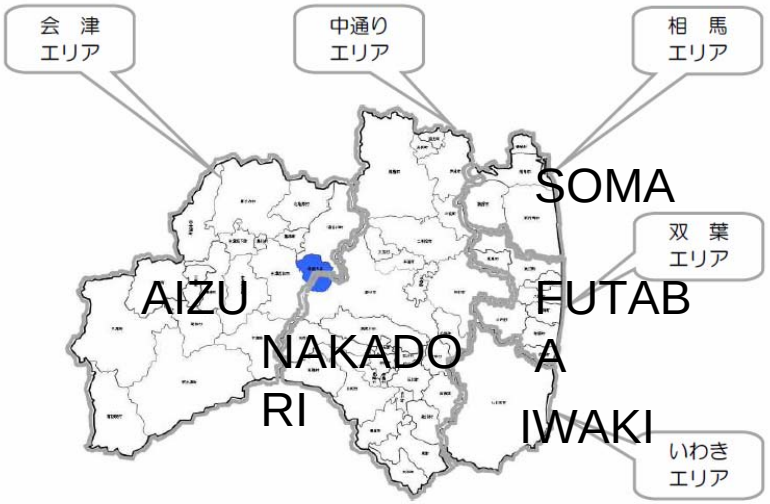
The total deposition of Cs-134 and Cs-137(as of December 16,2011)

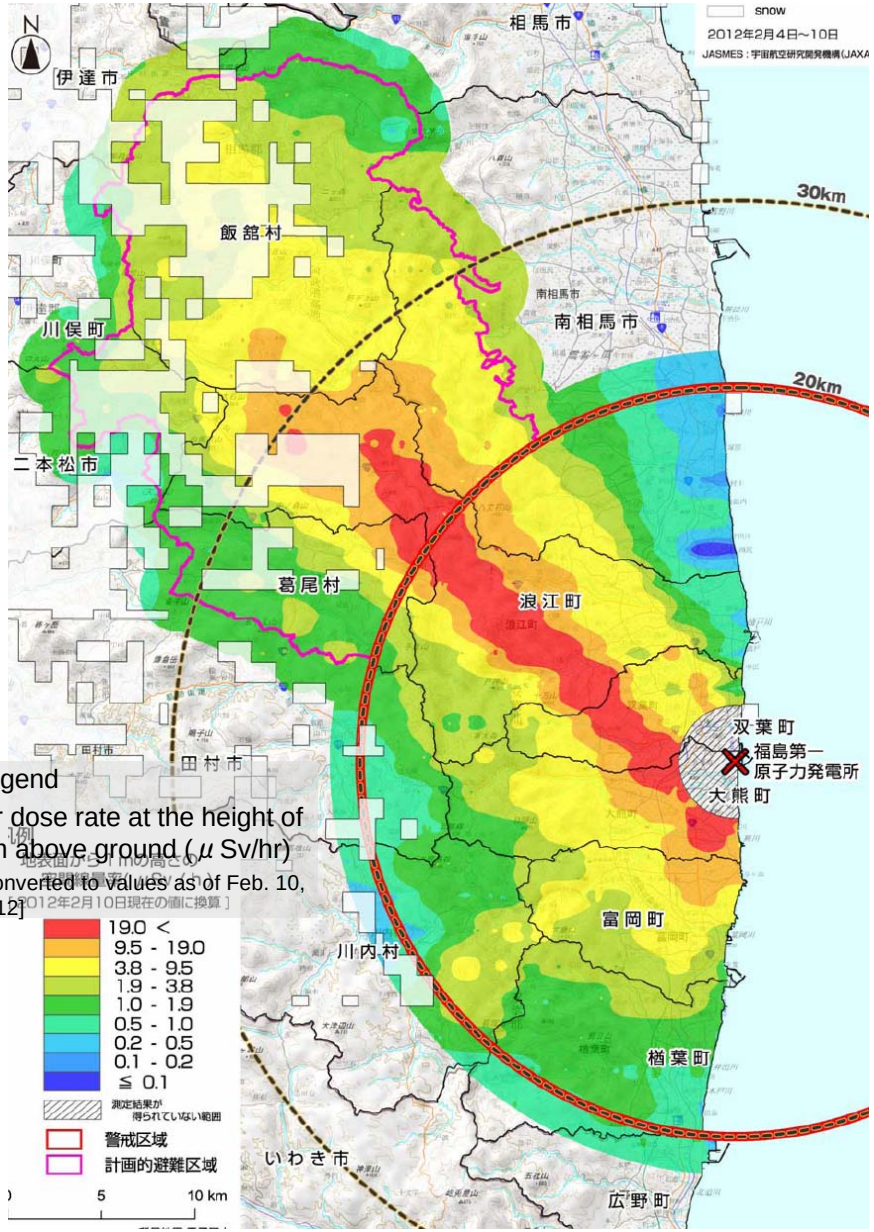


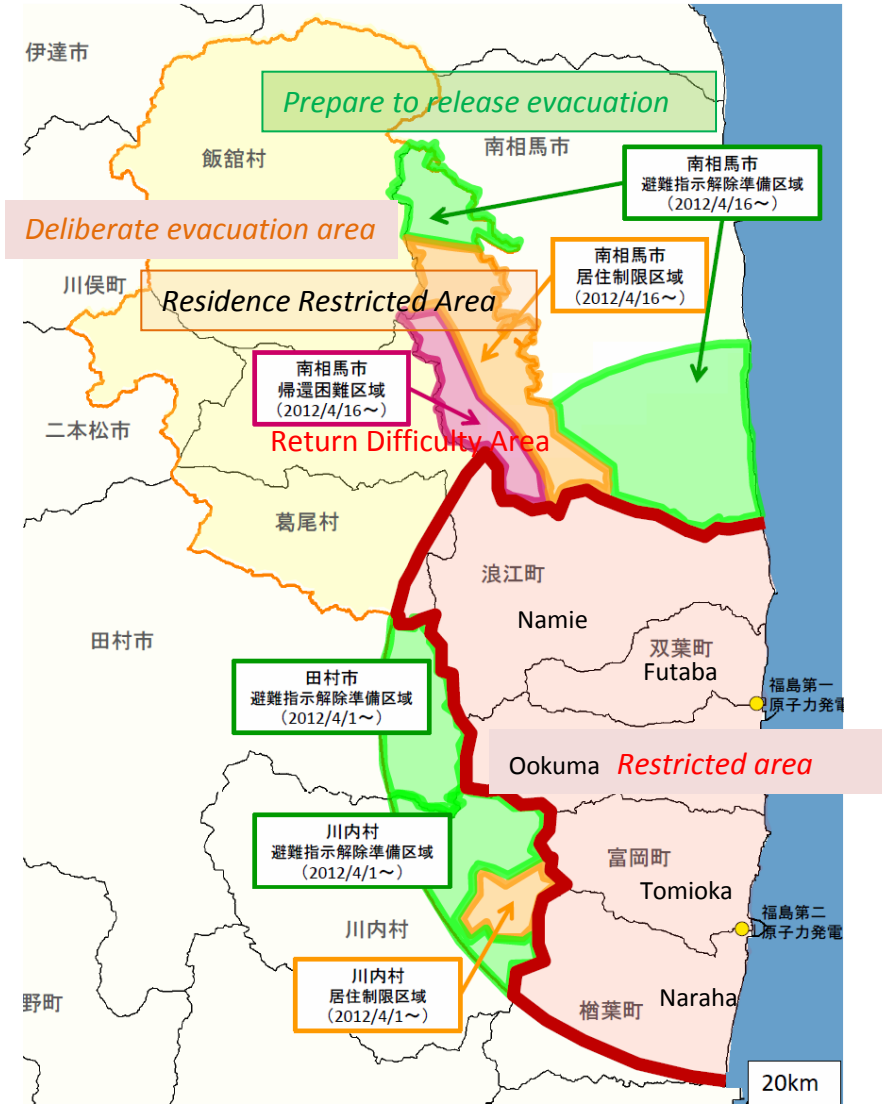
Source: MEXT

The total deposition of Cs-134 and Cs-137 on the ground surface throughout all of East Japan, reflecting the results of the fourth airborne monitoring






N
snow
2012年2月4日～10日
JASMES：宇宙航空研究開発機構(JAXA
伊達市
相馬市
飯舘村
南相馬市
川俣町
二本松市
葛尾村
浪江町
双葉町
大熊町
田村市
富岡町
川内村
楢葉町
いわき市
広野町
30km
20km
福島第一
原子力発電所
Legend
Air dose rate at the height of
1m above ground (μ Sv/hr)
[Converted to values as of Feb. 10, 2012]
19.0 <
9.5 - 19.0
3.8 - 9.5
1.9 - 3.8
1.0 - 1.9
0.5 - 1.0
0.2 - 0.5
0.1 - 0.2
≦ 0.1
測定結果が得られていない範囲
警戒区域
計画的避難区域
5
10 km


伊達市
Prepare to release evacuation
飯舘村
南相馬市
南相馬市
避難指示解除準備区域
(2012/4/16～)
Deliberate evacuation area
南相馬市
居住制限区域
(2012/4/16～)
川俣町
Residence Restricted Area
南相馬市
帰還困難区域
(2012/4/16～)
二本松市
Return Difficulty Area
葛尾村
浪江町
Namie
田村市
双葉町
Futaba
福島第一
原子力発電
田村市
避難指示解除準備区域
(2012/4/1～)
Ookuma
Restricted area
川内村
避難指示解除準備区域
(2012/4/1～)
富岡町
Tomioka
川内村
福島第二
原子力発電
川内村
居住制限区域
(2012/4/1～)
野町
楢葉町
Naraha
20km

Habitant ratio over 20 mSv in Evacuation zone, *in case of no decontamination*

Municipalities (number to be evacuated)	present	5 years after	10 years after	15 years after
11city, town, village (total 85,988)	64%	32%	18%	10%
Ookuma (11,515)	100%	97%	81%	44%
Futaba (6,932)	99%	75%	49%	35%
Tomioka (16,001)	96%	34%	1%	0%
Namie (20,905)	66%	24%	10%	8%

“Asahi Shinbun”, June 10,

Radioactive Materials to the Air and the Ocean (TEPCO, as of May 2012)

PBq to Air	Noble Gas	I-131	Cs-134	Cs-137	Iodine eq.
TEPCO May 2012	About 500	About 500	About 10	About 10	About 900
JAEA March 2012	-	120	-	9	480
NISA Feb 2012	-	150	-	8.2	480
IRSN	2000	200	30		-
Chernobyl	6500	1800	-	85	5200

PBq to Sea		I-131	Cs-134	Cs-137
TEPCO	Mar to Sept	11	3.5	3.6
JAEA	Mar to April	11.4	-	3.6
IRSN	Mar to July	-	-	27

1 PBq(peta Becquerel)=1,000 trillion Bq=10^{15} Bq

Fukushima Regional Data *@ end of 2011*

County	SOMA	FUTABA	IWAKI	NAKADORI	AIZU	TOTAL
Population of Jan. 2011	122,783	72,679	341,463	1,196,730	290,746	2,024,401
Evacuees inside Fukushima	26,714	51,859	6,596	10,592	8	95,769
Accepted	17,610	52	27,899	42,686	7,522	95,769
Evacuees outside Fukushima			61,659			61,659
Death	**1,208**	**364**	**310**	**32**	**1**	**1,915**
Missing	12	14	38	1	0	65
Houses lost	6,772	752	7,611	4,556	24	19,715
Half collapse	2,127	197	29,521	29,524	132	61,501

Accumulated Doses for Fukushima Dai-ichi Plant Personnel

from March 11 2011 to March 31 2012

mSv	No. of Tepco people	Associated industry	Total
Over 250	6	0	6
200 – 250	1	2	3
150 – 200	22	2	24
100 – 150	117	17	134
50 –100	437	364	801
20 – 50	632	2,357	2,989
10 – 20	501	2,811	3,312
Less than 10	1,706	12,047	13,753
Total	3,422	17,600	21,022
Max. mSv	678.80	238.42	
Average mSv	24.68	9.59	12.05

Overview of Fukushima habitant doses -1

April 26, 2012

- External dose estimation for Namie and Iidate 9,747 people:
  - Less than 1 mSv 57.8%
  - Less than 10 mSv 99.3%
  - Max 23 mSv
- Personal dosimeters
  - Referred data to advisory group from 22 city/town/village, about 70 thousands residents: median less than 1mSv annual
  - Fukushima city (from city home page): median 0.8 mSv annual

Overview of Fukushima habitant doses -1

April 26, 2012

- External dose estimation for Namie and Iidate 14,412 people: @May 31
  - Less than 5 mSv 94.0 %
  - Less than 10 mSv 99.3 %
  - Max 25.1 mSv
- Personal dosimeters
  - Referred data to advisory group from 22 city/town/village, about 70 thousands residents: median less than 1mSv annual
  - Fukushima city (from city home page): median 0.8 mSv annual

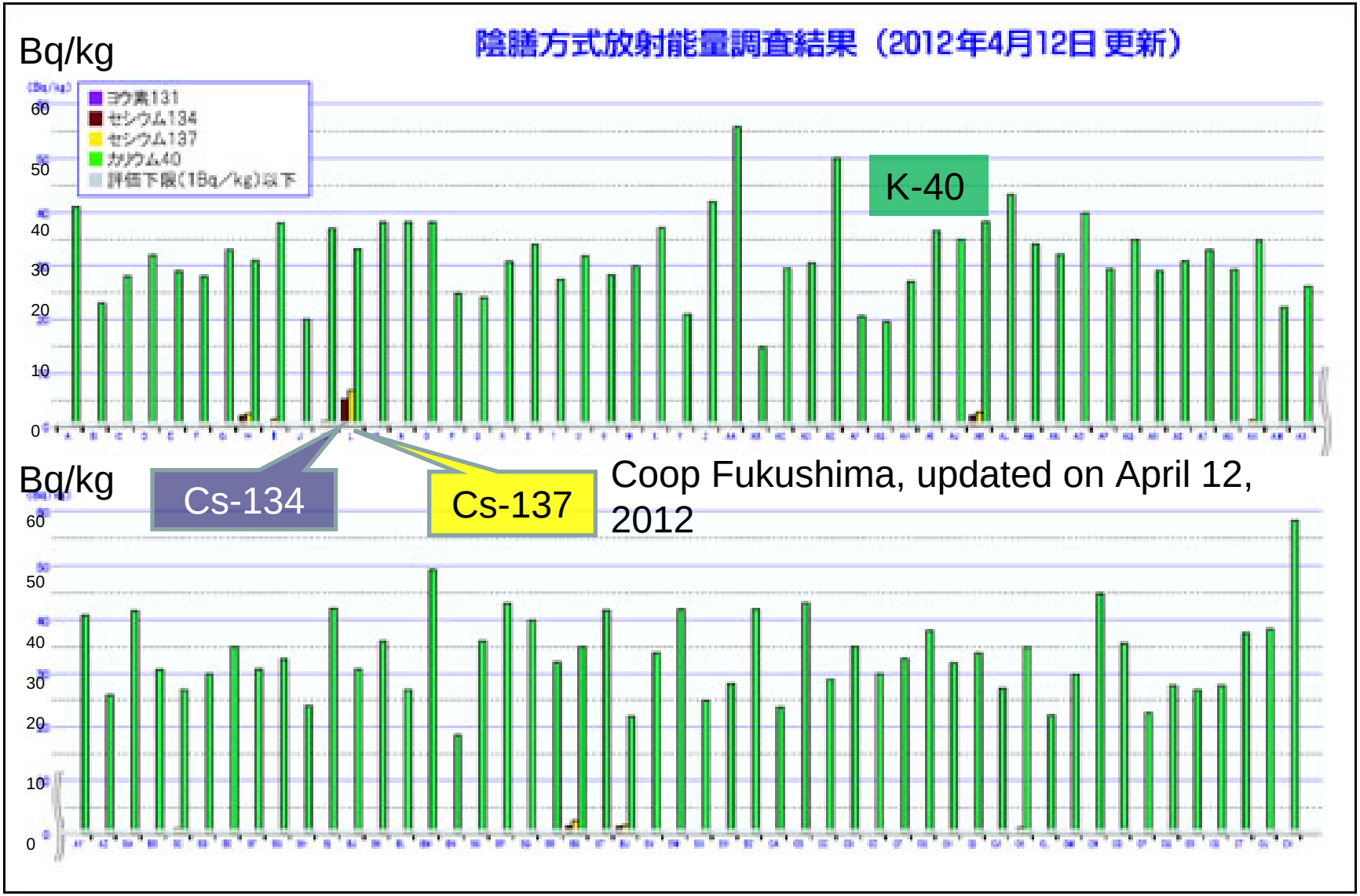
From the material at the Fukushima Prefecture Health Monitoring Committee

Overview of Fukushima habitant doses - 2

April 26, 2012

- Internal dose: committed dose less than 1 mSv 22,691 out of 22,717, 99.9%. Max 3 mSv for 2 persons.
- Doses from food:
  - 0.244 mSv at most, assuming selection of contaminated foods
  - 0. 01 ~ 0.14 mSv from meals survey by Coop Fukushima
  - About 0.02 mSv estimation by Market Basket Survey (Ministry of Health, Labor and Welfare)

Radioactivity survey on real meals of 100 families in Fukushima



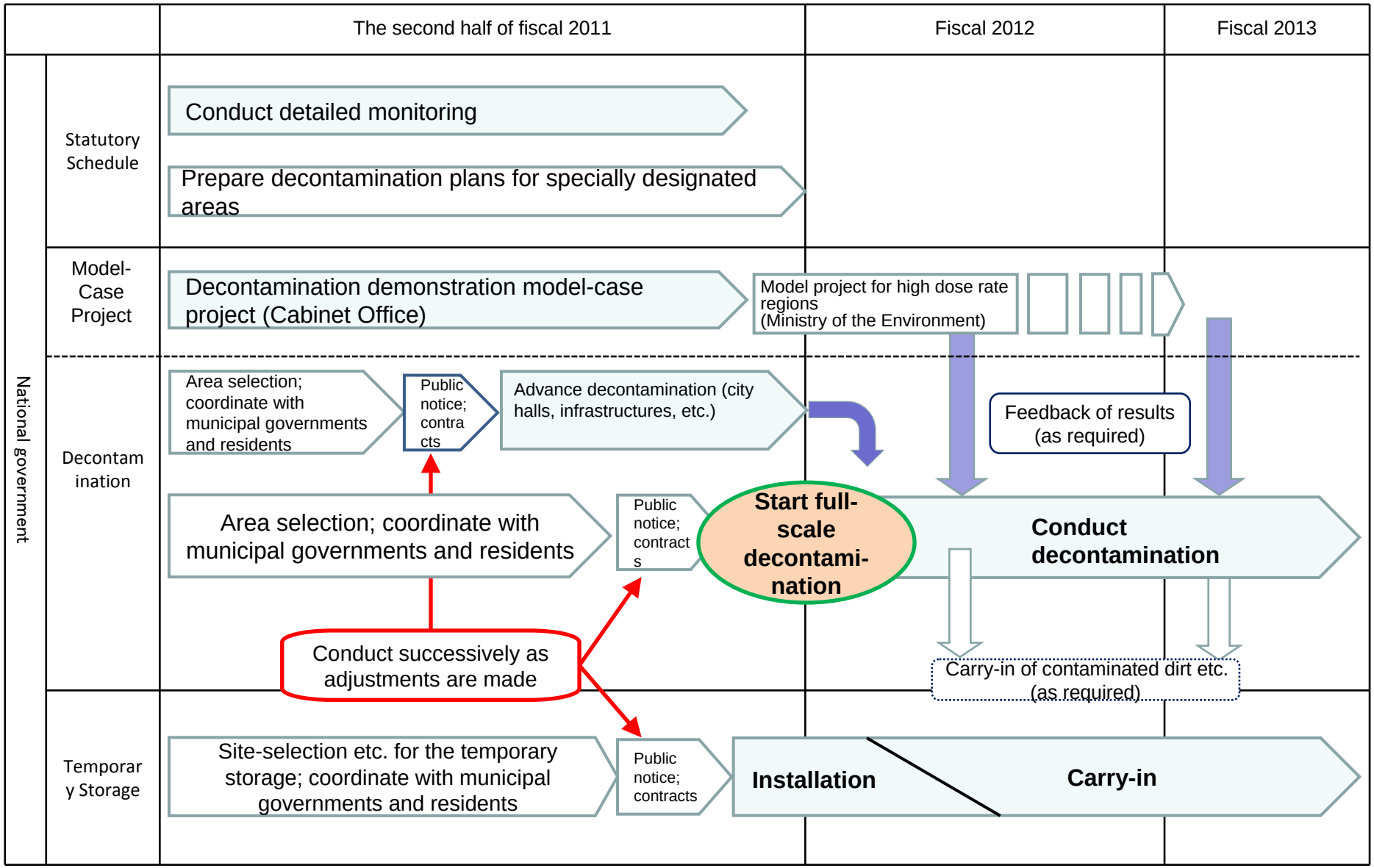
Preliminary personal observations

- Lack of imagination on beyond design base events both onsite and offsite *a case of Japanese arrogance*
- Collapse of Offsite Center designed to communicate to local and central governments, the plant and others was also out of scope of nuclear disaster prevention planning
- Low dose to habitants with probably minimal or no health effect due to the prompt evacuations by Emergency actions which are still to be reviewed and improved
- Death penalties;
  - Onsite 2 operators drowning by Tsunami at unit #4
  - Suicide ~13 farmers due to stress, desperate for future
  - Lack of care 50~ for olds who were forced to evacuate from the hospitals near the site and wander
  - Radiological 0
- New Standard limits for Radionuclides in Foods became effective in April 2012. Strict ones by orders for the sake of “mother’s anxiety” may hamper restoration of local agriculture, fishery
- Neglect of lessons learnt from Chernobyl which was finished up as issues on Safety Culture

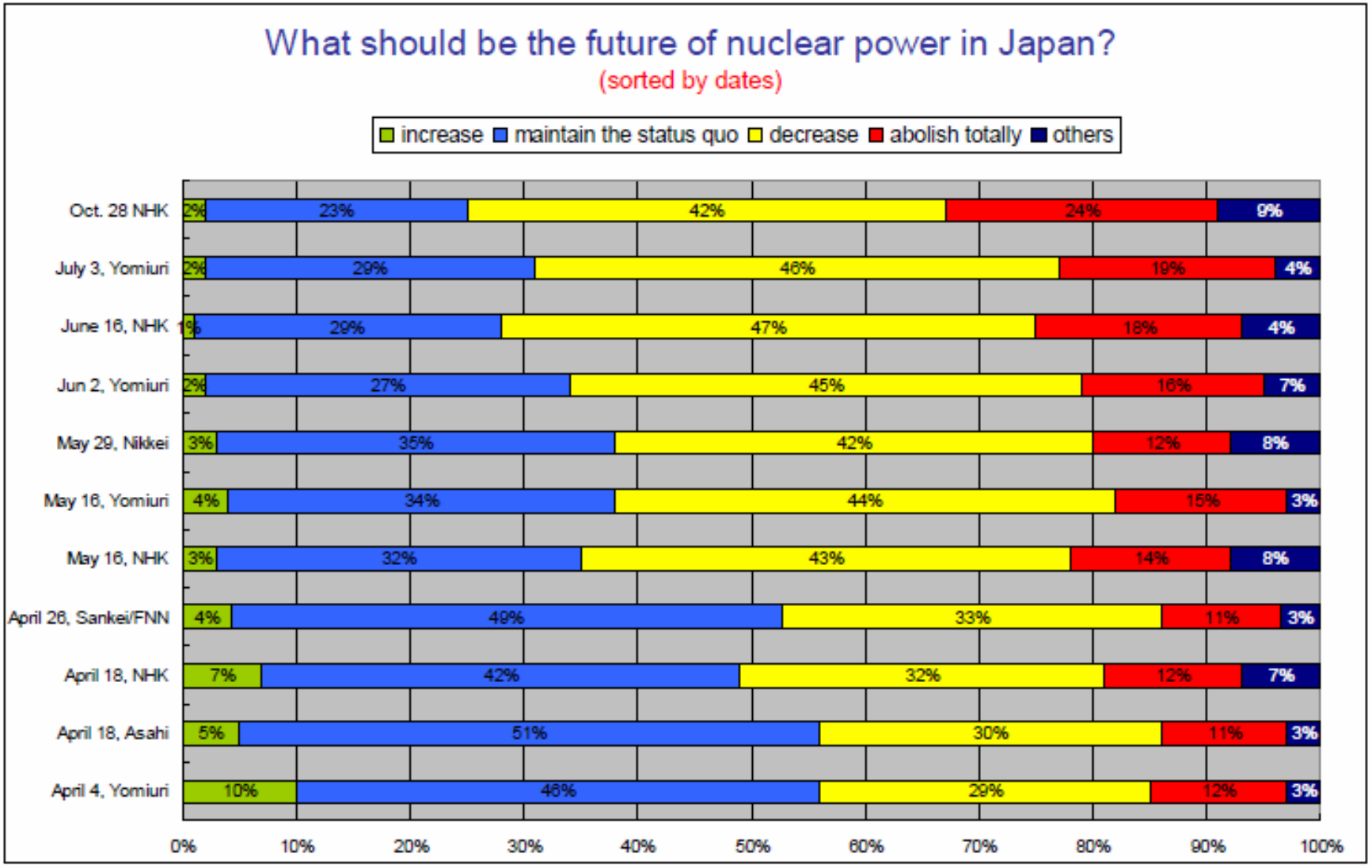
Off-Site Decontamination Project

- Reduce the size of the areas where exposure is larger than 20 mSv/y ; national government responsibility
- Reduce exposures where it is now under 20 mSv/y by 50% in 2 years
- Where exposures are now 1 mSv/y, concentrate in hot spots
- Huge amounts to be processed/stored/disposed (contaminated soils, incinerator ashes, sewage sludge, rice straw, etc.)
  - 33 million cubic meters, 4.5 trillion yen ; IAE estimates
  - Suffering from NIMBY

Outline of Off site Decontamination Project



Public Opinion Survey by Mass Media



http://www.jaif.or.jp/english/news_images/pdf/ENGNEWS02_1320397876P.pdf

4. Present Issues

- Re-start up of Ohi 3 & 4 of Kansai EPCo
  - 2.7 GWe PWR deadly needed for base load to peak out in the summer
  - Pre-determined safety reviews done and endorsed, but not-adjacent local governments of Osaka, Kyoto reluctant to accept
  - 50 other NPP waiting for “go” to save fossil fuel charge of about three trillion yen per annum
- Role of Nuclear in Energy Portfolio
  - Erosion of confidence not only in safety but regulation and operators
  - Options of 0 to 25% in 2030 were proposed
  - National debates maybe in the summer time
- Nuclear Fuel Cycle Activities?
  - Rokkasho Spent Fuel Reprocessing Plant
  - Monju Prototype Fast Reactor