Energy in Japan

-challenge for the future・・・A Brighter Tomorrow?-

Hisanori Nei

Professor,
National Graduate Institute
For Publich Studies,Japan

2014,Dec.3rd at CEE

Energy in Japan

After the Great East Japan Earthquake and the TEPCO's Fukushima nuclear accident, the circumstance of energy in Japan has changed drastically as follows:

/No NPS operation・・・288Gkwh(2010）Lost

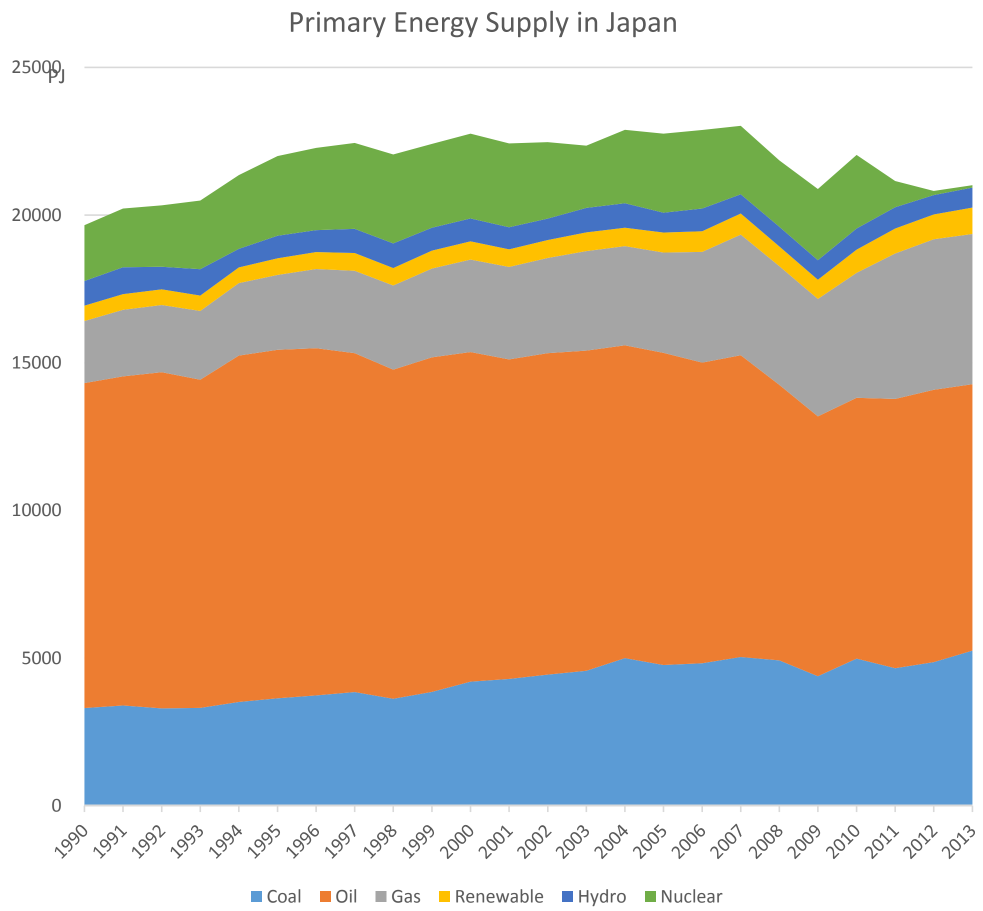
/LNG import increase・・・73.3Mt(2010) ➡ 85.9Mt(2011),90.1Mt(2013)

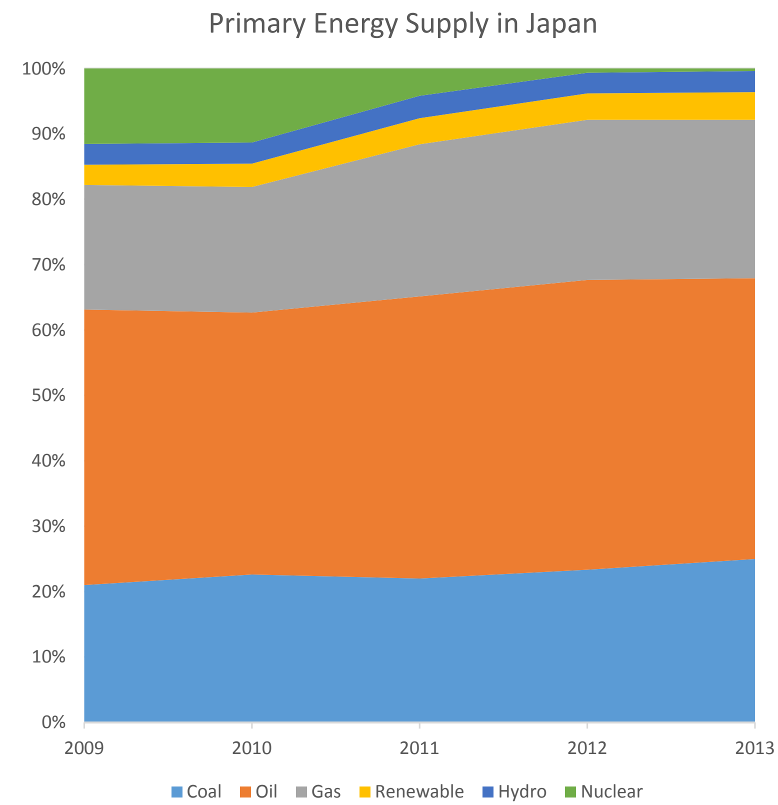
/Energy Consumption Down・・15.0EJ(2010) ➡ 14.5EJ(2011),14.2(2013)

/Electricity Tariff Increase

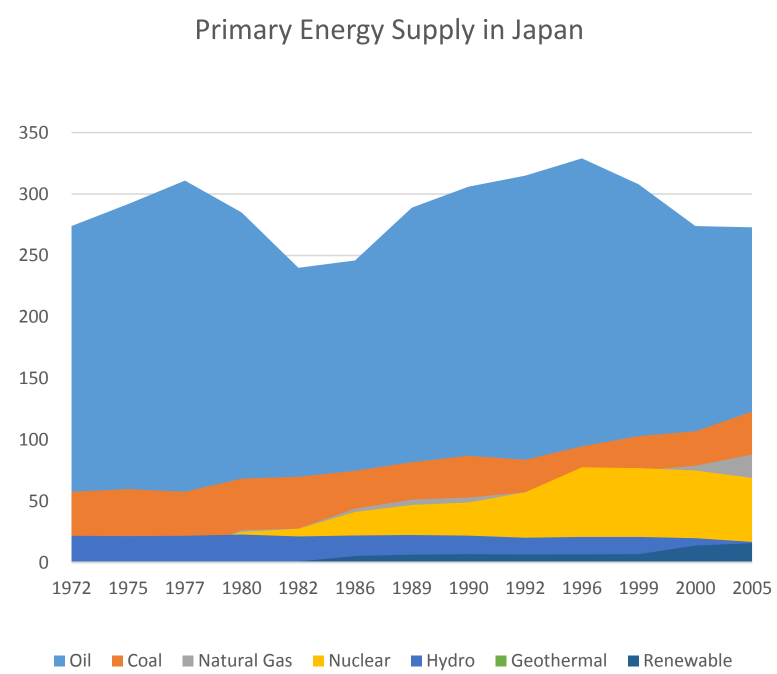
/Increase Fuel Cost・・・3.6Trillion Yen (30 billion US$)/year

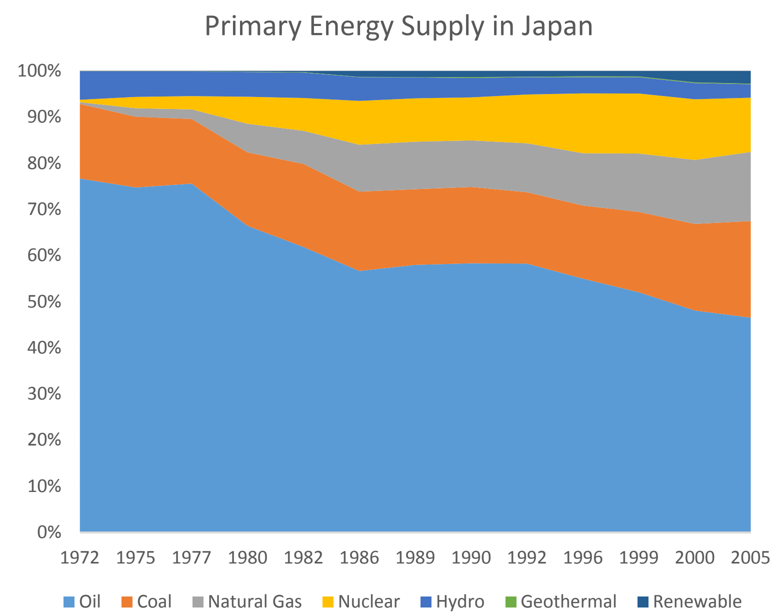
Diversification of Energy Supply after Oil Crisis mainly by Nuclear





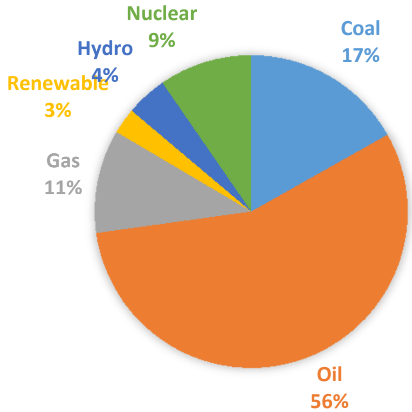
Increase Nuclear Energy Supply for last 4 Decades



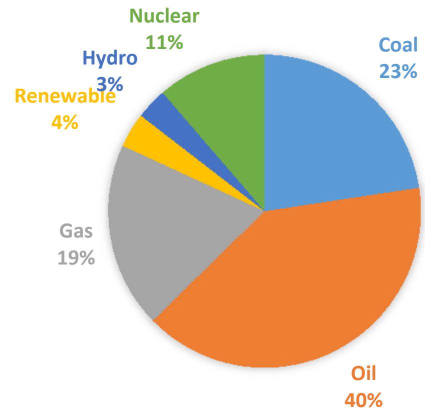


After Fukushima Energy Figure in Japan goes back to almost 4 decades ago

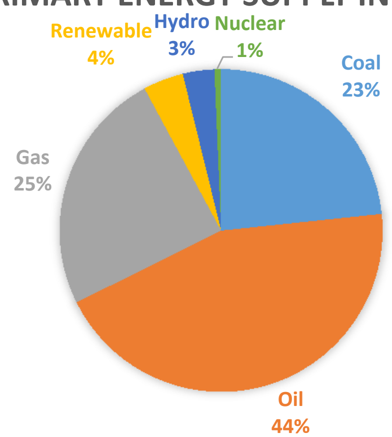
PRIMARY ENERGY SUPPLY IN 1990



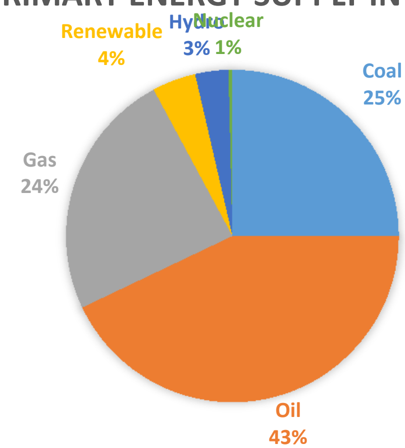
PRIMARY ENERGY SUPPLY IN 2010



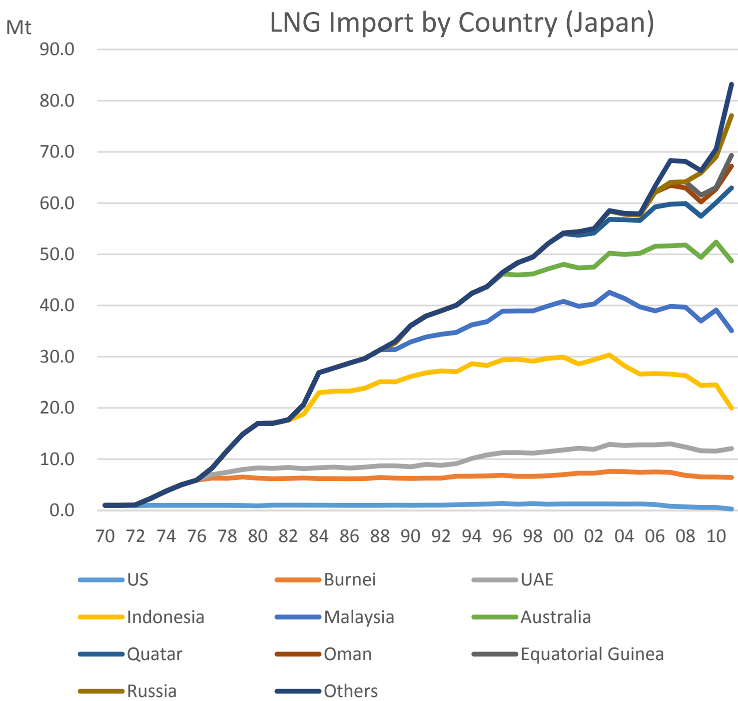
PRIMARY ENERGY SUPPLY IN 2012



PRIMARY ENERGY SUPPLY IN 2013

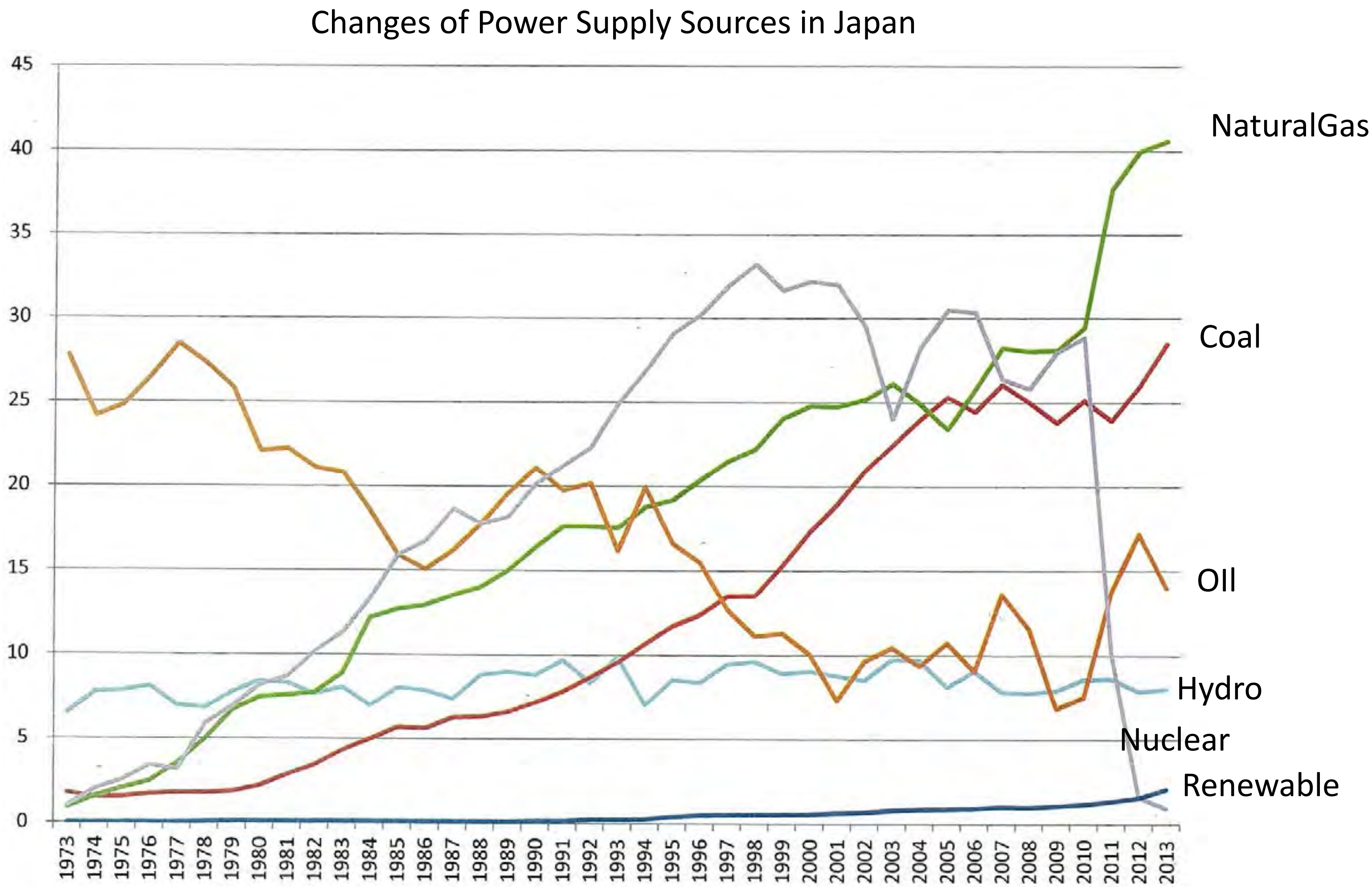


LNG is major energy source cover the loss of NPS

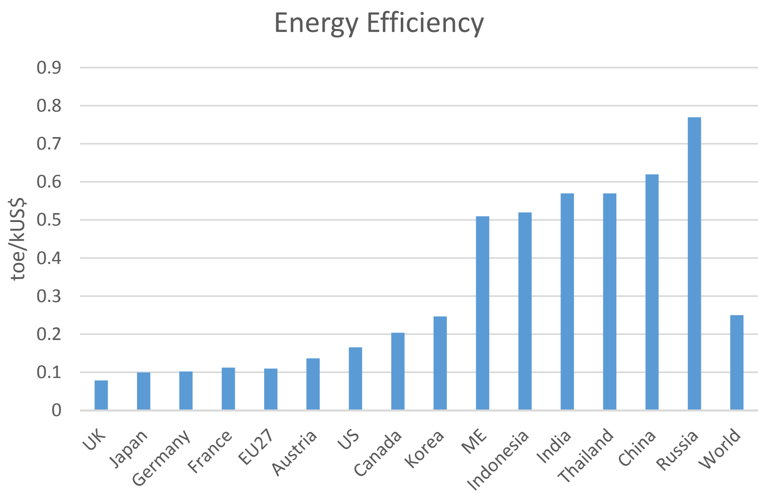


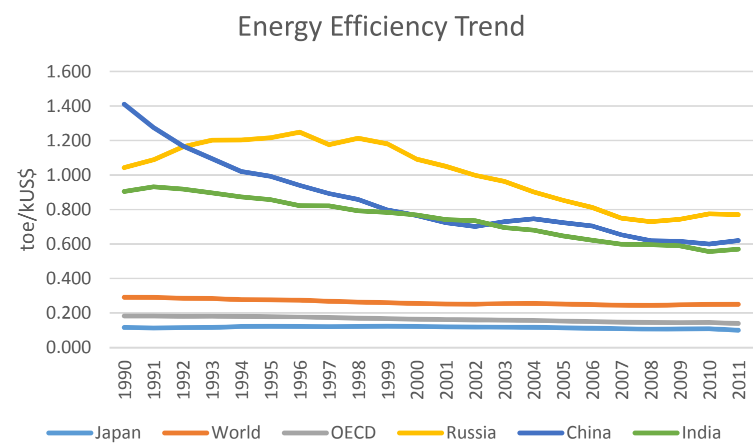
Mt	Long Term	Import 2011	Import 2010
UAE	4.3	5.6	5.1
Burnei	6.0	6.2	5.9
Malaysia	15.4	15.1	14.6
Indonesia	5.8	7.9	12.9
Quatar	6.0	14.3	7.7
Oman	3.0	4.2	2.7
Australia	13.3	13.6	13.2
Russia	4.9	7.8	6.0
U.S.A		0.2	0.6
Others		9.0	1.5
Total	58.8	83.2	70.6

Coal consumption link with Total energy demand.

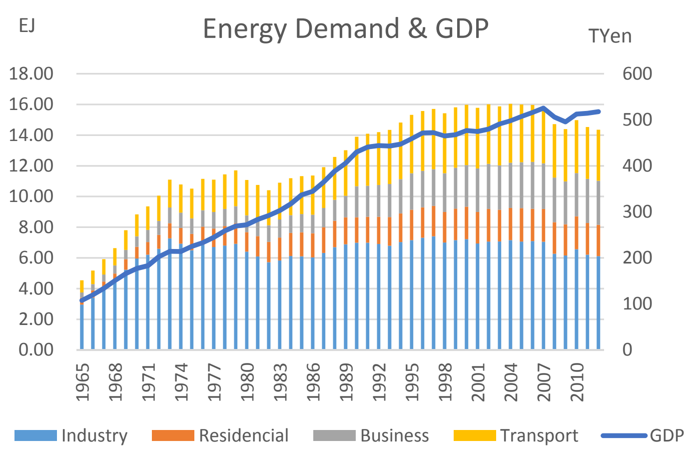


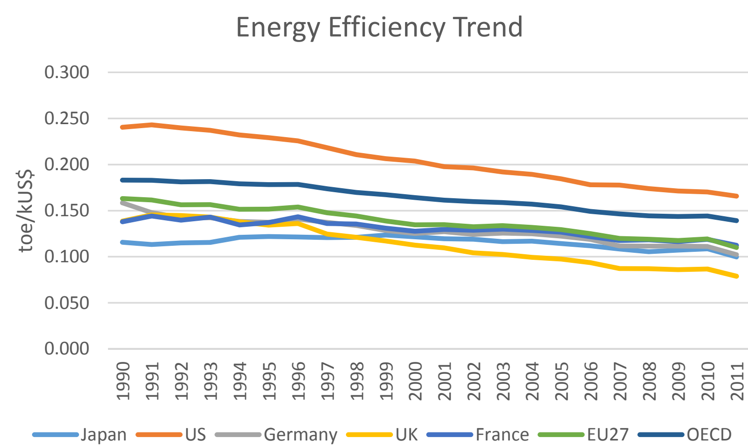
Maintain High Energy Efficiency





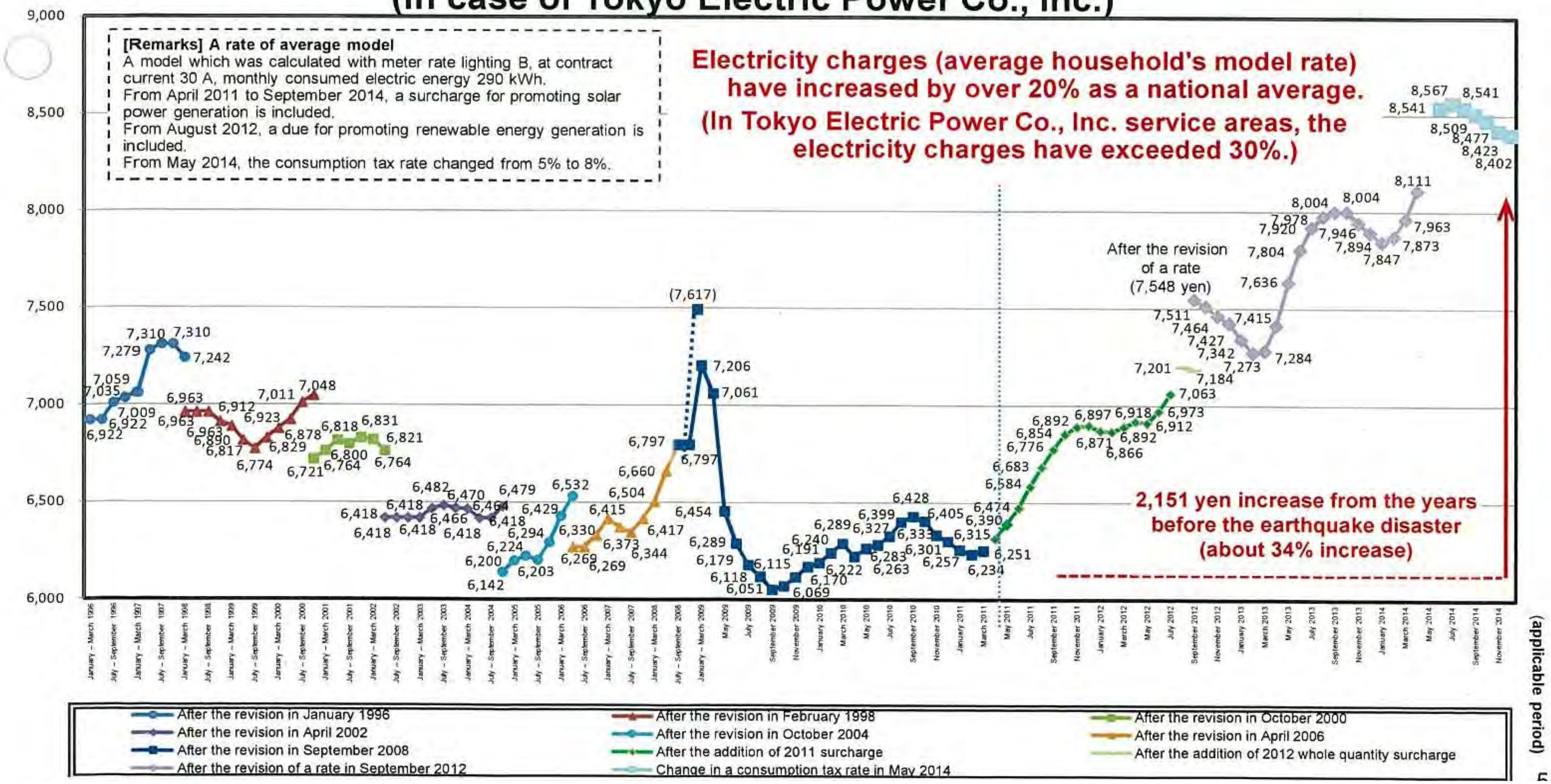
Souce:IEA

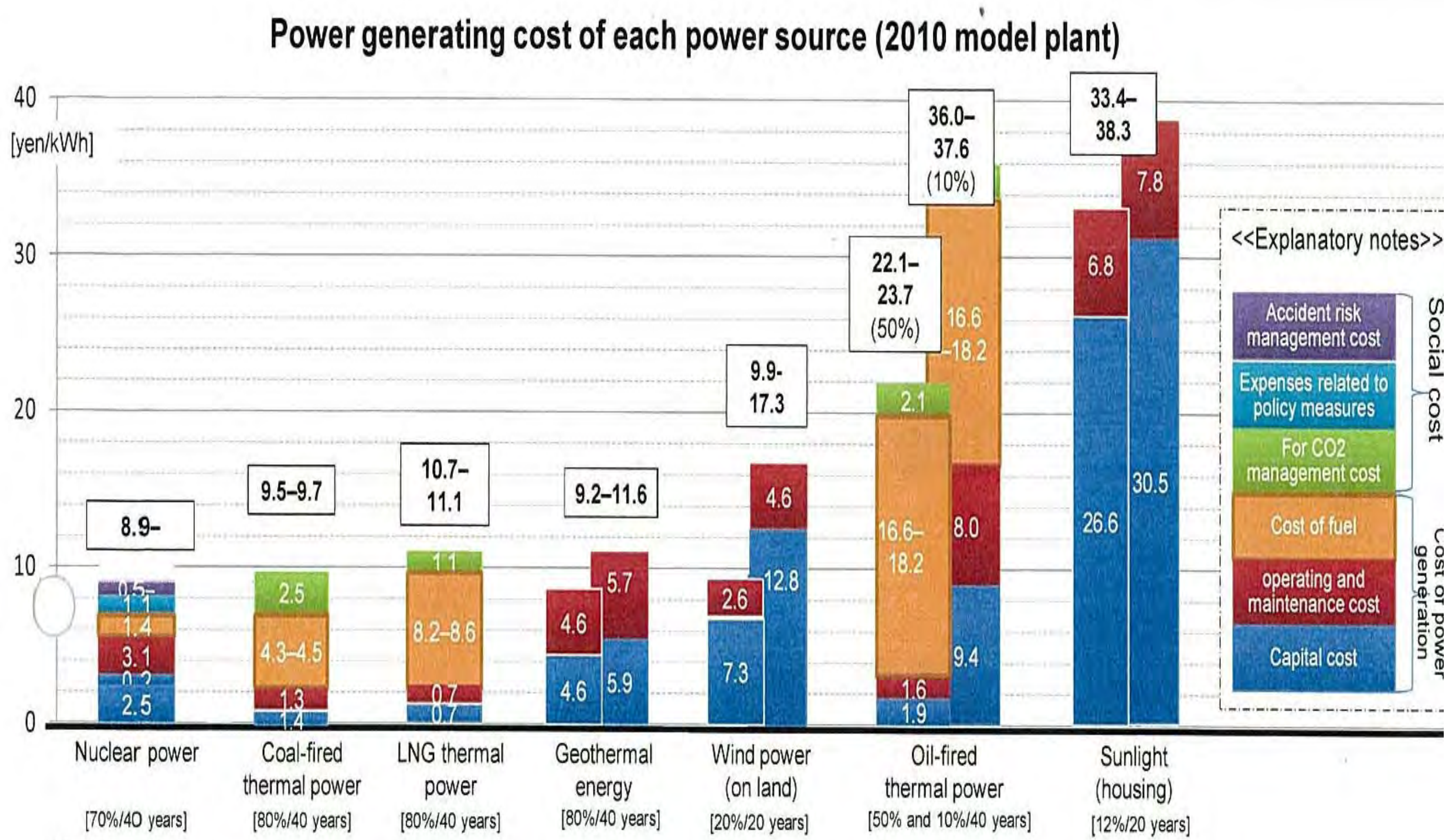




After the earthquake disaster, electricity charges have risen considerably.

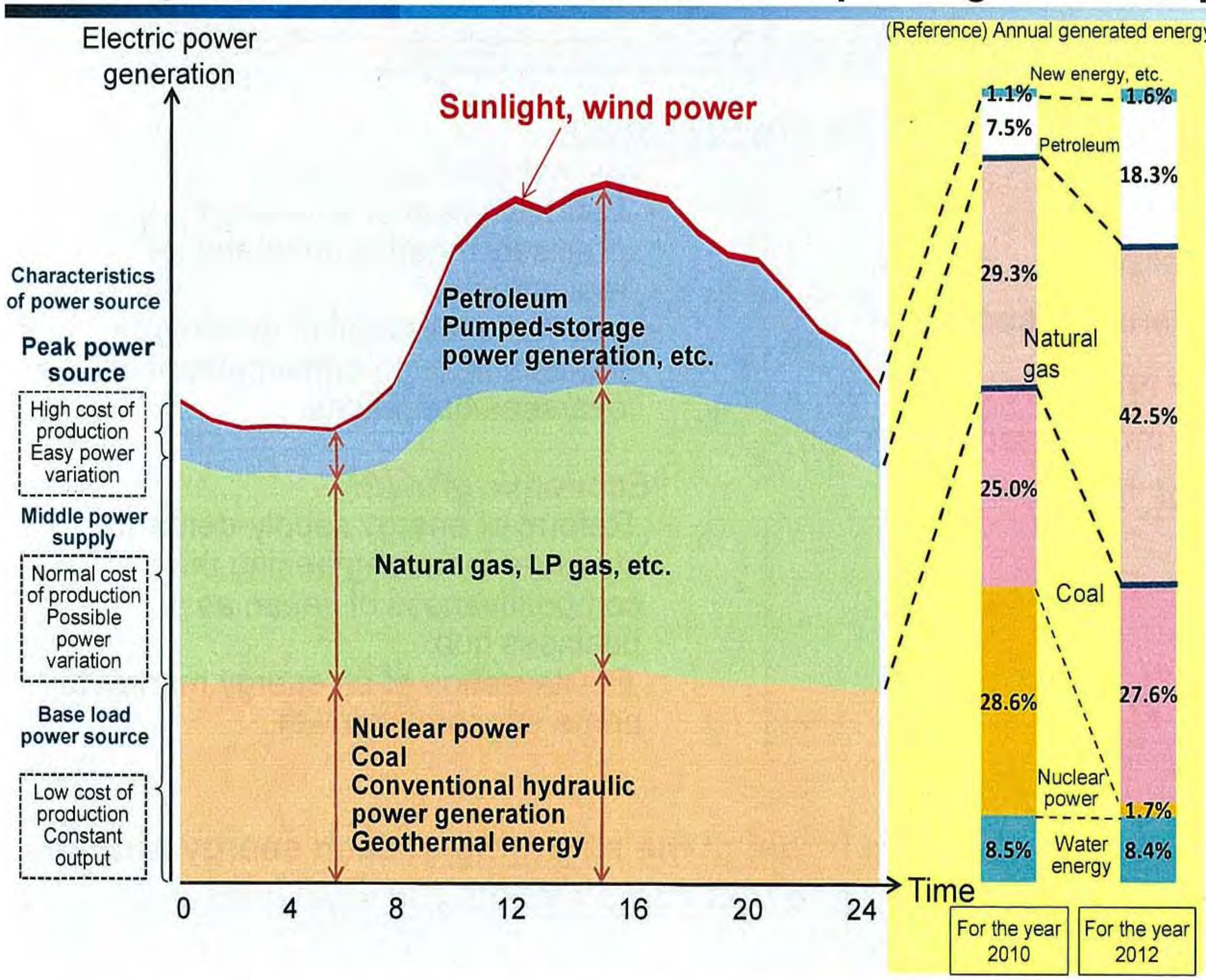
Transitions concerning an average model rate after the introduction of the fuel cost adjustment system
(in case of Tokyo Electric Power Co., Inc.)





Power generating cost of each power source (2010 model plant)
40
30
20
10
0
[yen/kWh]
8.9–
9.5–9.7
10.7–
11.1
9.2–11.6
9.9-
17.3
22.1–
23.7
(50%)
36.0–
37.6
(10%)
33.4–
38.3
2.5
3.1
1.4
1.1
2.5
4.3–4.5
1.3
1.4
1.1
8.2–8.6
0.7
0.7
4.6
4.6
5.7
5.9
2.6
7.3
4.6
12.8
2.1
16.6–
18.2
1.6
1.9
16.6
–18.2
8.0
9.4
6.8
26.6
7.8
30.5
Nuclear power
[70%/40 years]
Coal-fired
thermal power
[80%/40 years]
LNG thermal
power
[80%/40 years]
Geothermal
energy
[80%/40 years]
Wind power
(on land)
[20%/20 years]
Oil-fired
thermal power
[50% and 10%/40 years]
Sunlight
(housing)
[12%/20 years]
<<Explanatory notes>>
Accident risk
management cost
Expenses related to
policy measures
For CO2
management cost
Social cost
Cost of fuel
operating and
maintenance cost
Capital cost
Cost of power
generation

Composition of electrical sources corresponding to electric power demand



Conception of the composition of electrical sources

◊ There are no energy sources superior in every single aspect (stable supply, co[st], environmental impact, safety).

◊ With regard to the composition of electrical sources, taking into account characteristics with respect to each energy source, an actual and balanced supply-demand structure shall be established.

◊ The goal of a best mix shall be indicated in the future.

History of Electricity System Reform in Japan

No competition in the electricity market before 1995.
10 vertically integrated GEUs(General Electricity Utilities) dominated and controlled the market

1995

・Open the IPP (Independent Power Producer) market

2000

・Introduce partial retail competition (>2000kw)

・Accounting separation of Transmission/Distribution sector

2005

・Expand retail competition(>50kw)

・Establish the whole sale power exchange(JEPX)

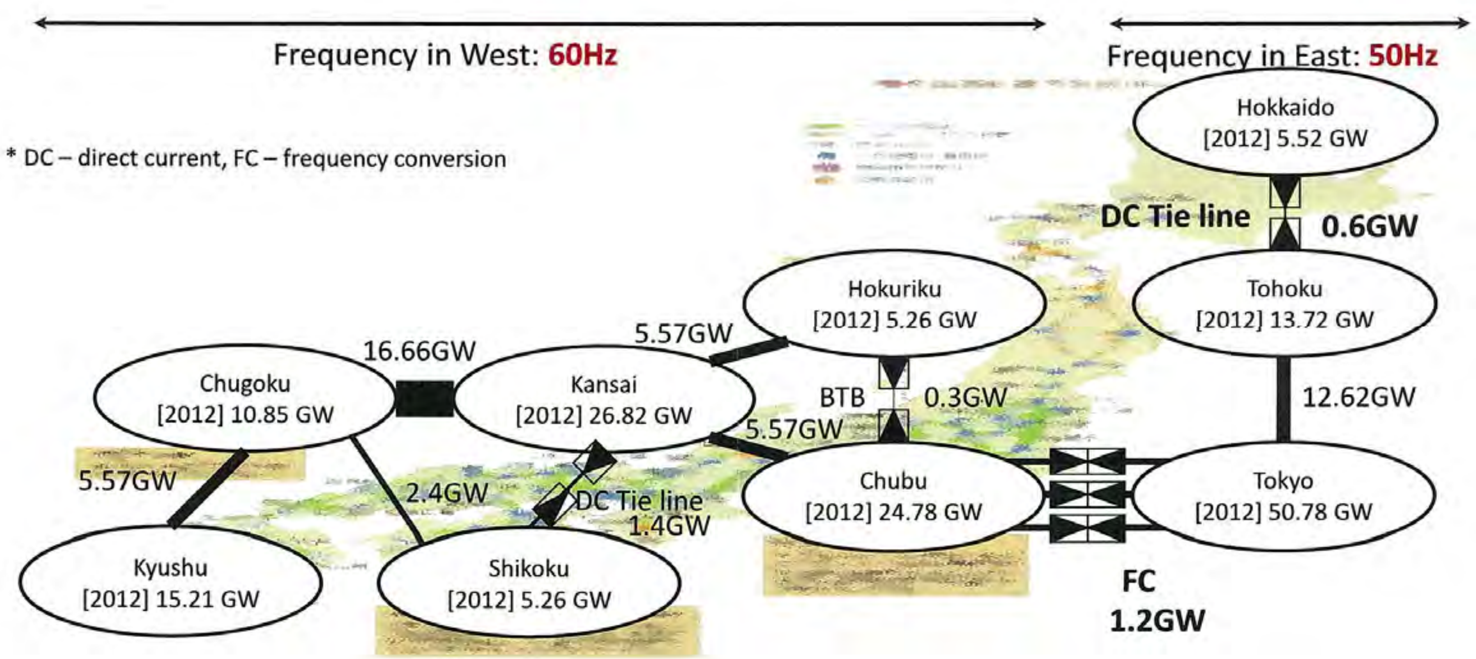
(2008)

・Modify the rule of wheeling rates

Current electricity system

・Partial liberalization : retail competition for over 50kw customers
・Retail players : 10 big GEUs(vertically integrated, regional monopoly), PPS, etc
・Situation is…
  ・Share of non-GEU power producer and supplier : 3.6%
  ・0.6% of the total retail market sales is transacted at JEPX

Negative aspects of regional monopoly were revealed by 3.11
1.Lack of system to transmit electricity beyond regions.
2.Little competition and strong price control
3. Limit in digesting the change in energy mix (cf. renewables)



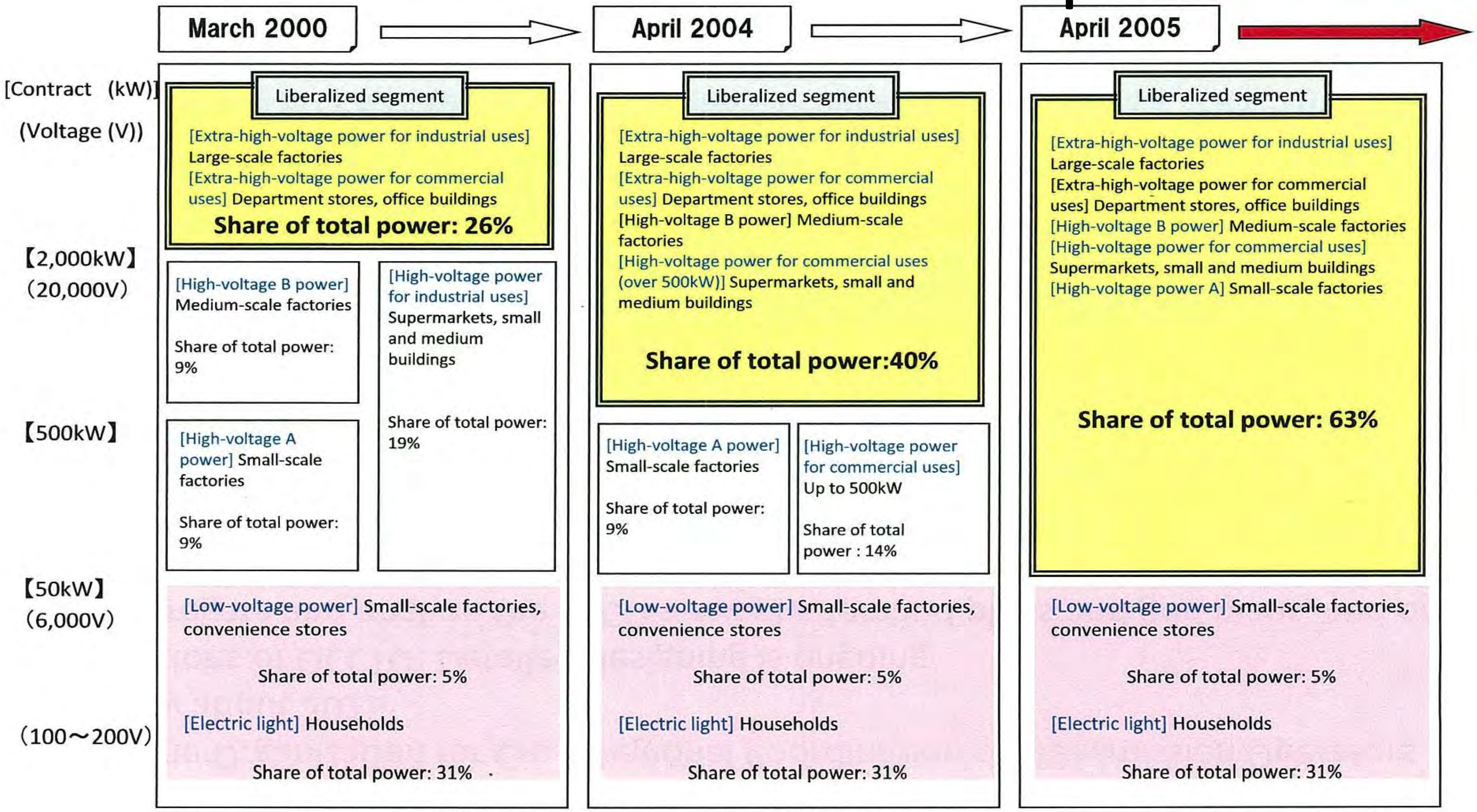
Decision on Electricity System Reform in 2013

・The Cabinet decided to execute the Policy on Electricity System Reform on April 2, 2013

Objectives:
/Securing the stable supply
/Suppressing electricity rates to the maximum extent possible
/Expanding choices for consumers and business opportunities

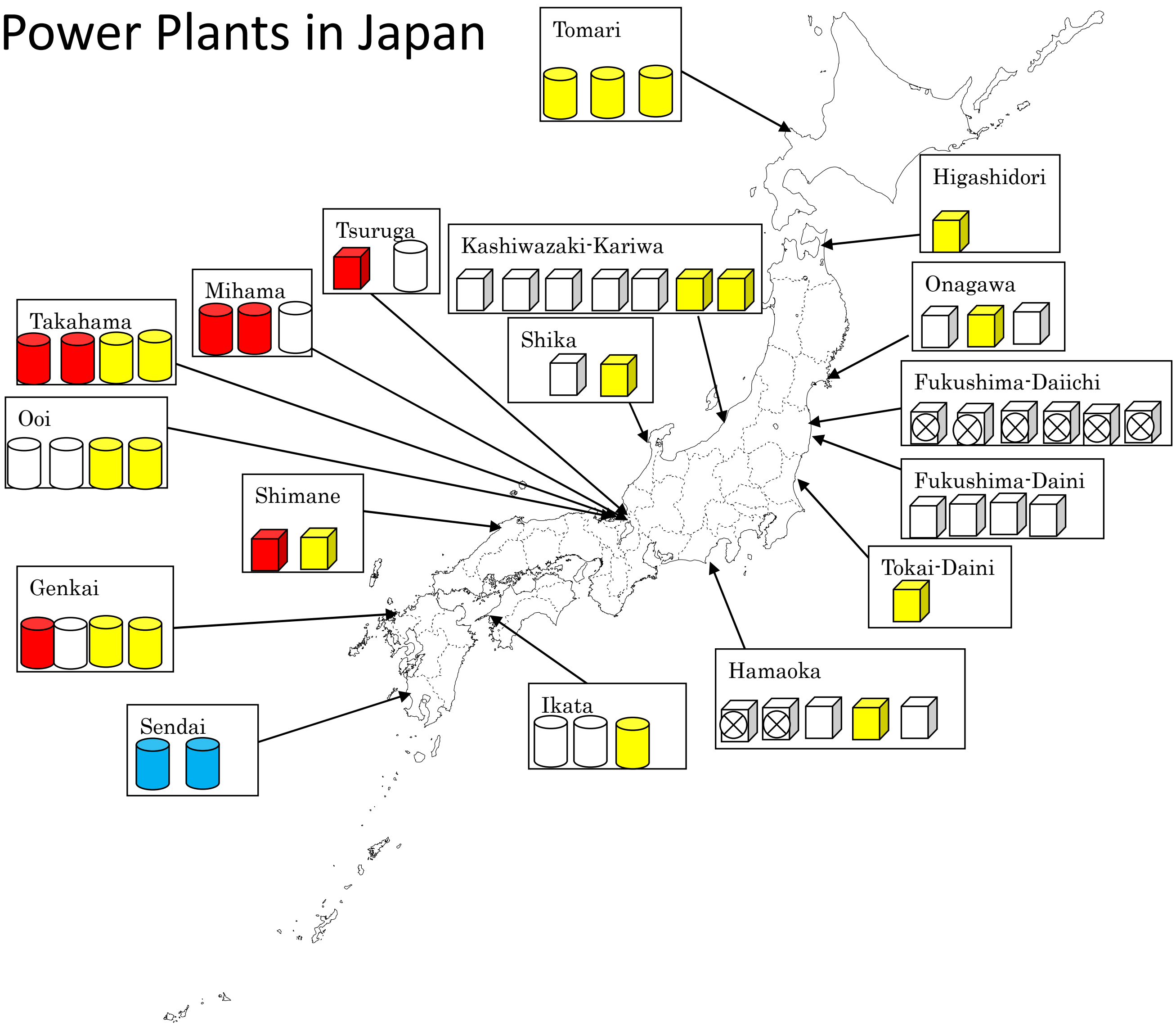
Process:
A bold reform will be steadily carried out step by step focusing on the 3 agendas:
/Cross-regional Coordination of Transmission Operators(by 2015)
/Full Retail Competition in around 2016 (regulated tariff expired by 2020)
/Unbundle the transmission/distribution sector by 2020

For Full Retail Competition



(Note) The scope of liberalization of Okinawa Electric Power Company was expanded in April 2004, from users of power over 20,000kW, 60,000V, to extra-high-voltage power users (over 2,000kW, in principle).

Nuclear Power Plants in Japan



																			Sendai2				
												Hamaoka2							Kashiwazaki kariwa1				
								Takahama1		Mihama3		Tokai-Daini	Ooi2					Sendai1	Fukushima-Daini3		Hamaoka3		
				Mihama1				Fukuhima-Daiichi2	Takahama2	Fukushima-daiichi3		Fukushima-Daiichi4	Fukushima-Daiichi6			Fukushima-Daini1		Onagawa1	Takahama4		Fukushima-Daini4		Tomari1
Tokai				Tsuruga1	Fukushima-Daiichi1	Mihama2		Shimane1	Genkai1	Hamaoka1	Ikata1	Fukushima-Daiichi5	Ooi1		Genkai2	Ikata2		Fukushima-Daini2	Takahama3		Tsuruga2		Shimane2
1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
48	47	46	45	44	43	42	41	40	39	38	37	36	35	34	33	32	31	30	29	28	27	26	25

			Hamaoka4																				
			Kashiwazaki kariwa3	Ikata3																			
Kashiwazaki kariwa2	Ooi3		Shika1	Kashiwazaki kariwa4			Genkai4								Higashidori1								
Kashiwazaki kariwa5	Tomari2		Ooi4	Genkai3	Onagawa2	Kashiwazaki kariwa6	Kashiwazaki kariwa7					Onagawa3			Hamaoka5	Shika2			Tomari3				
1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1

The Accident at Fukushima Dai-ichi NPS

- The accident at Fukushima Dai-ichi NPS was caused by long lasting complete power loss due to common cause failure (CCF) of electrical equipment following tsunami, and insufficient provision against severe accident.
- It is rated at INES Level 7, and people where lived in the specific area including those within 20 km radius from the site are still not able to return home.

The moment when tsunami attacked Fukushima Dai-ichi NPS (source: TEPCO)

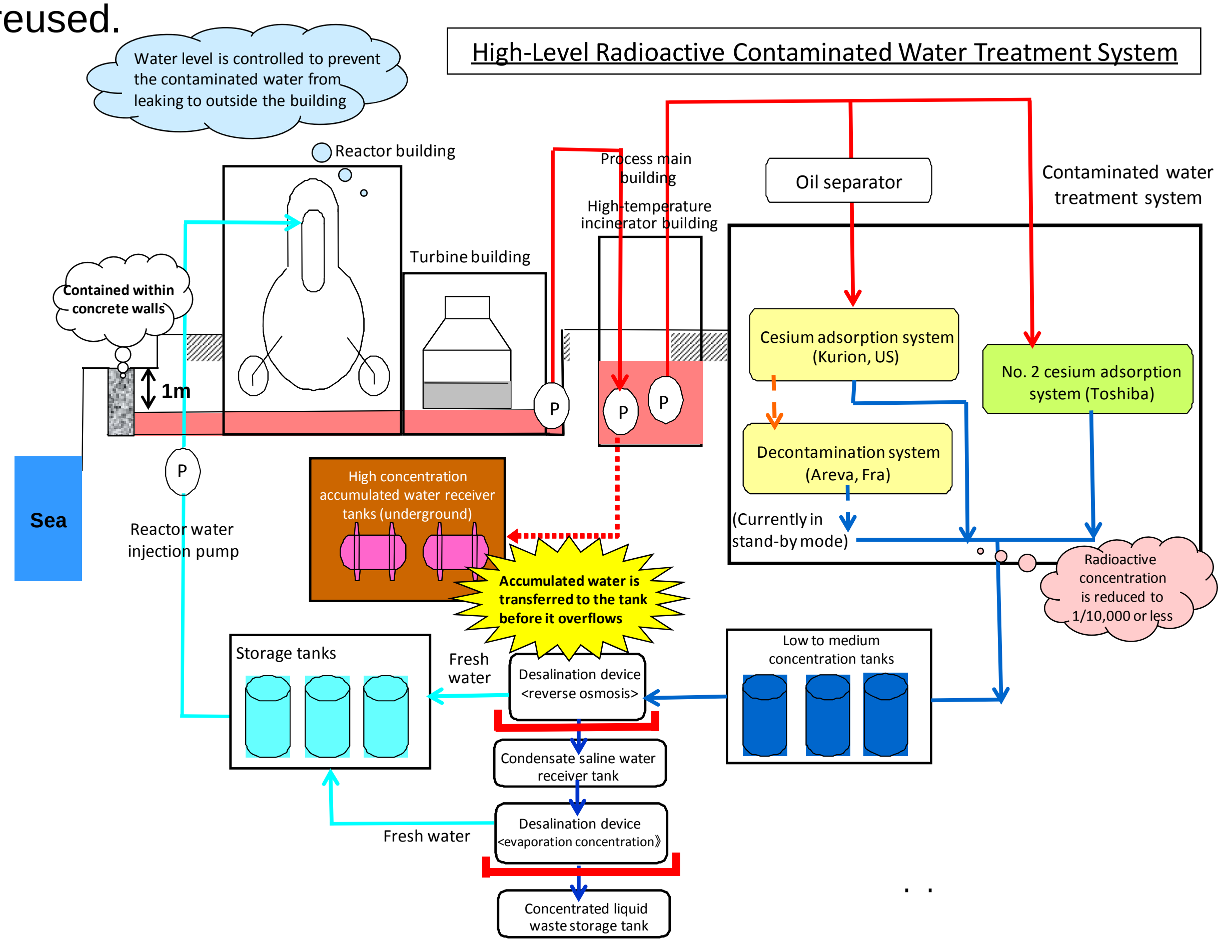
Technical Knowledge acquired from the Accident

In order to address root causes in a practical manner, we has closely investigated accident in the areas of:

- External power supply systems
- On-site power supply systems
- Cooling systems
- Confinement systems
- Communication, instrumentation and control systems, and emergency response arrangements

Treatment of High Level Radioactive Contaminated Water

- Highly-radioactive contaminated water accumulated in the reactor building and turbine buildings is treated to reduce the concentrations of radioactive materials and reused.



Progression of Accident (Outline of Accident Progression Common to Units 1-3)

Automatic reactor shutdown due to earthquake, loss of off-site power supply

Dependency on emergency power was inevitable.

- Emergency diesel generator started up and power supply was secured.
- Reactor was cooled by core cooling system.

Start-up / Shutdown operations for IC・RCIC were going on.

Most of electric systems including emergency diesel generators and switchboards were unavailable due to tsunami.

(Only one of emergency air cooling DGs in Unit 6 maintained its function)

Cooling sea water pumps installed along the coast were also unavailable. (Loss of ultimate heat sink)

Station Blackout

(On March 13, Unit 5 received power supply from Unit 6 on emergency basis.)

Motor operated pumps etc. were unavailable. (Emergency cooling was carried out by emergency condenser IC in Unit 1, reactor core isolation cooling system [RCIC] in Unit 2, and RCIC and high pressure core injection system HPCI in Unit 3.)

Soaking depletion of battery, depletion of compressed air, etc.

Many on-site works were necessary due to difficulty of measurement / control / communication.

Shutdown of core cooling system

Unit 1 has lost its function at an early phase. Due to this reason, there was only short time to address the situation.

Fuels were exposed and melt down while cooling was not conducted.

Serious degradation of confinement led to the release of radioactive materials into environment.

Water injection from fire protection system (Alternative water injection)

The exposure time of fuels is considered to be prolonged due to insufficient reactor depressurization (reactor depressurization operation for containment, reactor containment depressurization [vent]) to the pressure lower than the fire extinguishing pump head.

Hydrogen generated through zirconium – water reaction. Explosions that seemed to be hydrogen explosion occurred in reactor buildings at Units 1, 3 and 4. (Pressure in the pressure suppression chamber in Unit 2 dropped simultaneously with the Unit 4 explosion.)

- The explosions deteriorated work performance in the surrounding areas.
- Water leakage from containments / buildings were observed.

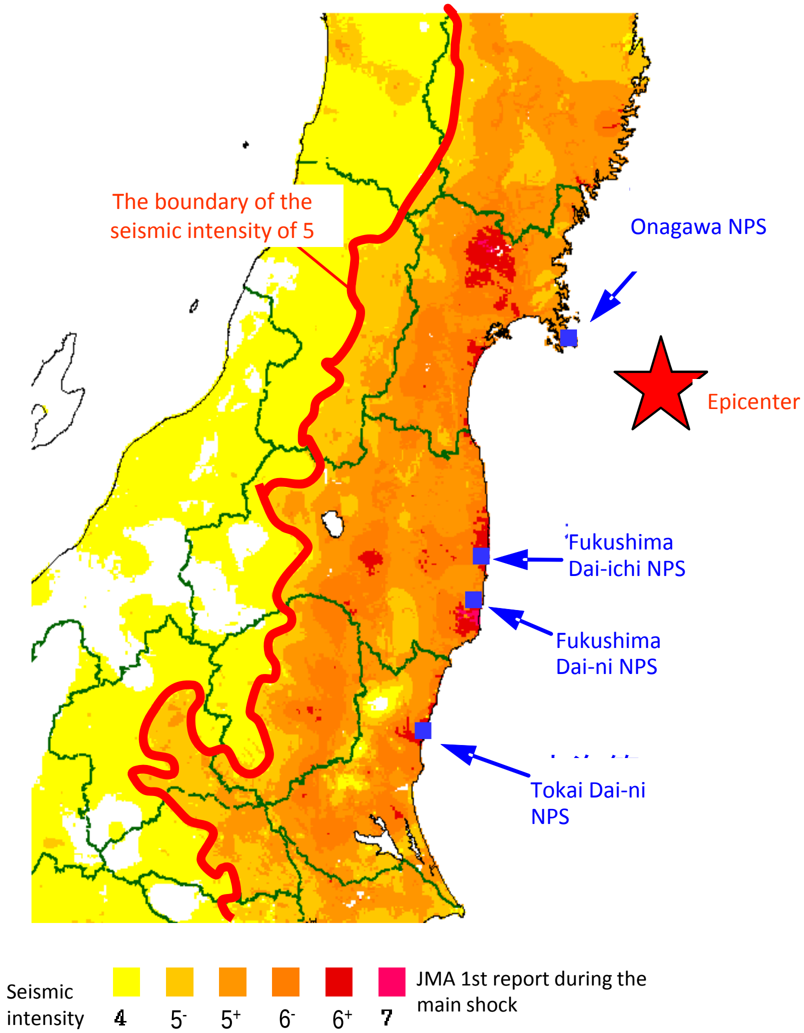
Max. Acceleration Values Observed in Reactor Buildings of each Unit

Loc. of seismometer (bottom floor of reactor bld.)		Record: Max. acceleration (Gal※2) NS	EW	UD	Max. response acceleration to the design basis ground motion Ss (Gal※2) NS	EW	UD
Fukushima Dai-ichi	Unit 1	460※1	447※1	258※1	487	489	412
	Unit 2	348※1	550※1	302※1	441	438	420
	Unit 3	322※1	507※1	231※1	449	441	429
	Unit 4	281※1	319※1	200※1	447	445	422
	Unit 5	311※1	548※1	256※1	452	452	427
	Unit 6	298※1	444※1	244	445	448	415

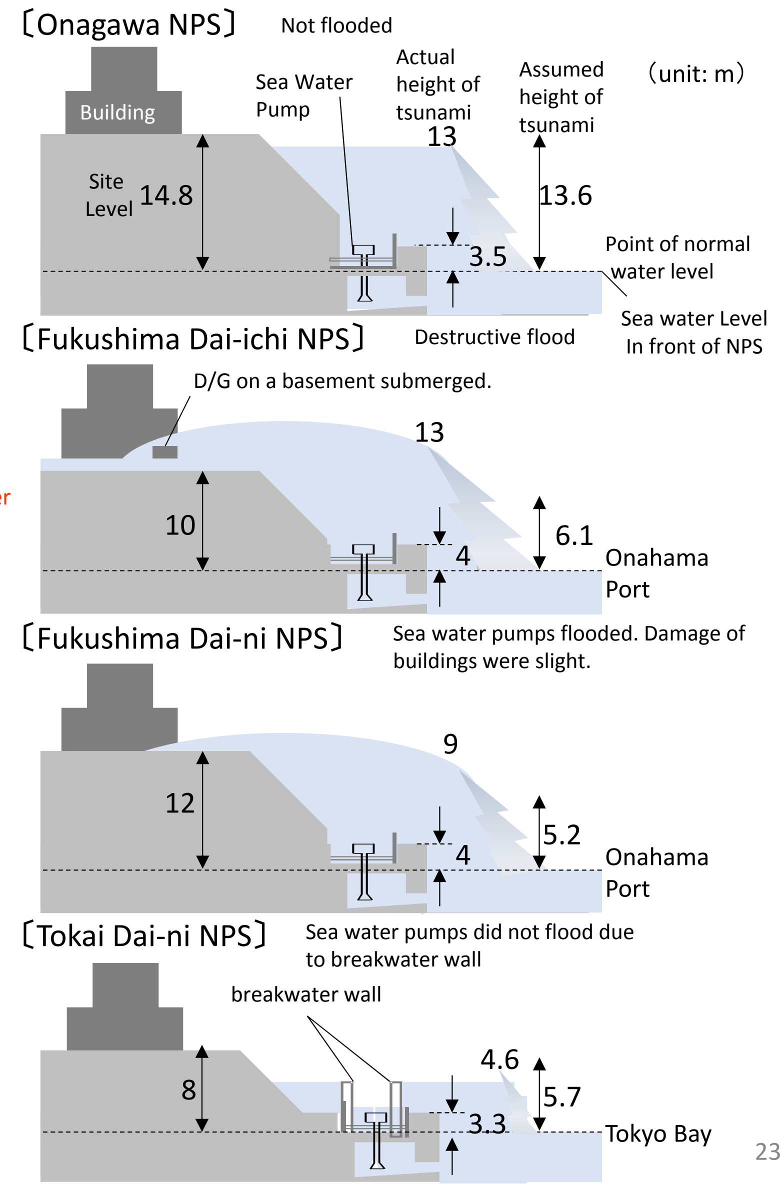
※1：Each recording was interrupted at around 130-150(s) from recording start time

※2：1Gal=0.01m/s^2 , 981Gal=1G

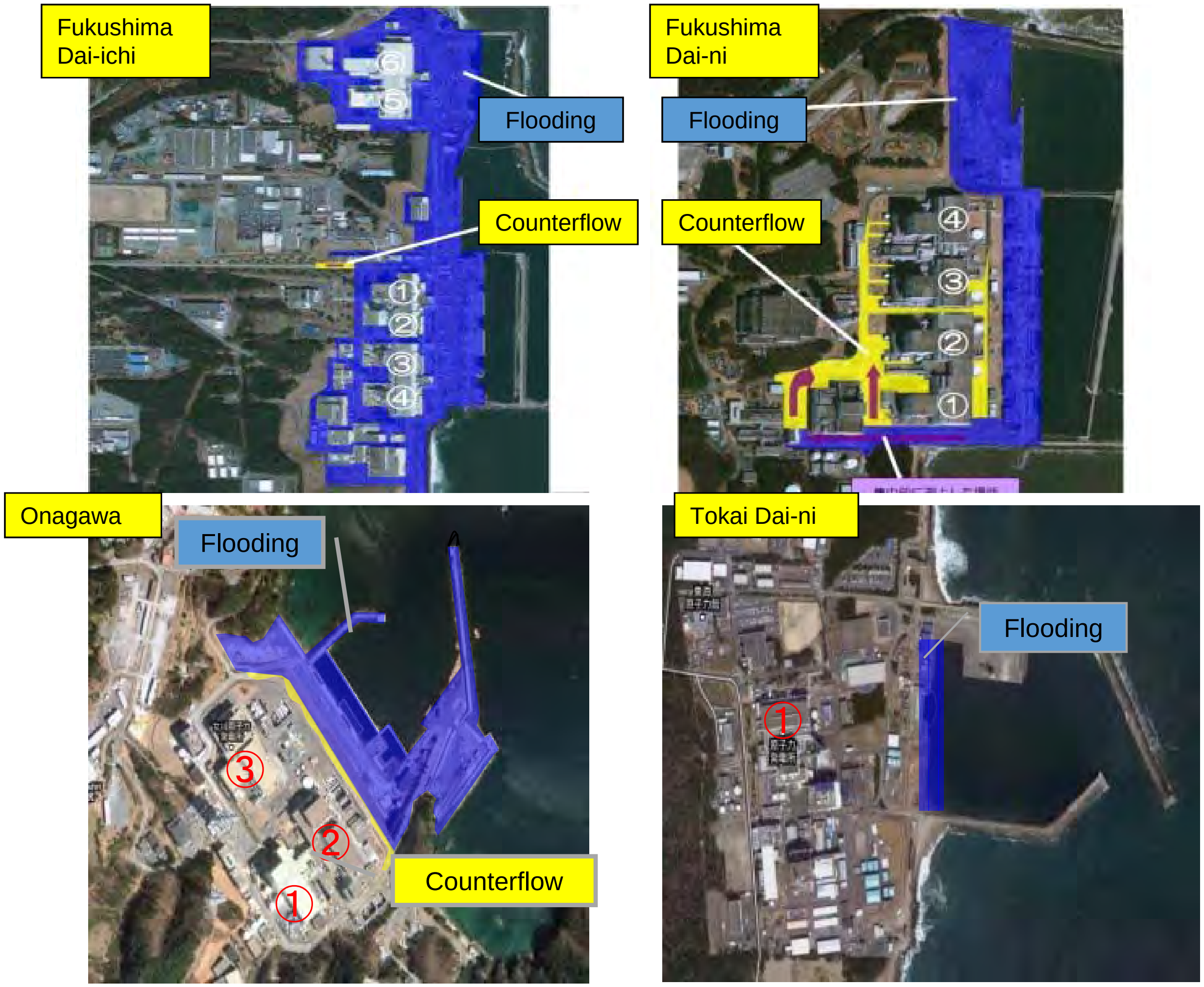
Assumed Height and Actual Height of Tsunami in Each NPS



⊙ Reference: JMA "Tohoku District-Off the Pacific Coast Earthquake in 2011(1st Report)," http;//www.jma.go.jp/jma/index.html, partially modified by JNES

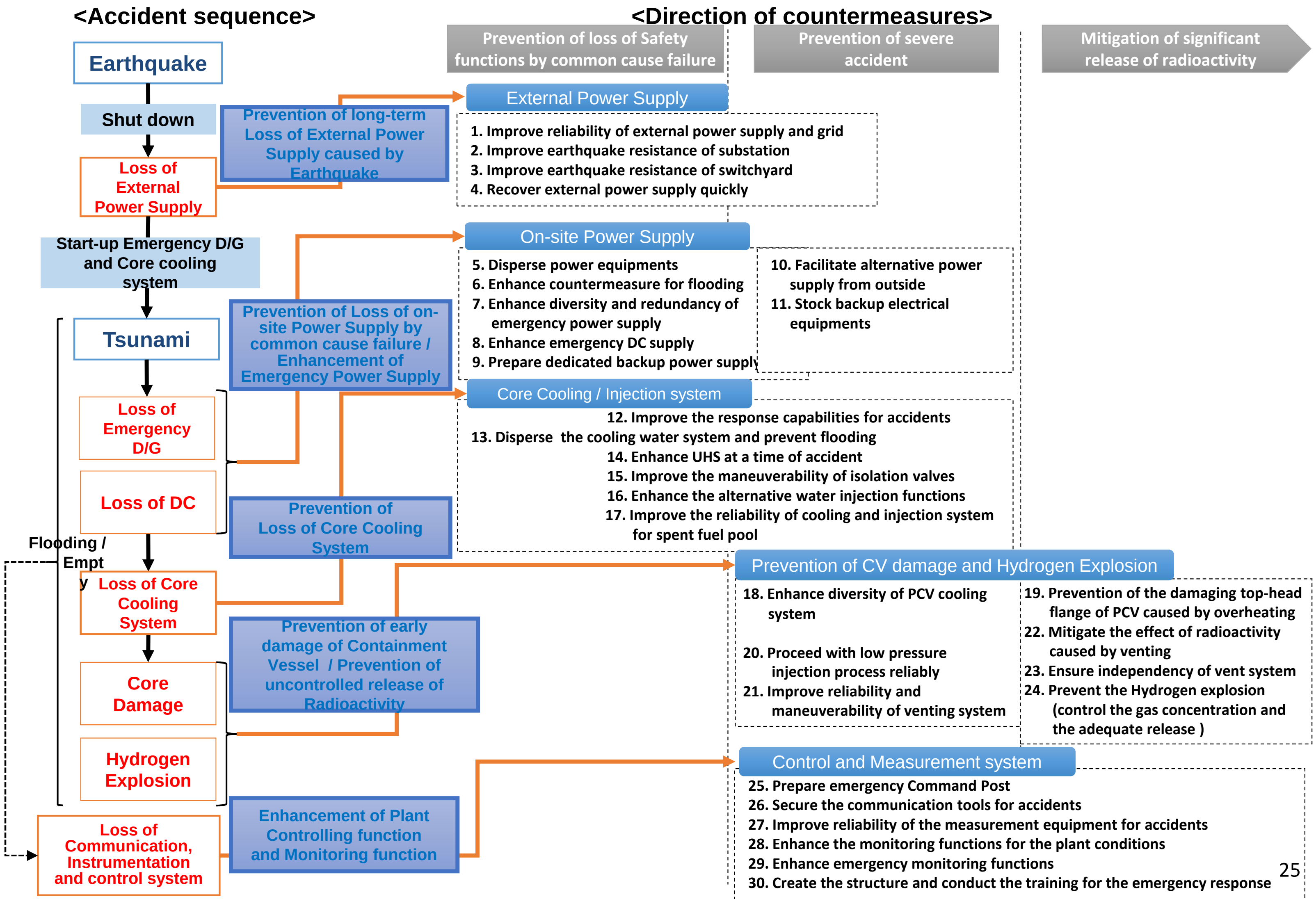


Areas inundated by Tsunami at Each NPS



Text added by NISA to published materials from Niigata Prefectural Technology Committee and Google

Technical Knowledge about Accident at Fukushima Dai-ichi Nuclear Power Station, TEPCO
Direction of Countermeasures (Point) - Interim Report -

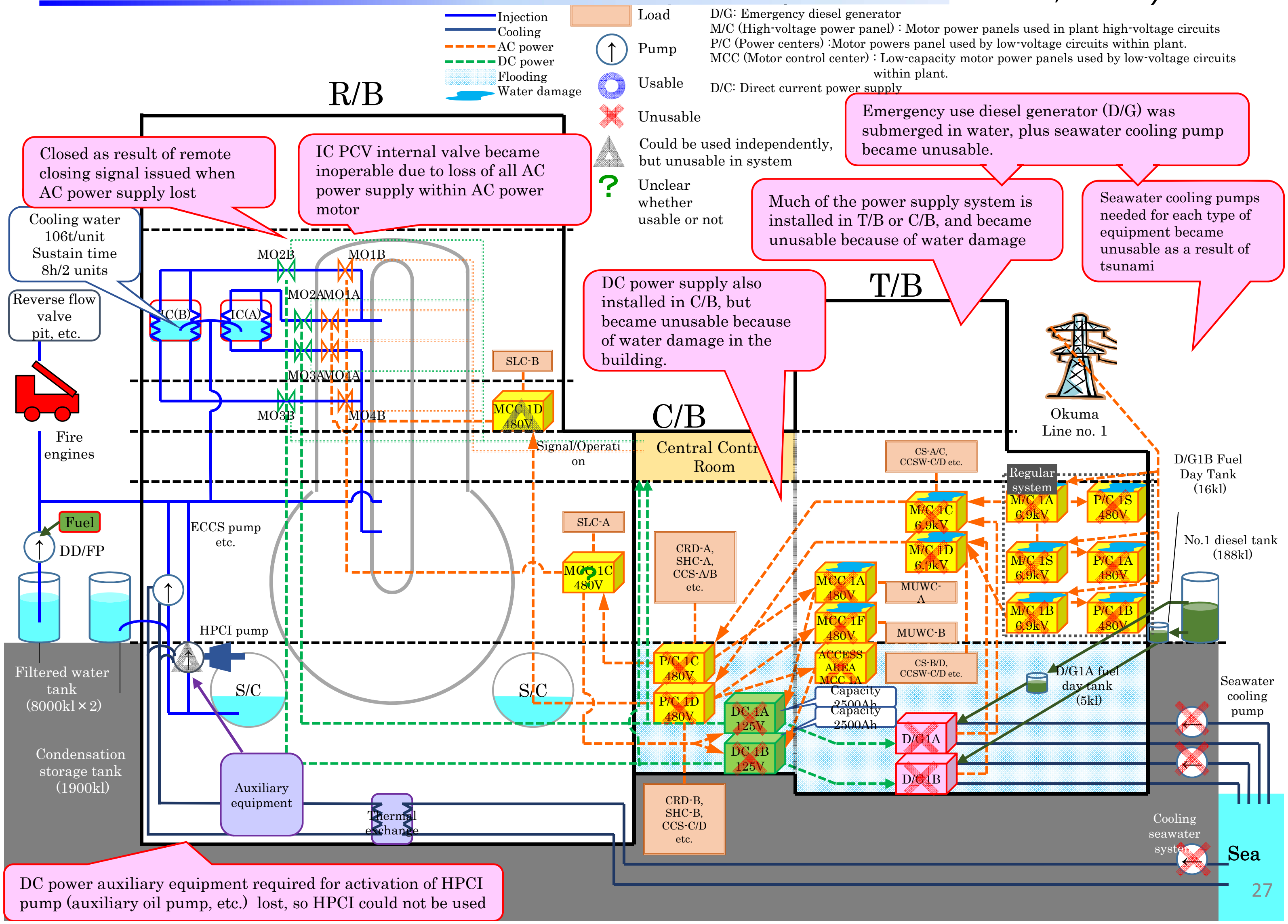


Impact of Tsunami on On-site Power Supply and Cooling Systems

	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6
Emergency Diesel Generator	× 1A, 1B (T/B basement)	× 2A (T/B basement) 2B (Common pool 1F)	× 3A, 3B (T/B basement)	× 4A (T/B basement) 4B (Common pool 1F)	× 5A, 5B (T/B basement)	△ 6A: R/B basement 6B: DG building 1F (Usable) HPCS: R/B basement
high-voltage switch boards	× T/B 1F	× T/B basement, etc.	× T/B basement, etc.	× T/B basement, etc.	× T/B basement, etc.	△ R/B 2F basement
Power center (note)	× T/B 1F etc.	△ T/B 1F etc.	× T/B basement, etc.	△ T/B 1F, etc.	△ T/B 2F, etc.	△ R/B 2F basement, etc.
DC power (battery)	× C/B basement, etc.	× C/B basement, etc.	○ T/B mezzanine basement	× C/B basement, etc.	○ T/B mezzanine basement	○ T/B mezzanine basement
Emergency core cooling equipment	△ However, IC required inspection	△ (RCIC usable)	△ (RCIC and HPC usable)	–	–	–

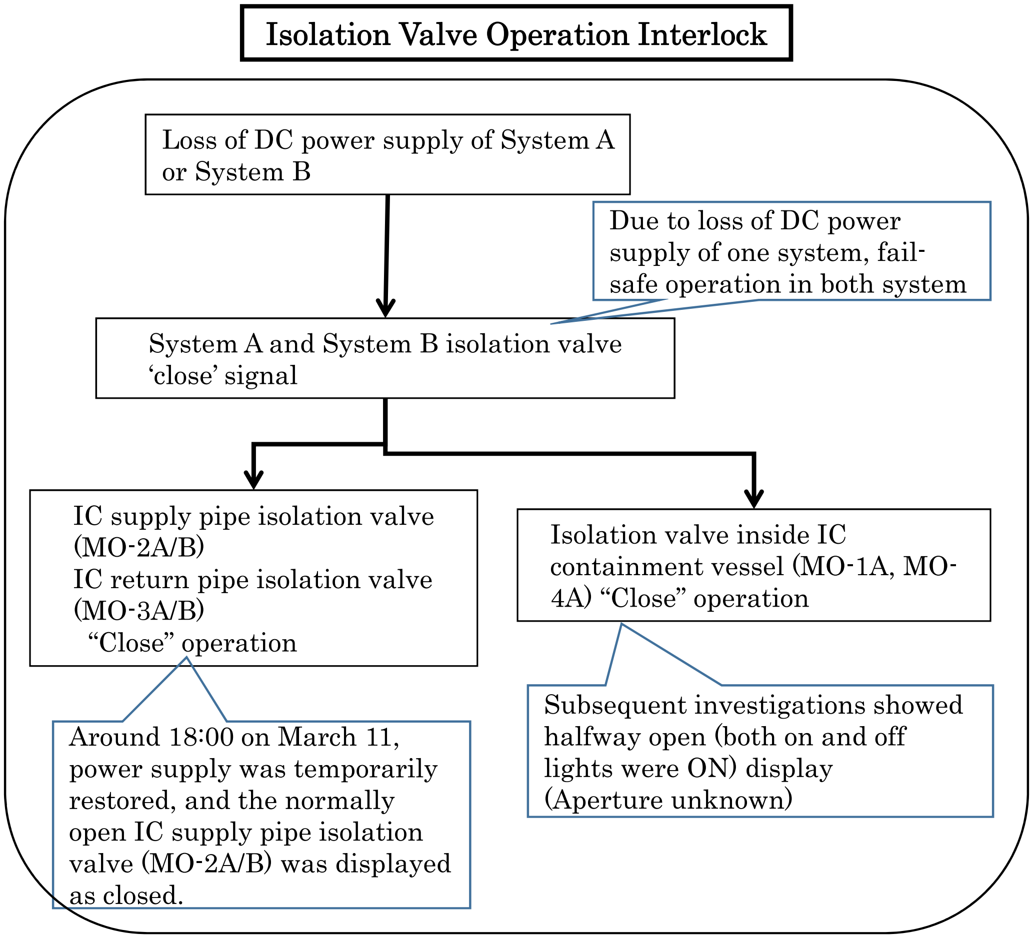
×: Unusable due to flooding or water damage △: Partially unusable ○: Usable T/B: Turbine building C/B: Control building R/B: Reactor building
(Note) Air circuit breaker (ACB), guard relay and peripheral equipment stored in a compact manner using a motive power panel that uses low-voltage circuits within the plant

State of Damage to On-site Power Supply Equipments (Fukushima Dai-ichi, Unit 1)



Operating Conditions of Isolation Condenser (IC) of Unit 1

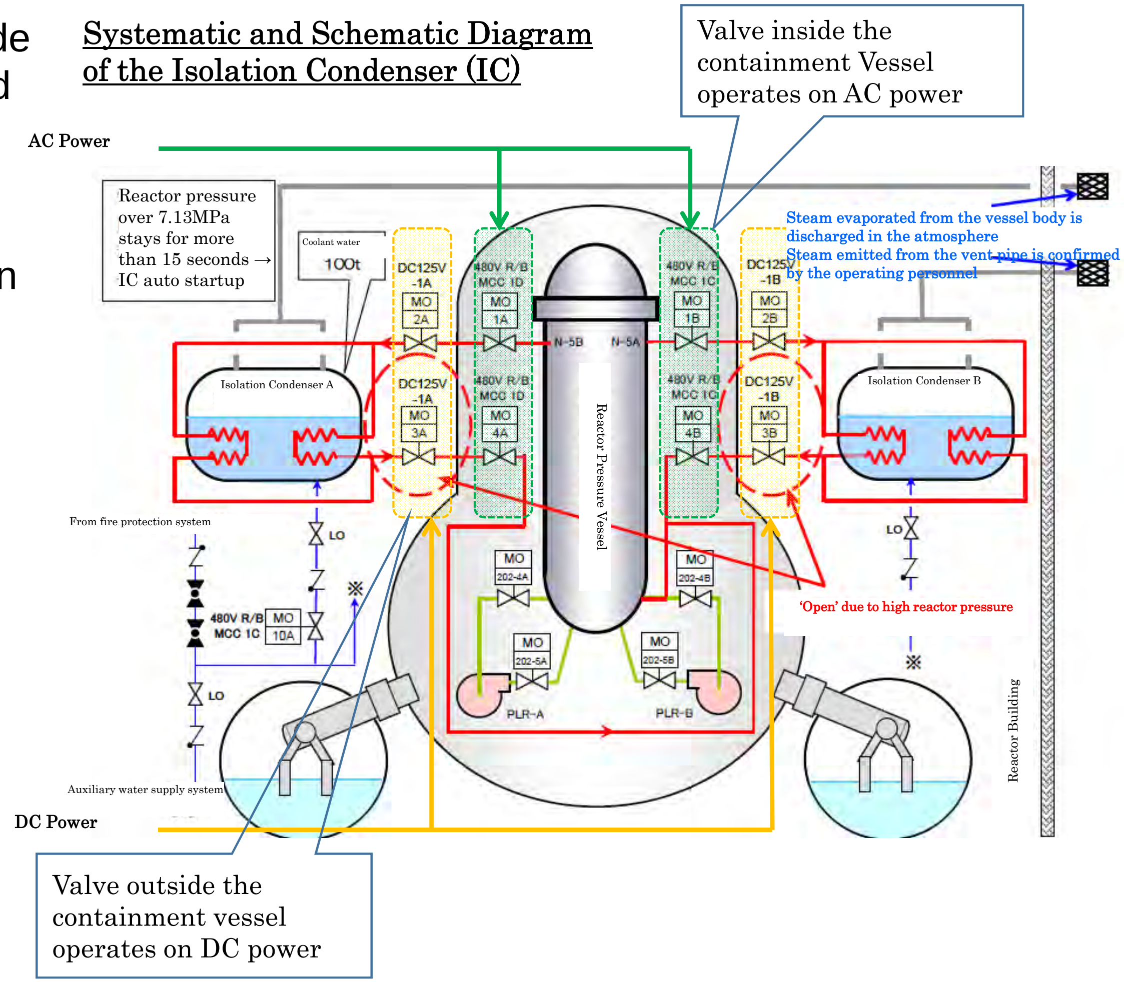
- Due to loss of DC power supply after tsunami, the indication of the valve status (open or close) went off, and the IC became uncontrollable.
- Due to loss of DC power supply, the interlock of the isolation valve in fail-safe mode closed the IC valves.



Operating Conditions of the Isolation Condenser (IC) of Unit 1 (cont.)

- Since the valves inside the PCV are operated with AC power, both status-check and operation were impossible even when the DC power supply was temporarily restored.
- The status of the IC was misunderstood.

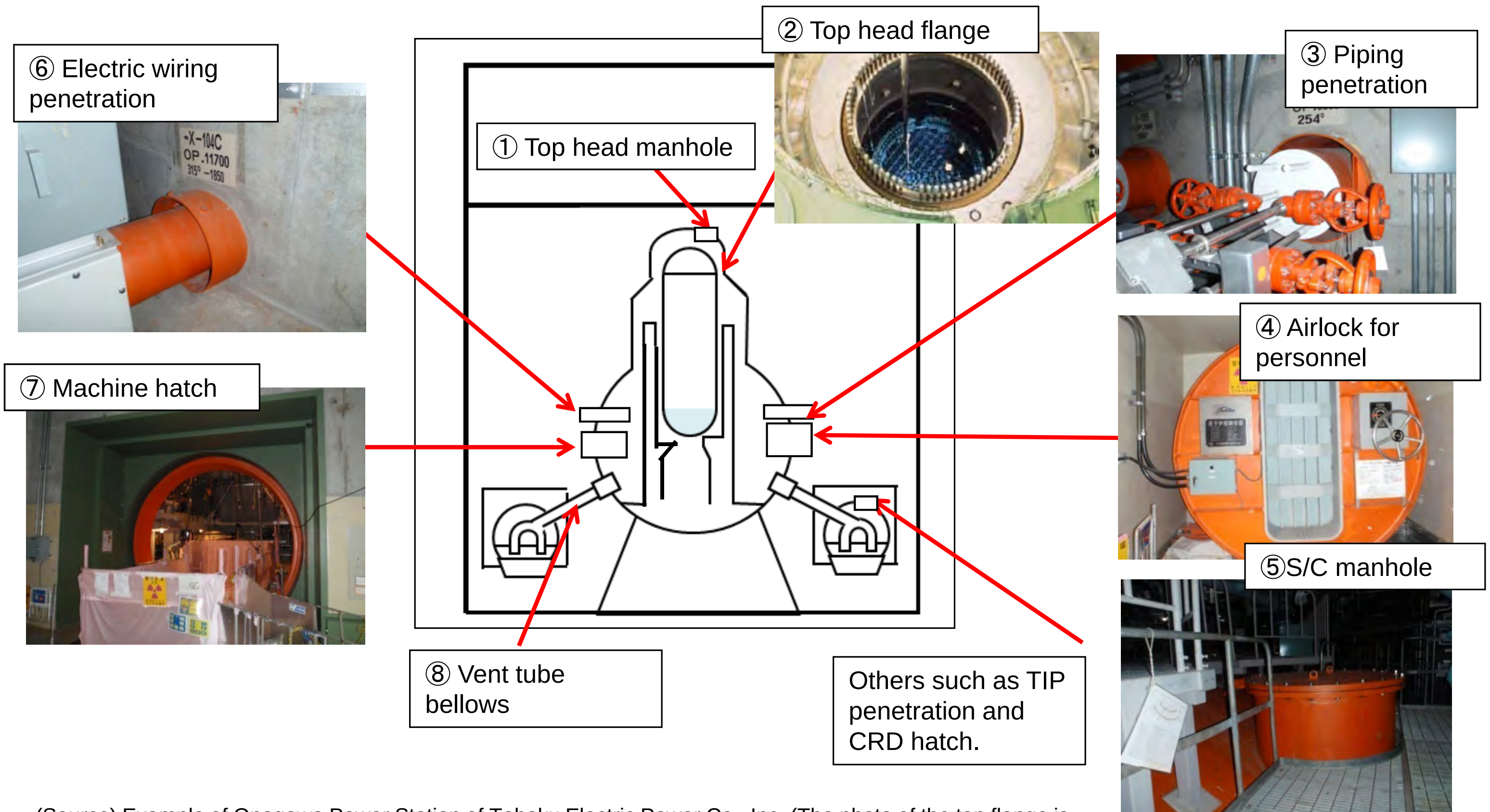
Systematic and Schematic Diagram of the Isolation Condenser (IC)



Impact on Loss of Function of Confinement Systems

- Radioactive material leakage presumably occurred when the pressure of the PCV was increased before the venting because the radioactive dose had increased after increasing of the pressure of the PCV of the Unit 1. Possible location of leakage was top flange, penetration of the containment vessel and/or equipment hatches.
- It is highly possible that the leakages were caused by deterioration of the organic sealing as a result of high temperatures by thermal radiation directly from the pressure vessel.
- When venting was conducted, the standby gas treatment systems (SGTS) was not properly isolated, thus hydrogen gas back flew into the reactor building. (in particular, Unit 4)

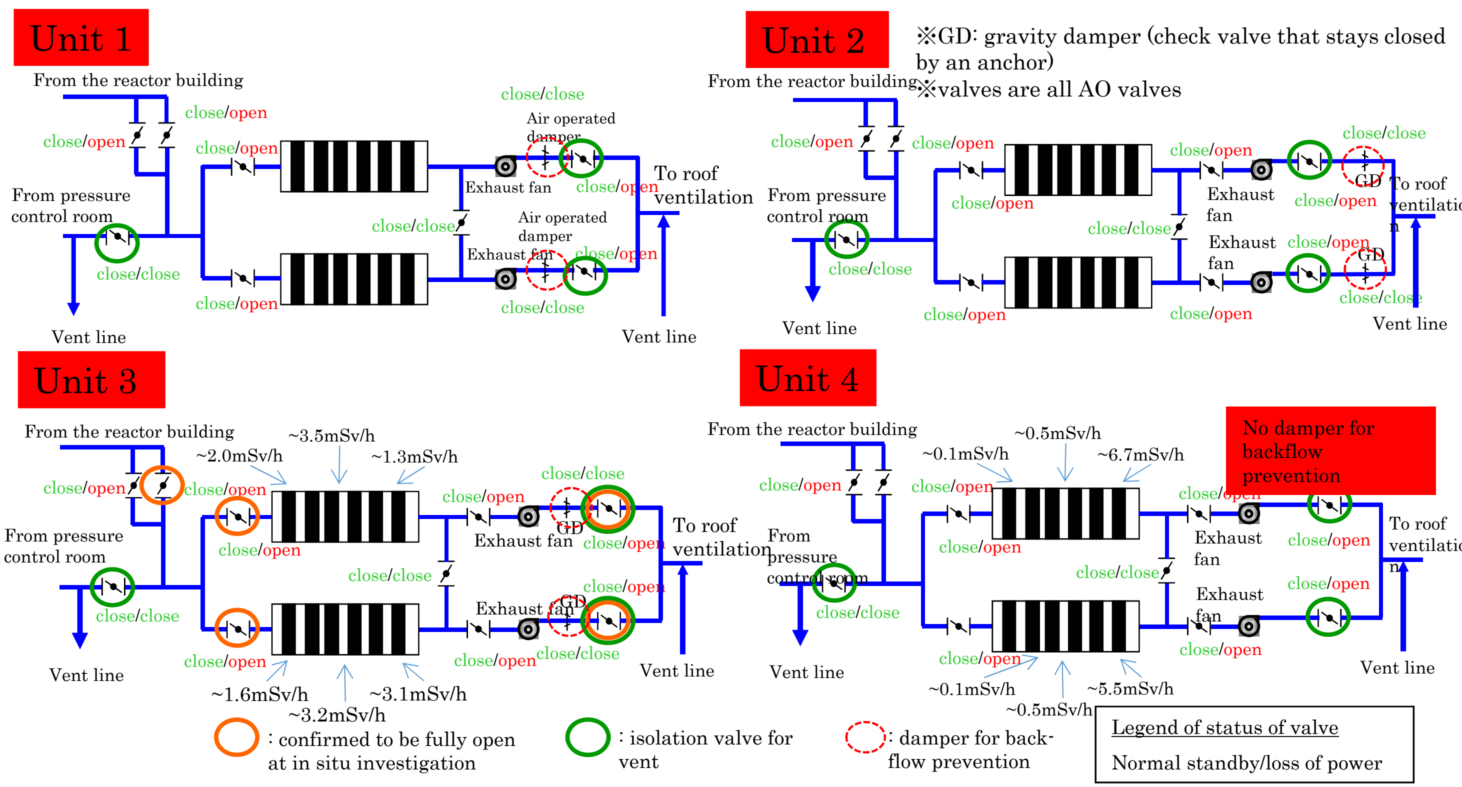
Places of Possible Leakage (Example of Mark-I type Reactor)



(Source) Example of Onagawa Power Station of Tohoku Electric Power Co., Inc. (The photo of the top flange is courtesy of Tokyo Electric Power Co., Inc.)

Possibility of Back-flow to R/B by PCV Vents (Units 1-4)

- To isolate SGTS at the time of PCV vents, the outlet valves of SGTS must be closed according to the operational procedure. But the outlet valves of SGTS of Unit 3 were not isolated. Those of Unit 4 were thought not to be isolated as well.
- Because of the damper at the outlet for Units 1-3 which closes during loss of power, the flow into the reactor building was supposed to be more prevented than Unit 4. Regarding Unit 3, there are no significant backflow in one direction into the building but it is difficult to deny the occurrence of backflow itself.



Change of Nuclear Regulatory System

Reform of Nuclear Regulatory Organization

/Independence

Separate the functions for nuclear regulation and nuclear promotion

Establish the Nuclear Regulation Authority(NRA) as an independent commission body

Amendments to the Nuclear Regulation Act

/New regulation on severe accidents

/Regulation based on the state-of-the art information (backfiting)

/40-years operational limit for NPPs (exceptional less-than-20 years extension)

New Regulatory Requirement

/Strengthening of Design Basis

/Severe Accident Measures

/Enhanced Measures for Earthquake/Tsunami

Principle of Regulation

/Place emphasis of Defense-in-Depth

/Eliminate common cause failure

/Protective measures against extreme natural hazards

Strengthening of Design Basis

/Comprehensive consideration of natural hazards including volcano, tornado and forest fire in addition to earthquake and tsunami, etc

/Reinforcement of fire protection measures

/Enhanced reliability of SSCs important to safety (e.g. Redundancy of piping)

/Reinforcement of off-site power supply (connection to different substations through multiple lines)

/Protection of systems for Ultimate Heat Sink

Strengthen Requirement of Counter Measures for Severe Accident (SA)

Prevention of Core Damage (ATWS, Loss of RCF・RDF・RCF・UHF etc.)

Prevention of Containment Failure (CV spray, Filtered venting etc.)

Prevention of hydrogen explosion at reactor building etc.

Cooling at SFP

Prevention of fuel damages during shutdown

Emergency Response Center

Enhanced Measures for Earthquake/Tsunami

Tsunami

More Stringent Standards on Tsunami

/Define “Design Basis Tsunami” – Exceeds the largest in the historical records

Enlarged Application of Higher Seismic Resistance

/SSCs for Tsunami protective measures such as Tsunami Gate are classified as Class S equivalent to RPV etc.

Earthquake

More Stringent Criteria for active faults

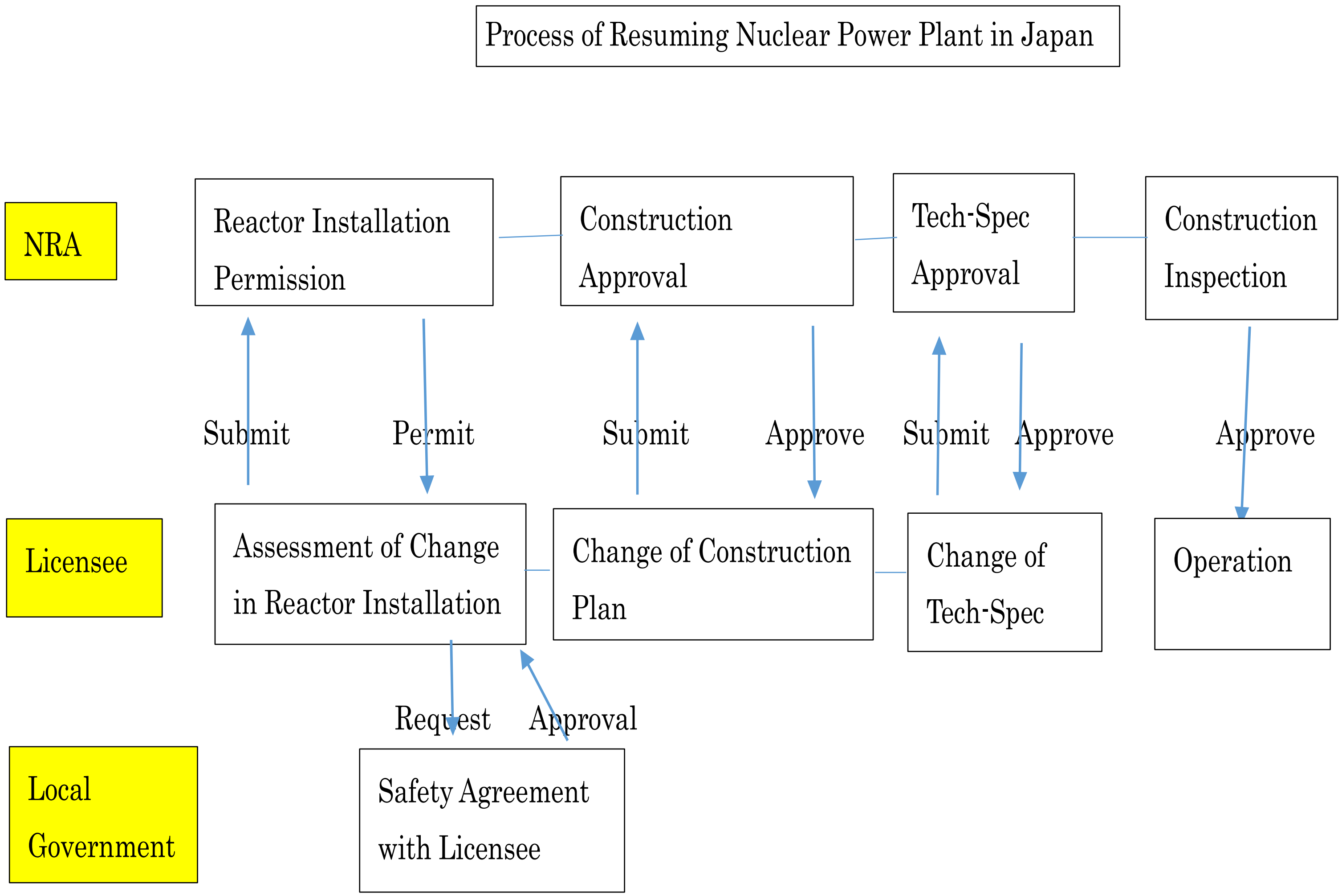
/Active faults with activities later than the Late Pleistocene be considered for seismic design
/Active in the Middle Pleistocene be investigated if needed

More Precise methods to define seismic ground motion

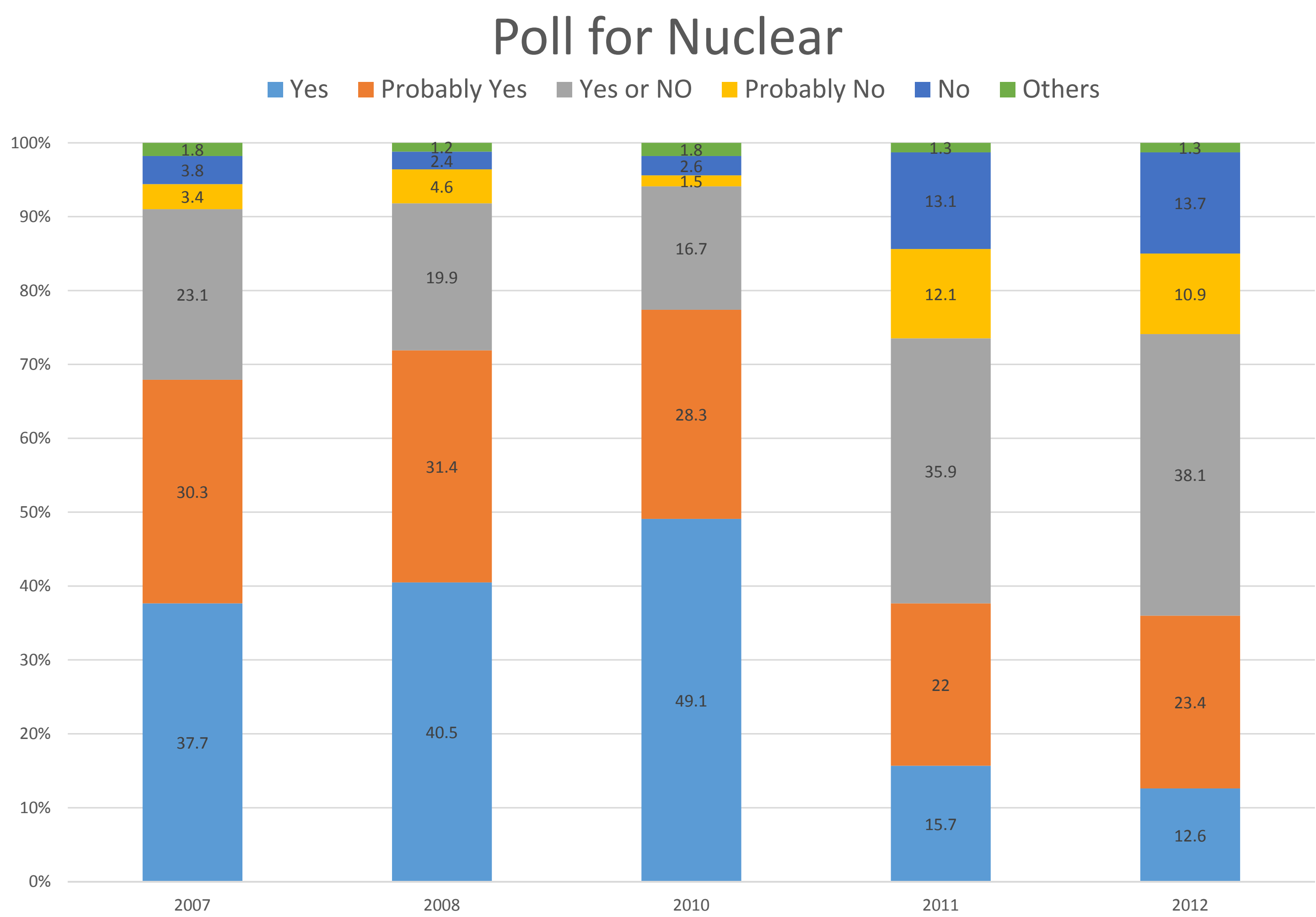
/3D observation of geological structure on the site

Displacement and Deformation

Class S buildings should not be constructed on the exposure of active faults


Process of Resuming Nuclear Power Plant in Japan
NRA
Reactor Installation Permission
Construction Approval
Tech-Spec Approval
Construction Inspection
Submit
Permit
Submit
Approve
Submit
Approve
Approve
Licensee
Assessment of Change in Reactor Installation
Change of Construction Plan
Change of Tech-Spec
Operation
Request
Approval
Local Government
Safety Agreement with Licensee

Question: Do you still believe nuclear is needed for Japanese economy?



NPS total Capacity at the Accident 48.96Mkw	48.96
Fukushima-Daiich 4.696Mkw Decommission Process	44.264
Fukushima-Daini 4.4Mkw Too Difficult to resume	39.864
Tsuruga Unit2 1.16Mkw Fault line Issue	38.704
5 first generation NPS difficult to fit 40years rule (Tsuruga1, Mihama 1,2, Shimane1, Genkai1) 2.216Mkw	36.488 Max

Twenty NPS submit TA report to NRA 20.10Mkw

Sendai Unit1, 2 Approved by NRA 1.78Mkw

Takahama Unit3, 4 Approved soon 1.74Mkw

Ooi Unit3,4 Close to finish soon 2.36Mkw

Genkai Unit 3,4 Close to finish soon 2.36Mkw

Tomari,Higashidori,Shika Fault line issue 4.375Mkw

Hamaoka Longer Construction 1.137Mkw

Simane, Onagawa,Ikata Midst of the Review 2.535Mkw

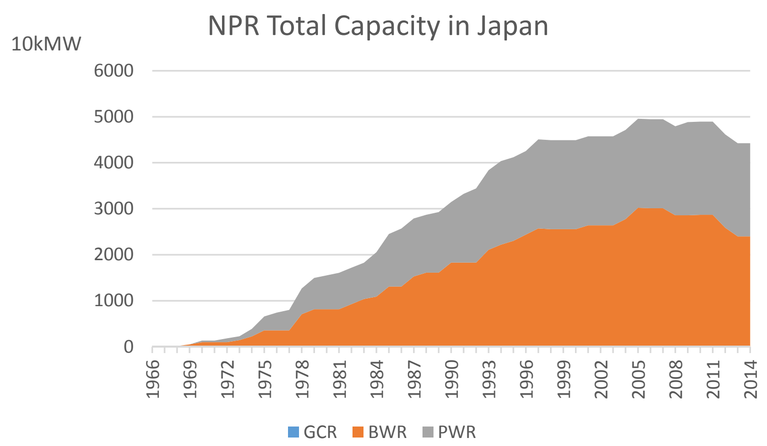
Kashiwazakikariwa, Tokai Daini Difficulty to get agreement with Local Government 3.812Mkw

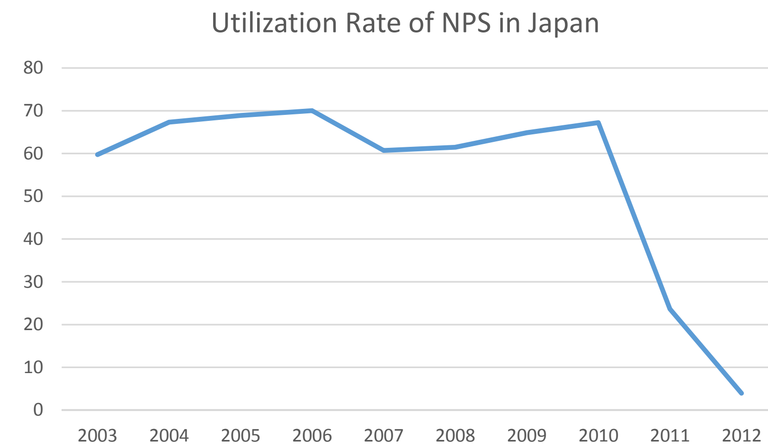
Not Submit Yet NPSs 18Unit 16.388Mkw

Onagawa 1,3	1.349Mkw	Fault Issue only
Kashiwazakikariwa 1-5	5.5Mkw	Unit2-4 never operated since 2007
Hamaoka 3,5	2.48Mkw	Longer Construction
Takahama 1,2	1.652Mkw	Challenge 40years Qualify
Mihama3, Ooi 1,2	3.176Mkw	Consider 40years challenge
Shika1, Ikata 1,2 Genkai 2	1.691Mkw	40 years challenge soon , Already changed RV

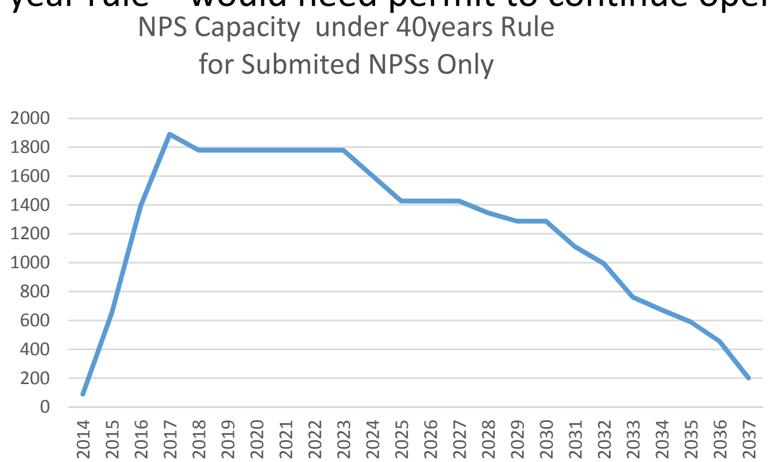
New Plant

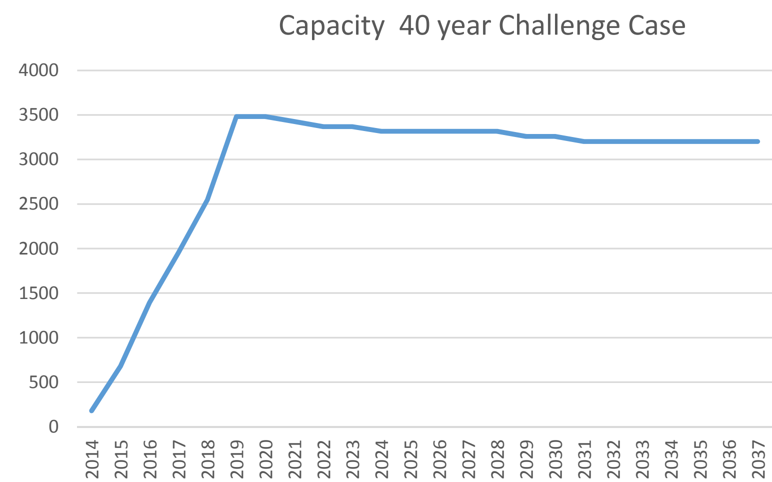
Shimane Unit3	1.373Mkw	93.6%complete
Ohma	1.383Mkw	37.6%complete





40 year rule – would need permit to continue operation





NOTE: Based only on repowering approval process

Conclusion

/Japanese Government has not determined the quantitative target of energy supply by sources yet.
/It will be published after the Unified Local Election in the spring of 2015.
/The share of nuclear would be put between 15 to 25 % of power supply .
/It could be possible to achieve but it takes at least 4 to 5 years.
/It reduce tentative demand for LNG to some extent but the loss of power demand would be compensate by increase demand in the field of cogeneration.
/LNG should compete with Coal by any means.
/FIT system for renewable energy will be redesigned soon and electricity market reform will be conducted by 2020.