Bilateral Exchange:

Post-Fukushima Safety Enhancement Measures of Taiwan's Nuclear Power Plants

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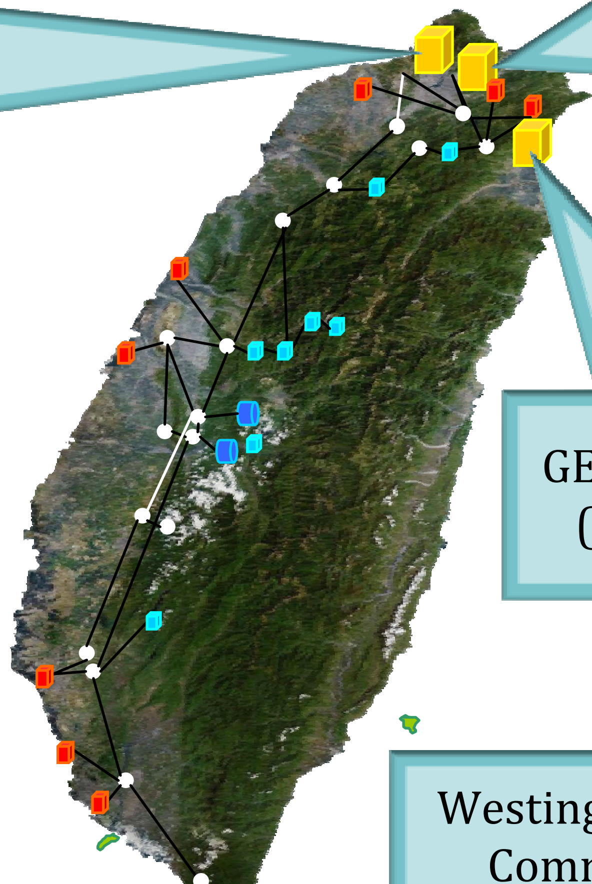
OUTLINE

- Background
- Comprehensive Safety Assessments after Fukushima
- Post-Fukushima Safety Enhancement Measures

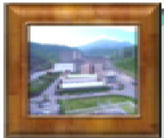
Background

- There are currently three operating nuclear power plants (NPPs) in Taiwan: Chinshan (CS) , Kuosheng (KS) and Maanshan (MS). In addition, the Lungmen NPP is under construction.
- Each of these four NPPs has two identical units. All the NPPs in the country are owned and operated by the Taiwan Power Company (TPC).
- The nuclear generation cost for TPC is much lower than that for other energy sources. Thus, TPC's 3 operating NPPs carry the function of balancing the huge loss suffered from the inability to raise electricity tariff.
- The power uprate and the efficiency uprate are the two major programs currently adopted by the TPC to further improve performance for the NPPs.

Outline of Taipower's NPPs



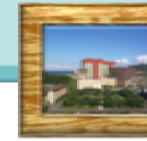
Chinshan



GE BWR-4
636 MWe x 2
Commercial
Operation Date :
1 Dec. 1978
2 July 1979

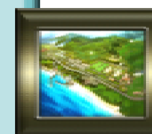
Kuosheng

GE BWR-6 985 MWe x 2
Commercial Operation
Date :
#1 Dec. 1981
#2 Mar. 1983



Lungmen

GE ABWR 1350 MWe x2
(Under Construction)

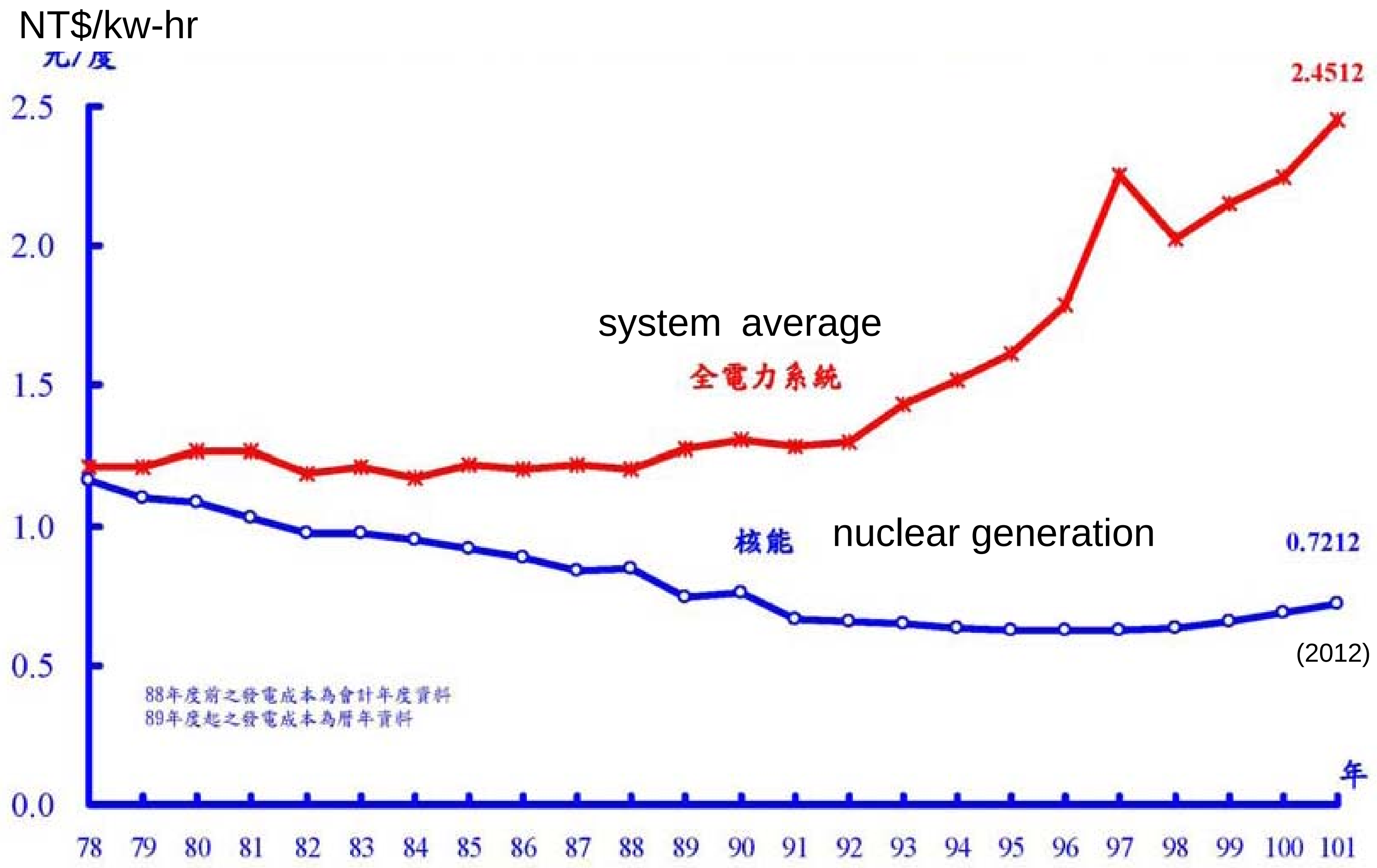


Nuclear Installed Capacity
5,144 MW

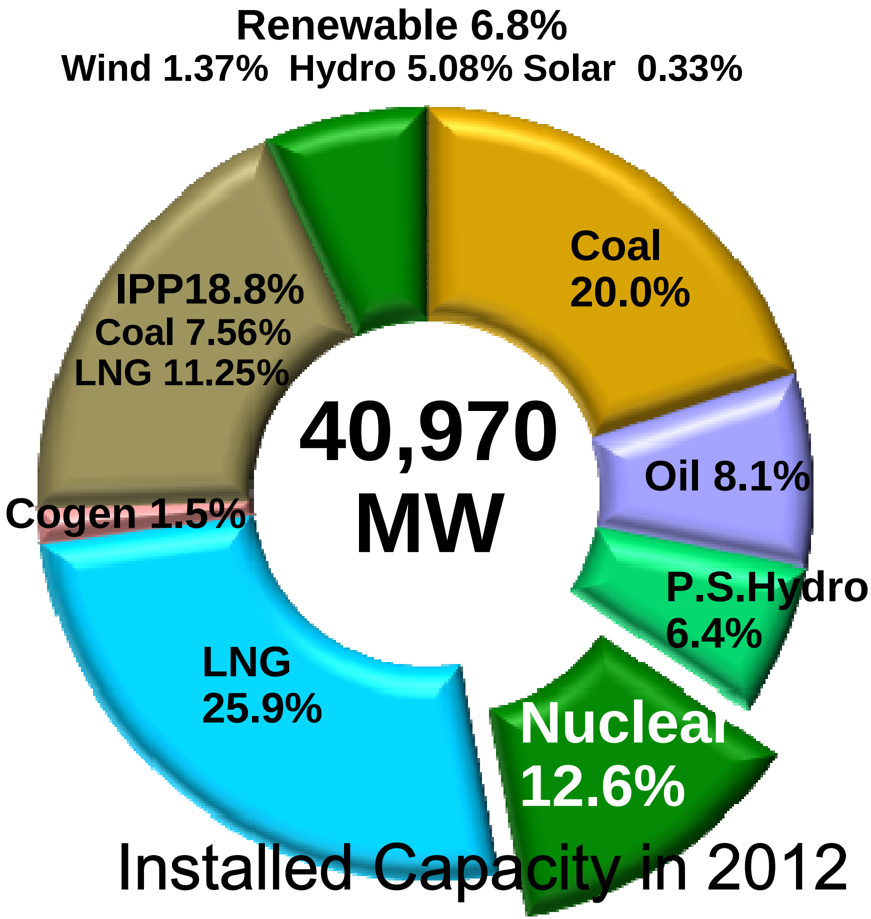
Electricity Generation
38.9 billion kWh (2012)

Maanshan

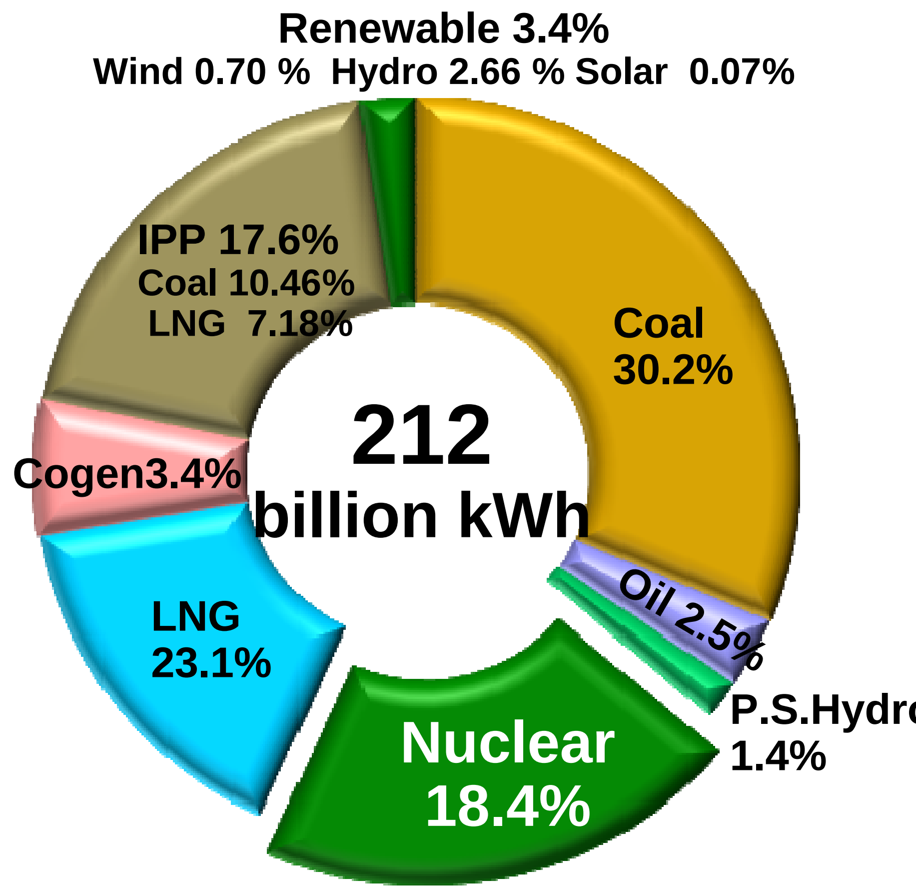
Westinghouse PWR 951 MWe x 2
Commercial Operation Date :
1 July 1984
#2 May 1985


NT$/kw-hr
元/度
2.5
2.0
1.5
1.0
0.5
0.0
2.4512
system average
全電力系統
核能
nuclear generation
0.7212
(2012)
88年度前之發電成本為會計年度資料
89年度起之發電成本為曆年資料
年
78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101

Power System Performance in Taiwan

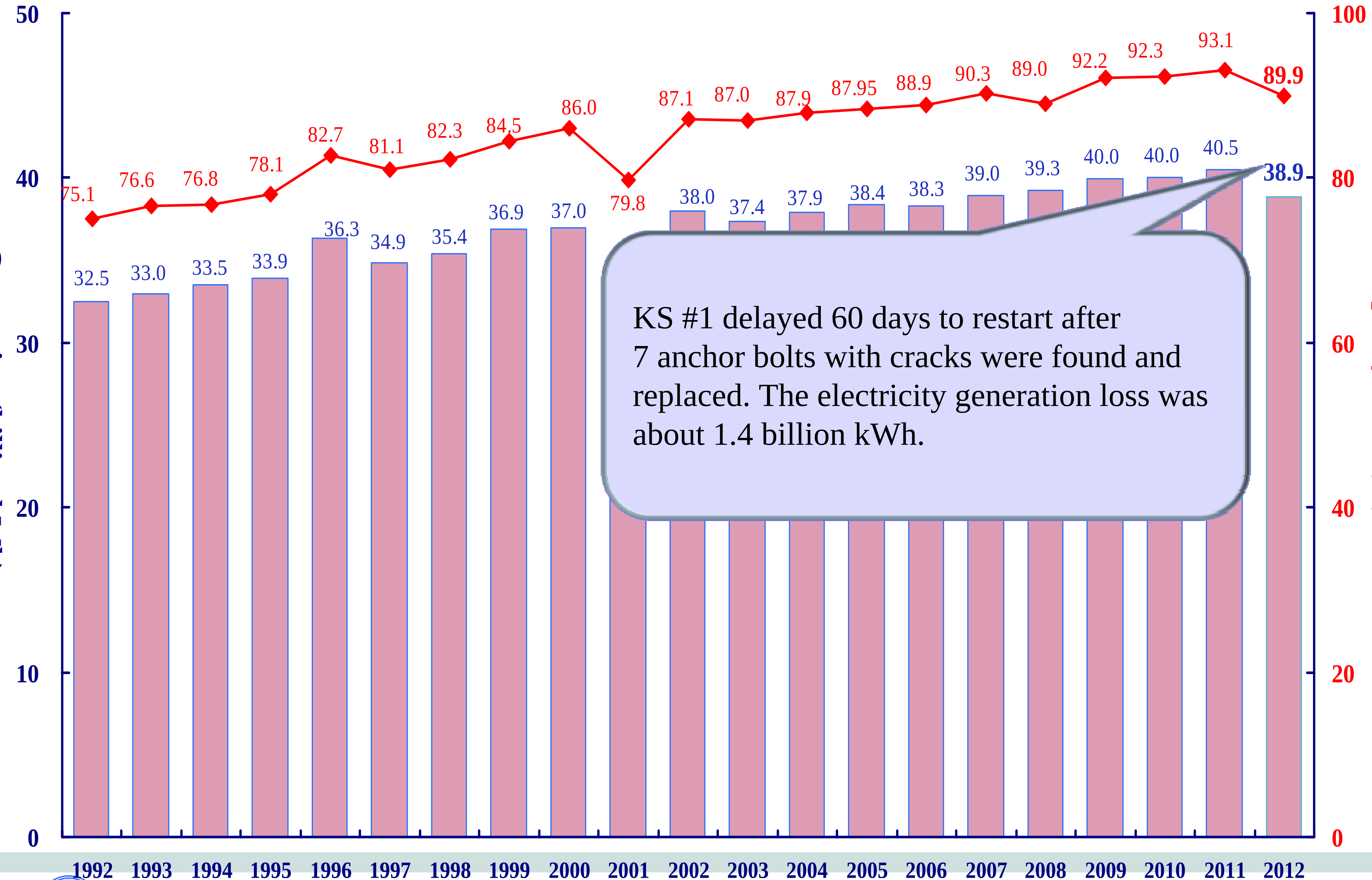


Installed Capacity in 2012

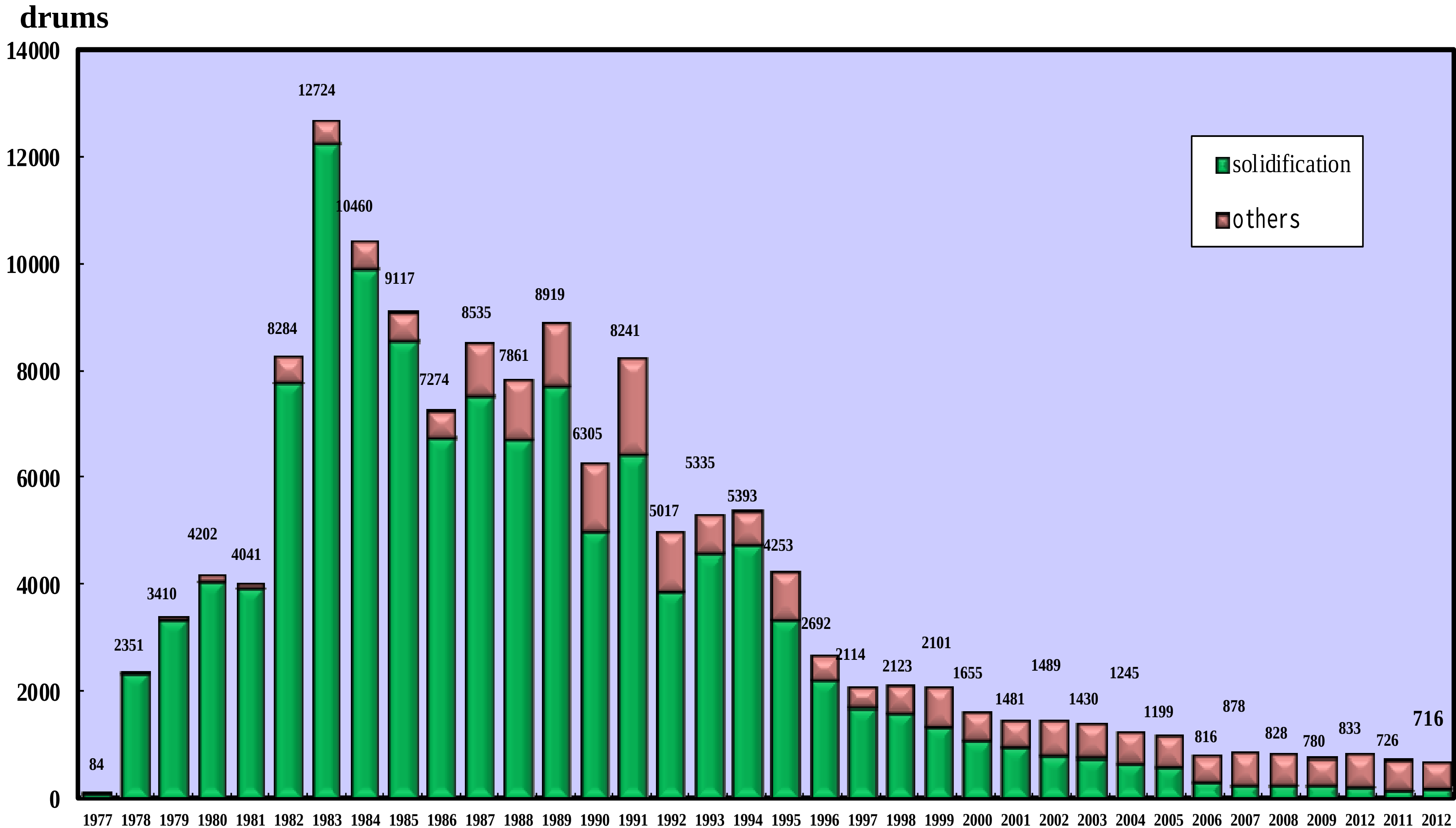


Electricity Generation in 2012

Nuclear Performance of TPC



Low-Level Radwaste



others：combustible, compressible, spent resin……

Electric Power gained from Power Uprate

MUR(1%)		55.64 MW	7/7,2007～7/7,2009
SPU(2%)		expecting 64 MW	scheduled 2012～2014
Chinshan	◆Unit 1	13.61MW	11/23, 2012
	◆Unit 2	14.11MW	11/29, 2012
Kuosheng	◆Unit 1	expecting 18MW	scheduled 2014
	◆Unit 2	expecting 18MW	scheduled 2014

Electric Power gained from H/P Turbine Rotor Replacement

H/P Rotor		34.83 MW	2012
Maanshan	◆ Unit 1	17.60MW	June, 2012
	◆ Unit 2	17.23MW	December, 2012

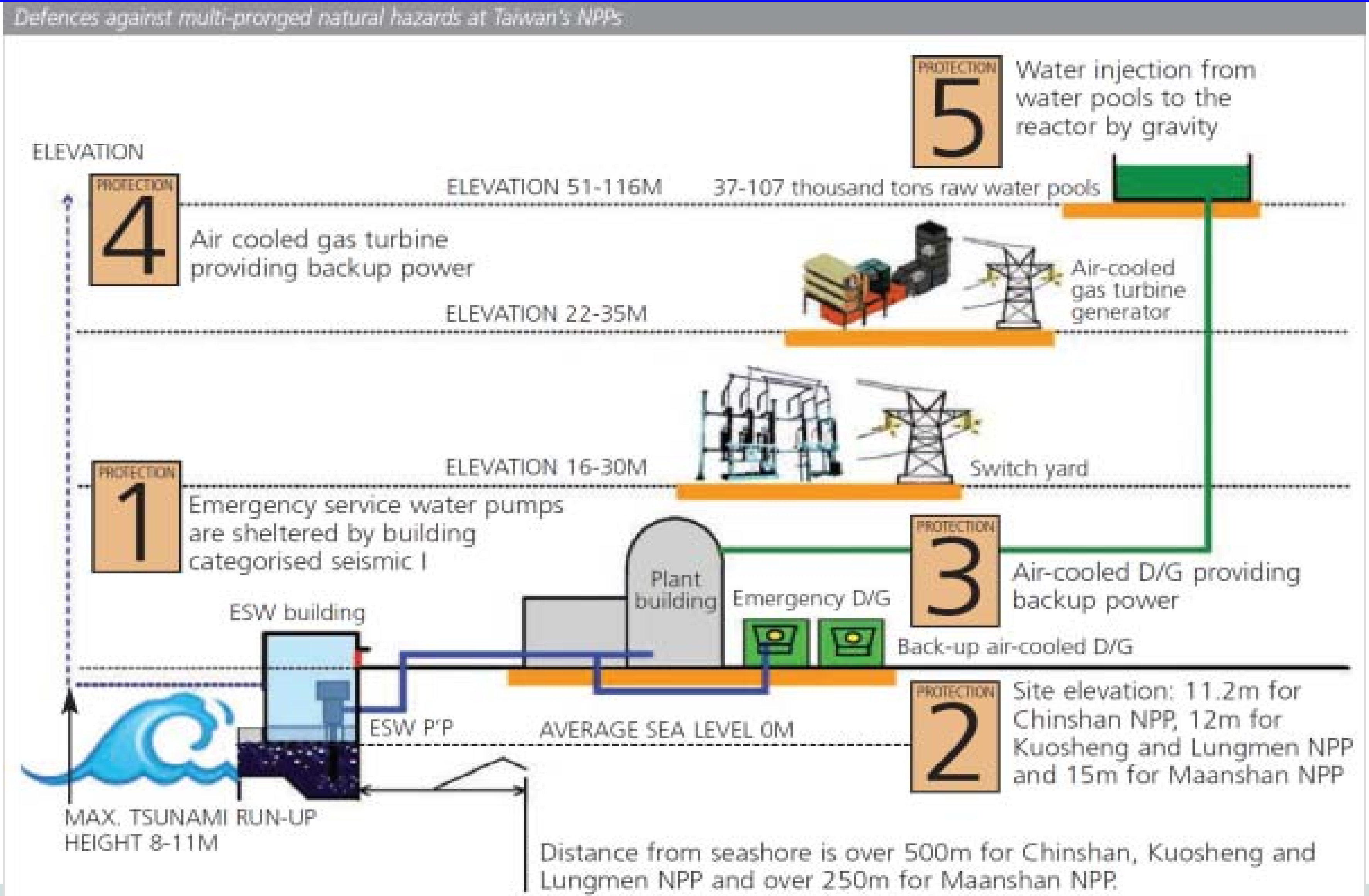
Comprehensive Safety Assessments After Fukushima Accident

Advantages of TPC's NPPs in coping with severe hazards

Measures taken by Taiwan to protect its NPPs have been illustrated as best practices for Loss of Ultimate Heat Sink and Protection Against Severe Tsunami in a Carnegie policy paper entitled "Why Fukushima was preventable".

#	Items	Fukushima Dai-ichi	TPC's NPPs
1	ESW pumps sheltered	None	Yes
2	Distance from sea shore	100 m	CS,KS,LM Over 500 m MS Over 250m
3	Back up air-cooled D/G (CS,KS,MS : 5th ; LM : 7th)	None	Yes (elevation 11.2~15 m)
4	Back up air-cooled G/T	None	Yes (elevation 22~35 m)
5	Raw water pool	None	Yes (37~107 thousand ton, 51~116 m)

Lessons Learned - Comparison



Responses to Fukushima Accident

- *Comprehensive Safety Assessments (CSA):*

1) Similar to Japan, Taiwan is also vulnerable to extreme seismic events. Immediately following the Fukushima accident, TPC established several task forces to take lessons from the event and initiated many safety enhancement measures.

2) In light of the Fukushima accident, President Ma of the ROC declared that "the comprehensive safety assessments in operating and under-construction NPPs shall be undertaken immediately" in a national security-level meeting for response to the disasters.

3) On the basis of request made by AEC on April 19, 2011 and under the prudent guidance of AEC, TPC planned out two phases of CSA – Safety Assessments and Stress Test.

Responses to Fukushima Accident

- *Comprehensive Safety Assessments (CSA):*

(1) Phase I *(Safety Assessment)*: Fully inspected/evaluated various aspects including site characteristics, design basis, construction quality, maintenance, accident management, and worked out improvement programs to enhance the capabilities of prevention and mitigation of accidents. *(CSA report)*

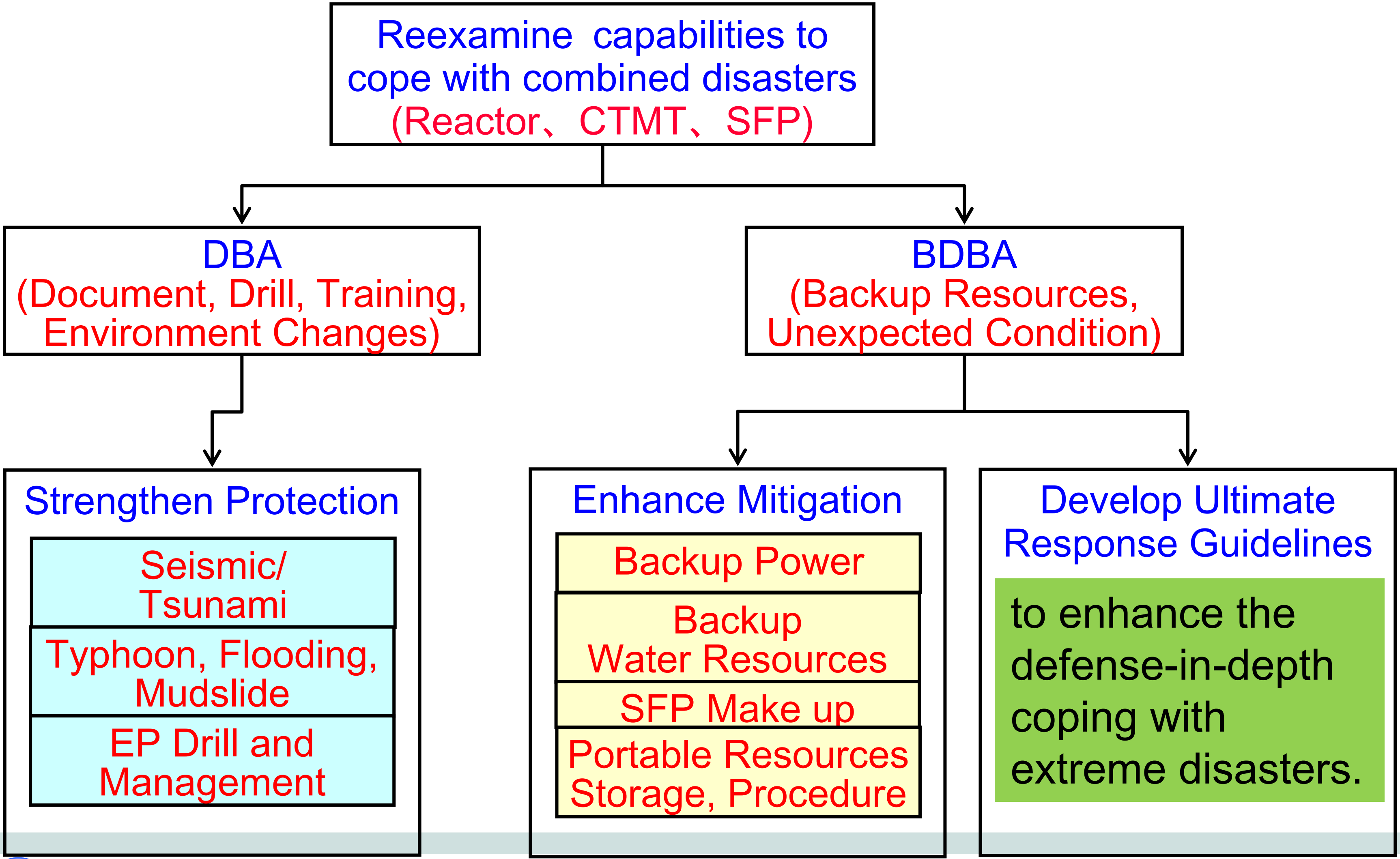
(2) Phase II *(Stress Test)*: Verify the robustness of design and recognize cliff-edge effect and hidden weakness. Refer to EU Stress Test specification and adopt PRA methodology to recognize the cliff-edge. *(Stress Test report)*

◆ *Comprehensive Safety Assessments (CSA):*

❖ *Schedule of CSA*

Phase	Plan	NPPs	Schedule
1	*Safety Assessment*	Operating Plants	March ~ June , 2011 (completed)
		Lungmen	May ~ December , 2011 (completed)
2	*Stress Test*	Operating Plants	July , 2011~February , 2012 (completed)
		Lungmen	January ~April , 2012 (completed)

Techniques of CSA-Phase I



11 major items examined during phase I

Major Items of Safety Assessments and reinforcement			
1	Station Blackout	7	Units 1/2 Mutually Back-up
2	Facility/Site Flood & Tsunami Protection	8	Resistance against Multi-pronged Severe Hazards
3	Integrity & Cooling Capability of Spent Fuel Pool	9	Mitigation against Beyond Design Basis Accident
4	Capability of Residual Heat Removal & Ultimate Heat Sink	10	Preparedness of Essential Facility/Equipment and Backup Equipment
5	Emergency Operating Procedure & Training	11	Efficient Manpower Deployment/Organization and Enhanced Safety Culture
6	Establish Ultimate Response Guidelines		

Safety Improvements

- According to the results of phase I of CSA, 96 key improvement items for operating plants and 67 items for Lungmen site have been developed.

- Improvements are classified into 4 areas：

1.Enhance earthquake-resistant capabilities

2.Enhance tsunami/flooding-protection capabilities

3.Enhance event mitigation capabilities

- Backup power supply
- Water resources and injection
- Spent fuel pool cooling
- Resources preparedness

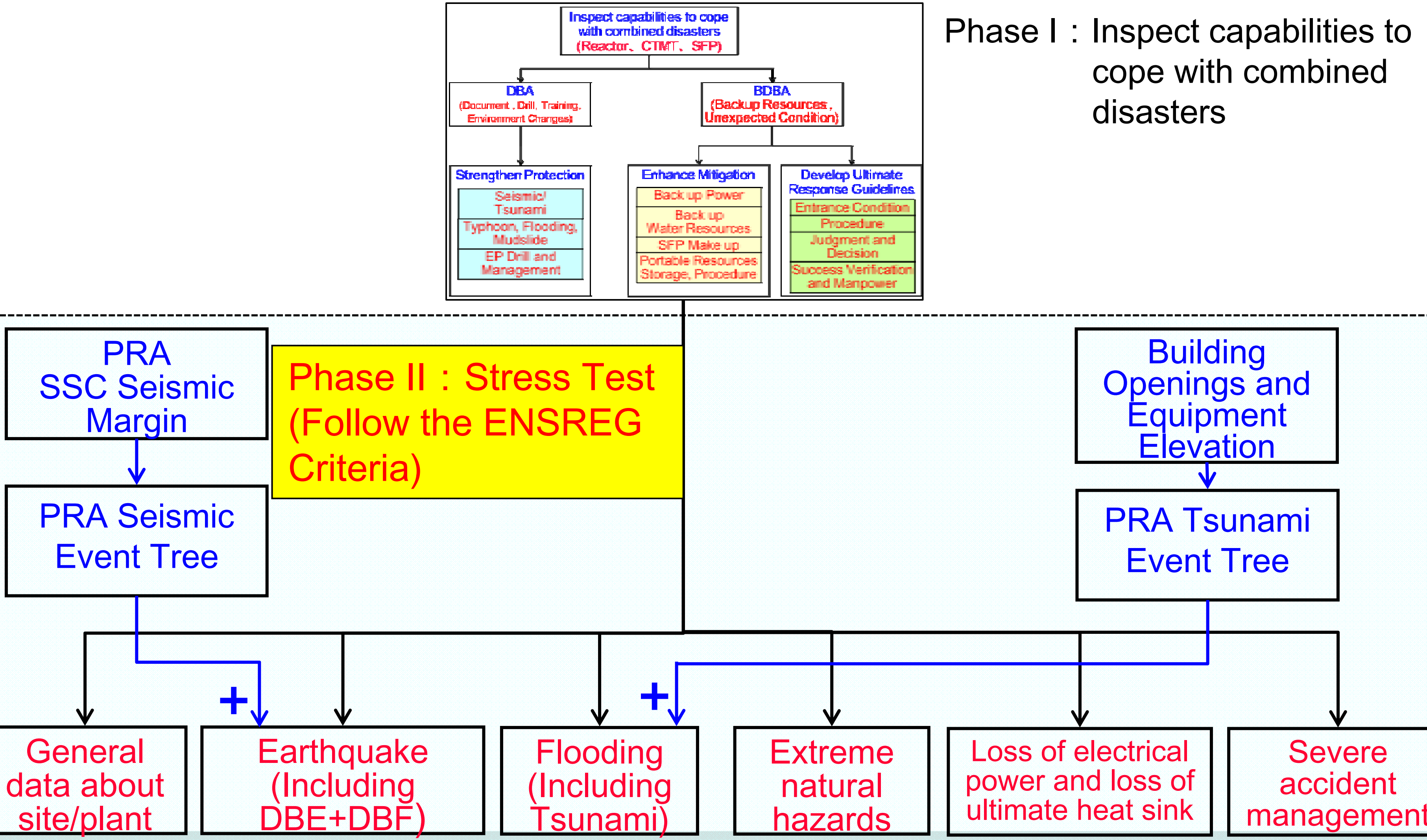
4. Ultimate Response Guidelines (URG)

Phase II : Stress Test

Verify the Safety Margin Against Natural Hazards

- Stress Test was implemented in accordance with the EU specification developed by European Nuclear Safety Regulators' Group (ENSREG) to recognize the cliff-edge and effectiveness of countermeasures developed in Phase I of CSA.
- Stress Tests focused on three principle areas:
  - Extreme external event initiators such as earthquakes, flooding and other extreme natural events
  - Loss of safety functions and systems due to loss of power and the ultimate heat sink, and the combination of both
  - Accident management
- The stress tests were completed in 2012 and reports were submitted to AEC for review.

Techniques of CSA-Phase II



Stress Test Results - Earthquake

- The impact evaluation of two newly identified active faults, namely Shanchiao fault (near CS and KS) and Hengchun fault (near MS) was performed.
- Preliminary results indicate that the free ground acceleration at foundation level of the Reactor Building, caused by the two newly identified active fault, is below the safe shutdown earthquake (SSE).

◆Maximum probable peak acceleration caused by ***Shanchiao fault***

Location	Chinshan NPP	Kuosheng NPP
Site design basis SSE	0.3 g	0.4 g
Calculated peak acceleration at foundation free surface	0.19 g	0.3 g

◆Maximum probable peak acceleration caused by ***Hengchun fault***

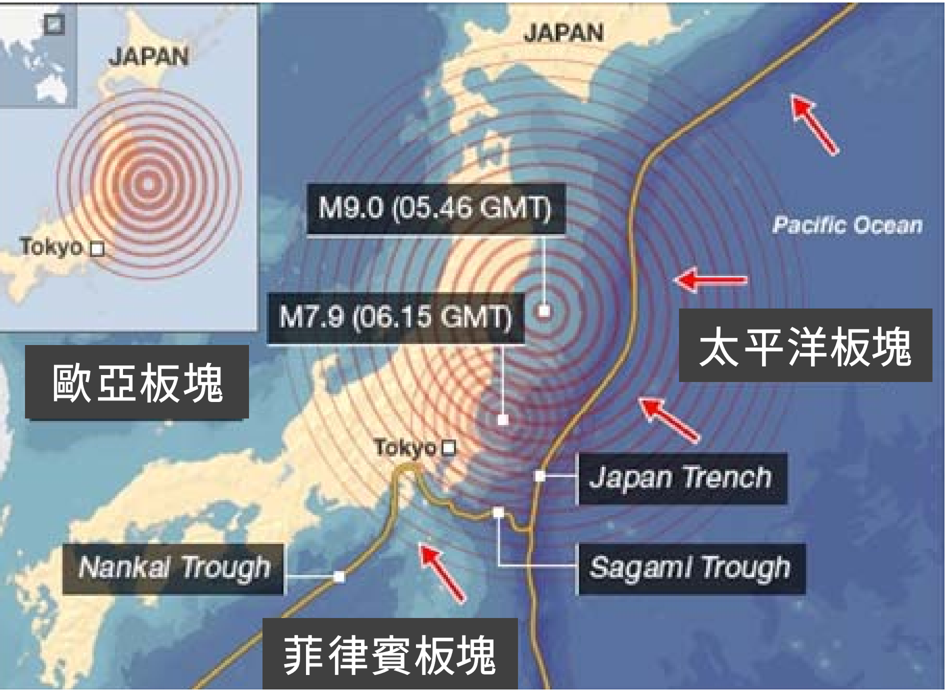
Location	Maanshan NPP
Site design basis SSE	0.4 g
Calculated peak acceleration at foundation level	0.22 g

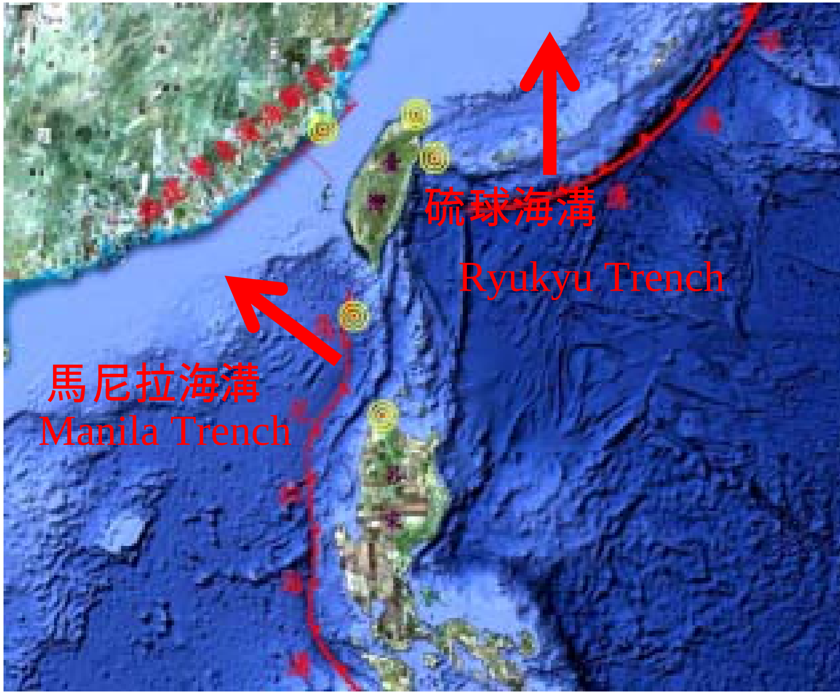
Stress Test Results - Tsunami

- 22 potential earthquake sources (including 18 trenches and 4 faults) of potential maximum tsunami in Taiwan have been evaluated.
- The maximum potential tsunami run-up height is still much lower than the design basis tsunami elevation assumed in FSAR.

Site Name	CS	KS	MS	LM
Site elevation	11.2m	12.0m	15.0m	12.0m
Simulated Tsunami maximum run-up	5.47m	4.54m	7.26m	3.92m
FSAR Tsunami run-up	10.73m	10.28m	12.53	8.07m

Topographic advantage of Taiwan





Post-Fukushima Safety Enhancement Measures

Safety Enhancements Against BDBA

Earthquake Resistant Capabilities Enhancement

- Conduct further geological survey.
- Conduct Seismic Hazard Re-evaluation (NTTF 2.1).
- Implement betterments based on results of SMA and SPRA (NTTF 2.1)(scheduled to be completed in 2015).
- Enhance RCIC and RHR system earthquake-resistant capabilities to guarantee success of URG.
- Establish connection of earthquake and tsunami alert system with Central Weather Bureau.
- Enhance earthquake-resistant capabilities of raw water pool, raw water piping and add flexible expansion.

Safety Enhancements Against BDBA
Earthquake Resistant Capabilities Enhancement

- conduct an enhancement evaluation of safety related SSCs for CS, and followed by the SSE upgrade from 0.3g to 0.4g.
- Planning to upgrade earthquake-resistant capabilities of plant fire brigade building structures.
- Planning to upgrade the existing non-seismically qualified technical support center (TSC).
- Planning the functionality upgrades for emergency response facilities (seismically isolated building or seismically qualified TSC).
- Conducted seismic walkdowns for the 3 operating nuclear power plants (NTTF 2.3).

Strengthen seismic capability of raw water

Safety Enhancements Against BDBA

Tsunami/flooding Resistant Capabilities Enhancement

- Inspected all tsunami/flooding – protective devices and seal functions (WANO SOER 2011-2 recommendations).
- Conduct Flooding Hazard Re-evaluation (NTTF 2.1).
- Simulate the mechanism of seismic and tsunami hazards.
- Added water-tight barrier on emergency circulating water system in KS and nuclear service cooling water system in MS.
- Enhanced tsunami protective gates in CS (motor operated).
- Procured 40 sets of engine driving drain pumps to strengthen portable drain capabilities.
- Planning to build Tsunami-protective wall for all plants with a margin of 6 meters above the current licensing basis.

Safety Enhancements Against BDBA

Tsunami/flooding Resistant Capabilities Enhancement

- Planning to build flooding-protective plate to enhance the water-tightness of the fire doors and penetrations of buildings containing important safety related equipment.
- Conducted flood walkdowns for the 3 operating nuclear power plants (NTTF 2.3).
- Enhance protection for equipment currently provided pursuant to 10 CFR 50.54(hh)(2) from the effects of design-basis external events (NTTF 4.2).
- Planning to perform a probabilistic risk assessment for volcanic event (one of extreme natural events other than earthquakes and flood).

Flood-protection wall and water-tight doors (KS)

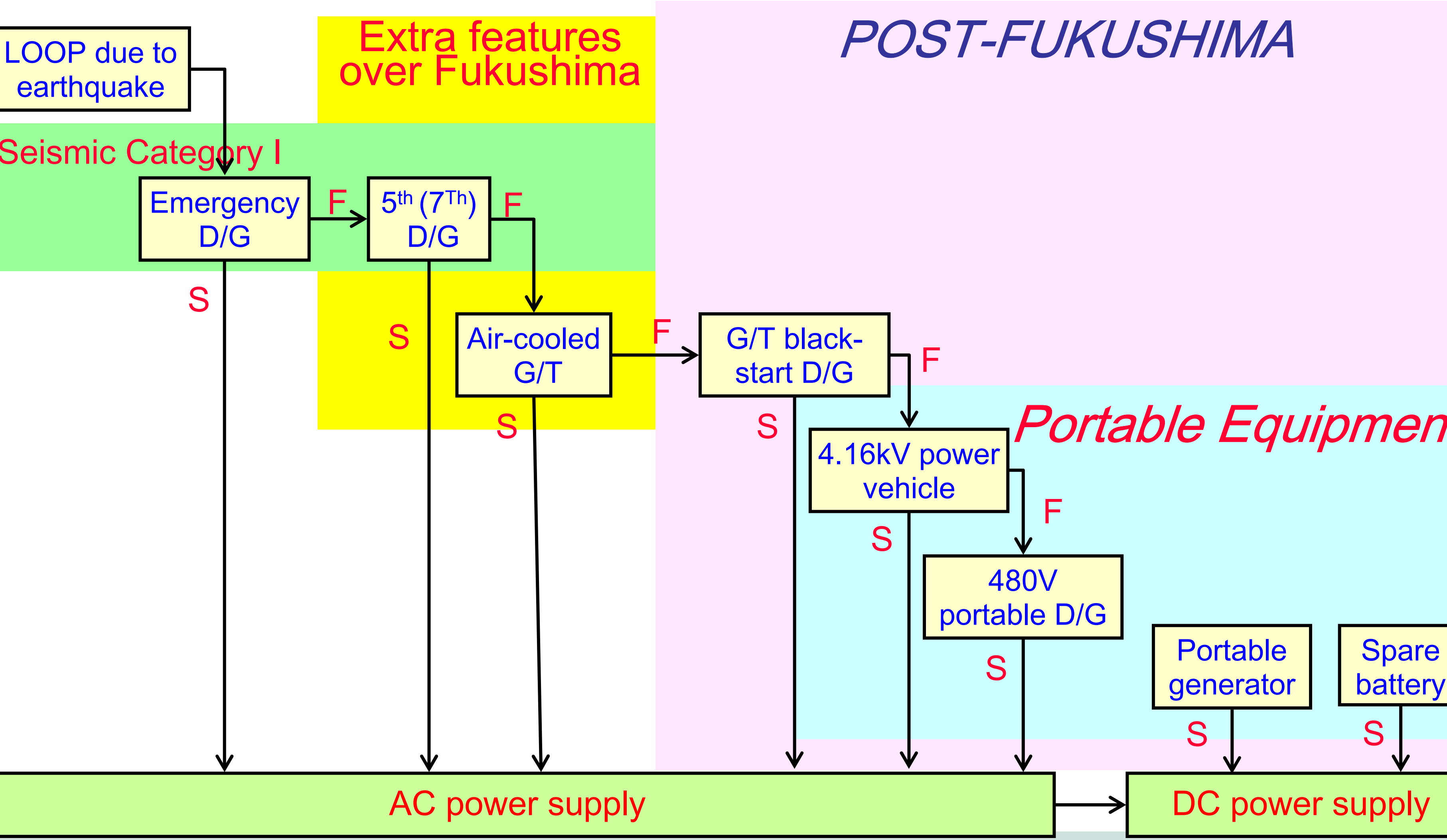
Physical Separation for NSCW Motors (MS)

Safety Enhancements Against BDBA

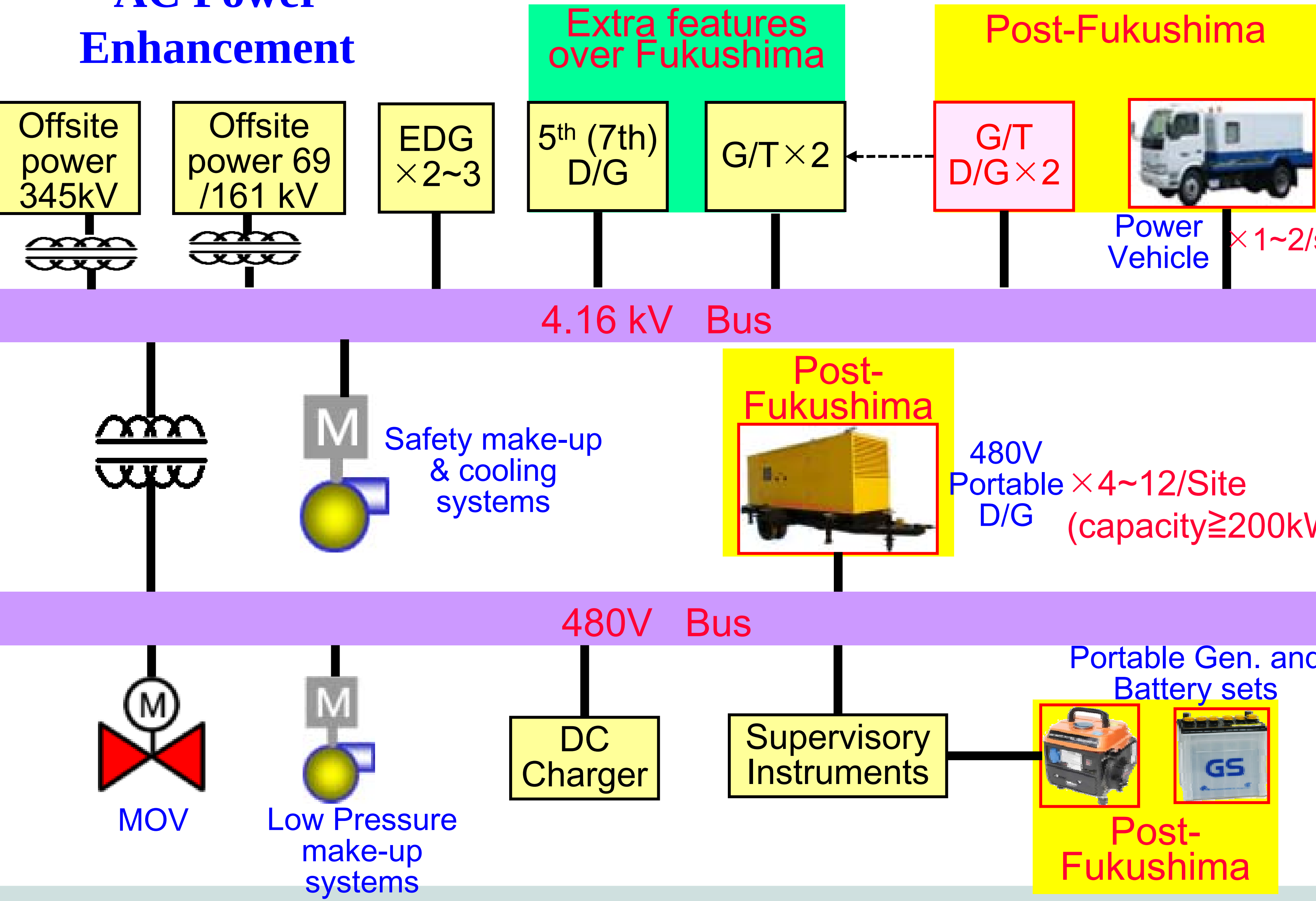
Electrical Power Source

- 5th D/G (swing D/G) can now supply emergency loads for both units simultaneously.
- Black-start D/G used to start G/T can now supply emergency loads for both units simultaneously.
- Planning to bunker the air-cooled swing D/G for 3 operating NPPs, and to install air-cooled G/T for Lungmen (inside a seismically isolated building).
- Procured 6 sets of 4.16 kV power vehicles and 26 sets of 480V portable D/Gs.
- Extended the storage capacity of DC power in response to requirement to extend SBO coping time from 8 to 24 hours.
- Prepared portable generators and batteries for control power and supervisory instruments.

Safety Enhancements Against BDBA
Electrical Power Source



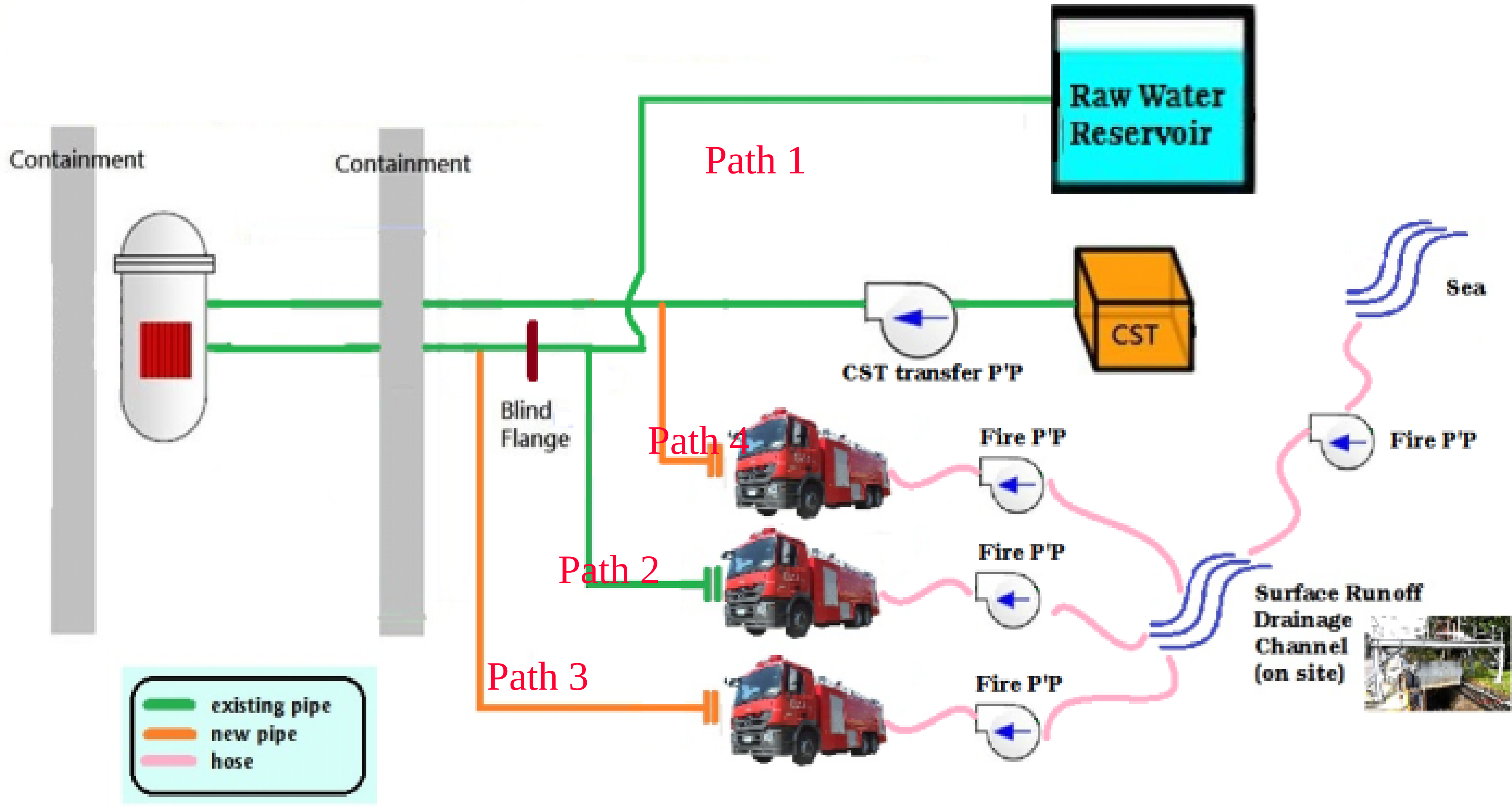
AC Power Enhancement



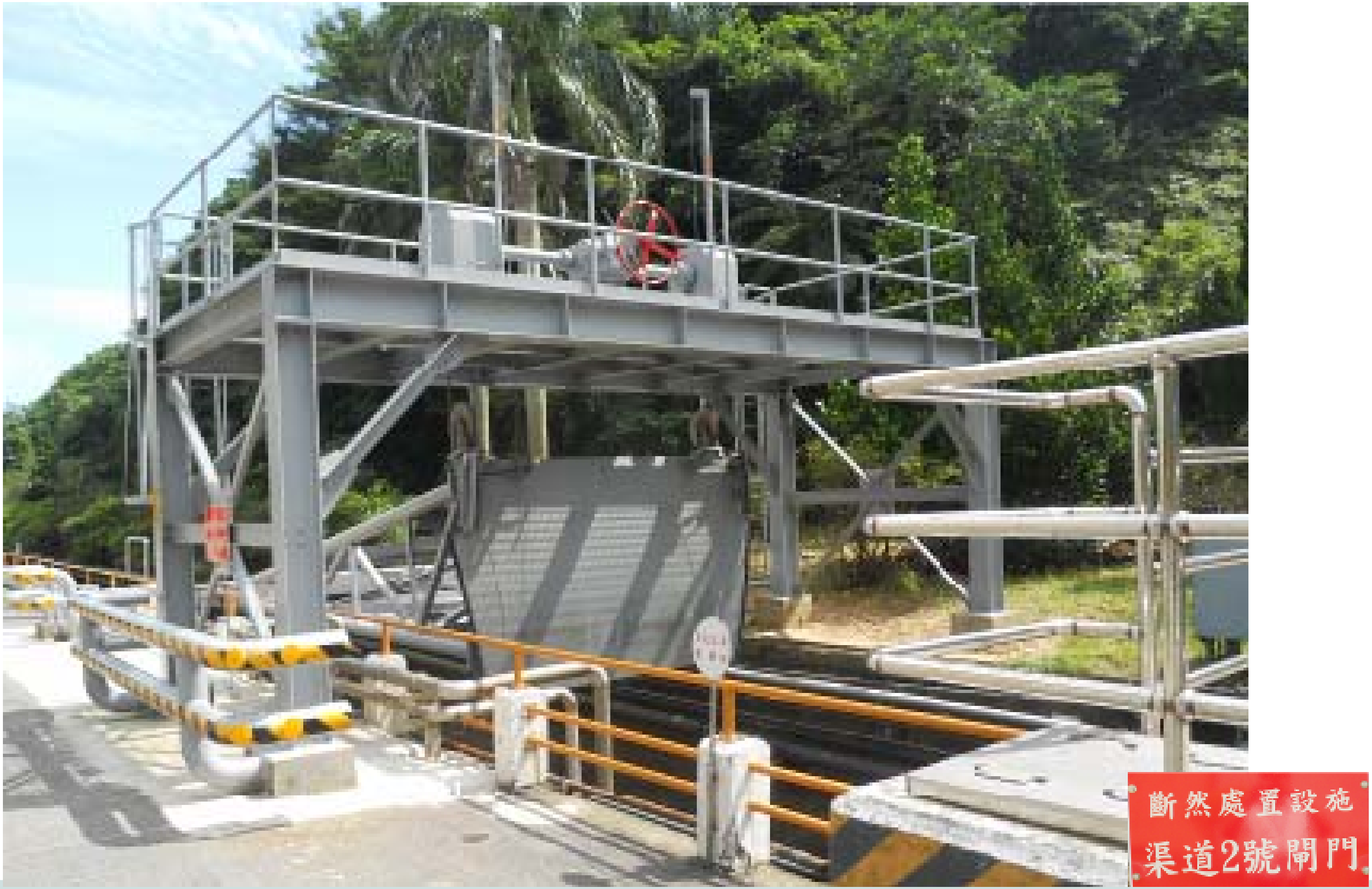
Safety Enhancements Against BDBA
Water Injection for Core Cooling

- Checked capacity of all water resources onsite and offsite, and developed transfer and injection procedures.
- Checked fire engine resources - quantity, capacity, discharge pressure, and procured redundancies.
- Developed a scheme of alternative reactor water injection (various paths).
- Developing an alternate ultimate heat sink.
- Developed a scheme for recovery of ultimate heat sink.
- Procured portable air compressors and spare nitrogen bottles for SRVs and air-operated valves.

Safety Enhancement of Core Cooling



Sluice Gate for Emergency Water Reservoir in KSNPP

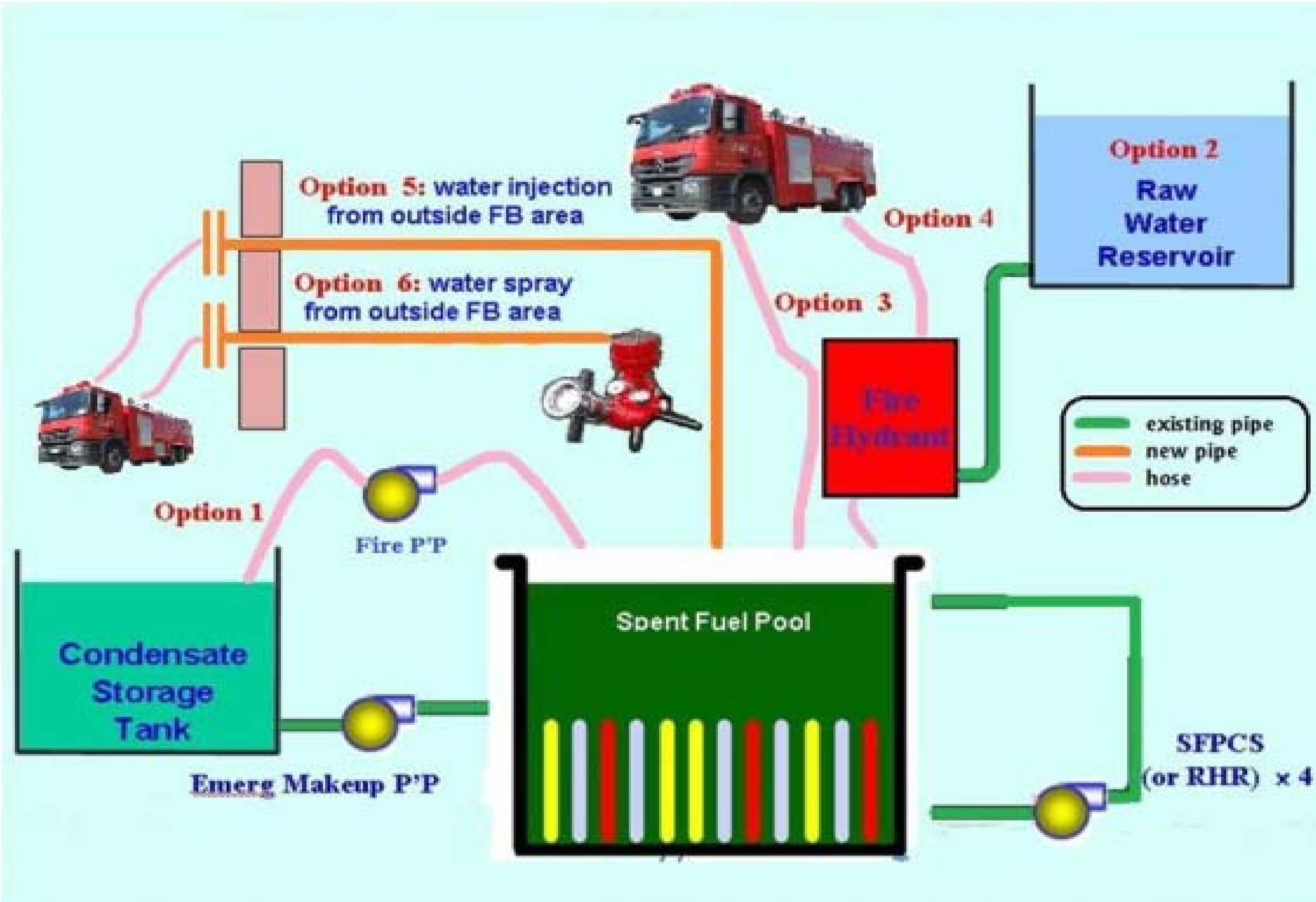


The New-Built Alternated Cooling Water Transfer Pipe

Safety Enhancements Against BDBA
Water Injection for SFP Cooling

- Various SFP make up strategies developed.
- Extra makeup and spray flow paths installed according to NEI 06-12.
- Enhance the spent fuel pool instrumentation, per NTTF 7.1.
  - Instruments for monitoring water level, temperature are to be upgraded to safety grade equivalent

Safety Enhancement of Spent Fuel Pool Cooling



New facilities for emergency water makeup / spray for spent fuel pool

Safety Enhancements Against BDBA
Containment Integrity and Hydrogen Control

- Adding a robust and reliable containment filter venting system is progressing per EU's experience.
- Adding Passive Autocatalytic Recombiners (PARs) for MS (PWR) is progressing per EU's experience.
- Containment early venting strategy developed.
  - Reduce the temperature and pressure rises in the torus
  - Lengthen the injection time for RCIC and enhancement the availability of RPV injection

Safety Enhancements Against BDBA
Newly Developed Ultimate Response Guidelines

- With lessons learned from Fukushima event, timely disposition in main control room is the key of preventing an Accident from an Event.
- The current EOPs are not effective for coping with complex external disasters.
- URG is specifically designed to cut off event evolution and make immediate actions to prevent core damage.
- URG will be integrated with EOPs, severe accident management guidelines, and extensive damage mitigation guidelines (NTTF 8).

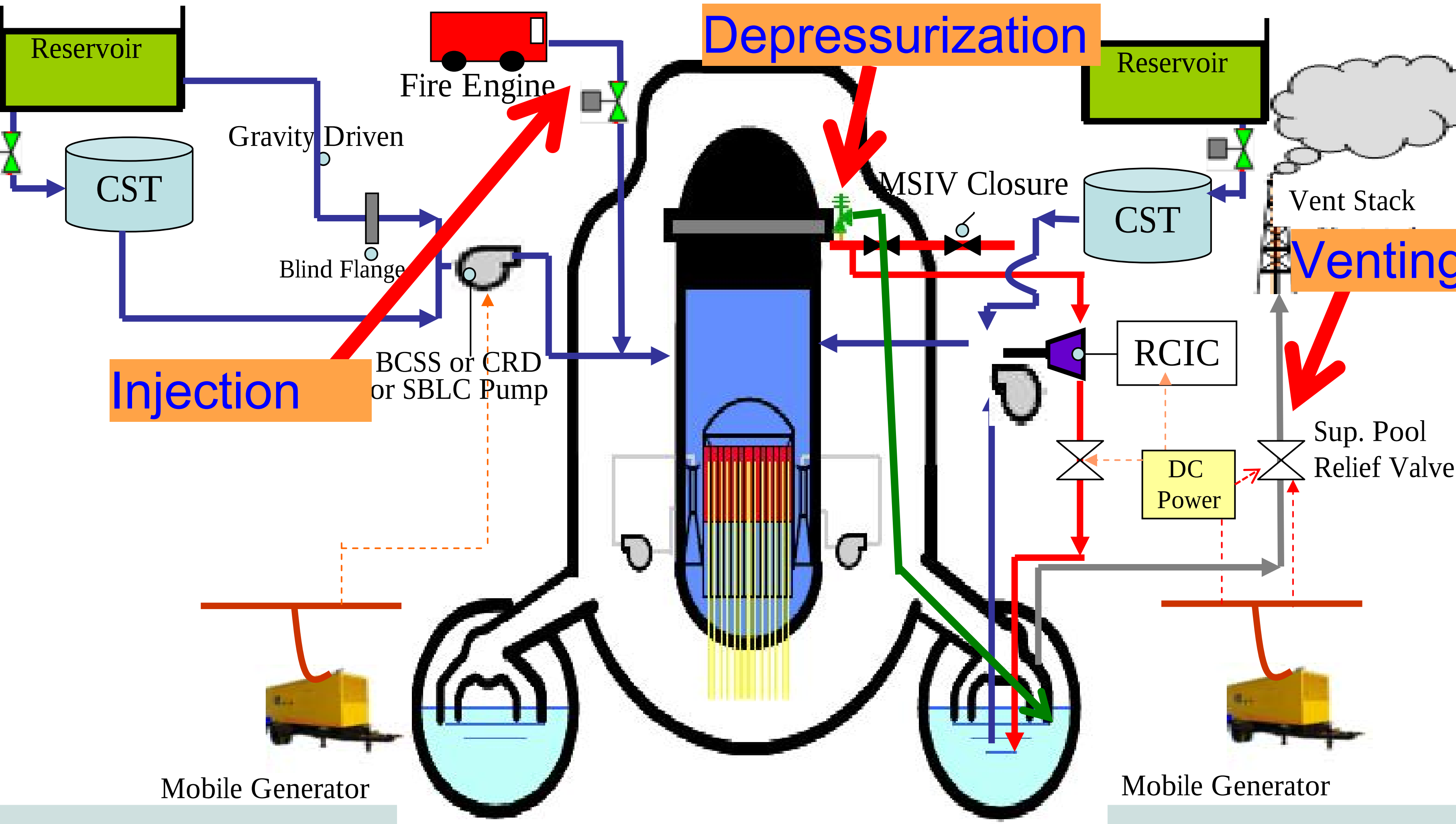
Safety Enhancements Against BDBA

Newly Developed Ultimate Response Guidelines

- Secure the reactor core by emergency depressurization, containment venting and inject any available water (even seawater) through any available injection paths as any of the 3 conditions reached:
  - Plant suffered from larger than SSE earthquake and Tsunami
  - SBO
  - Loss of UHS
- URG was named as DIVing plan, abbreviated from system depressurization, water injection and containment venting.

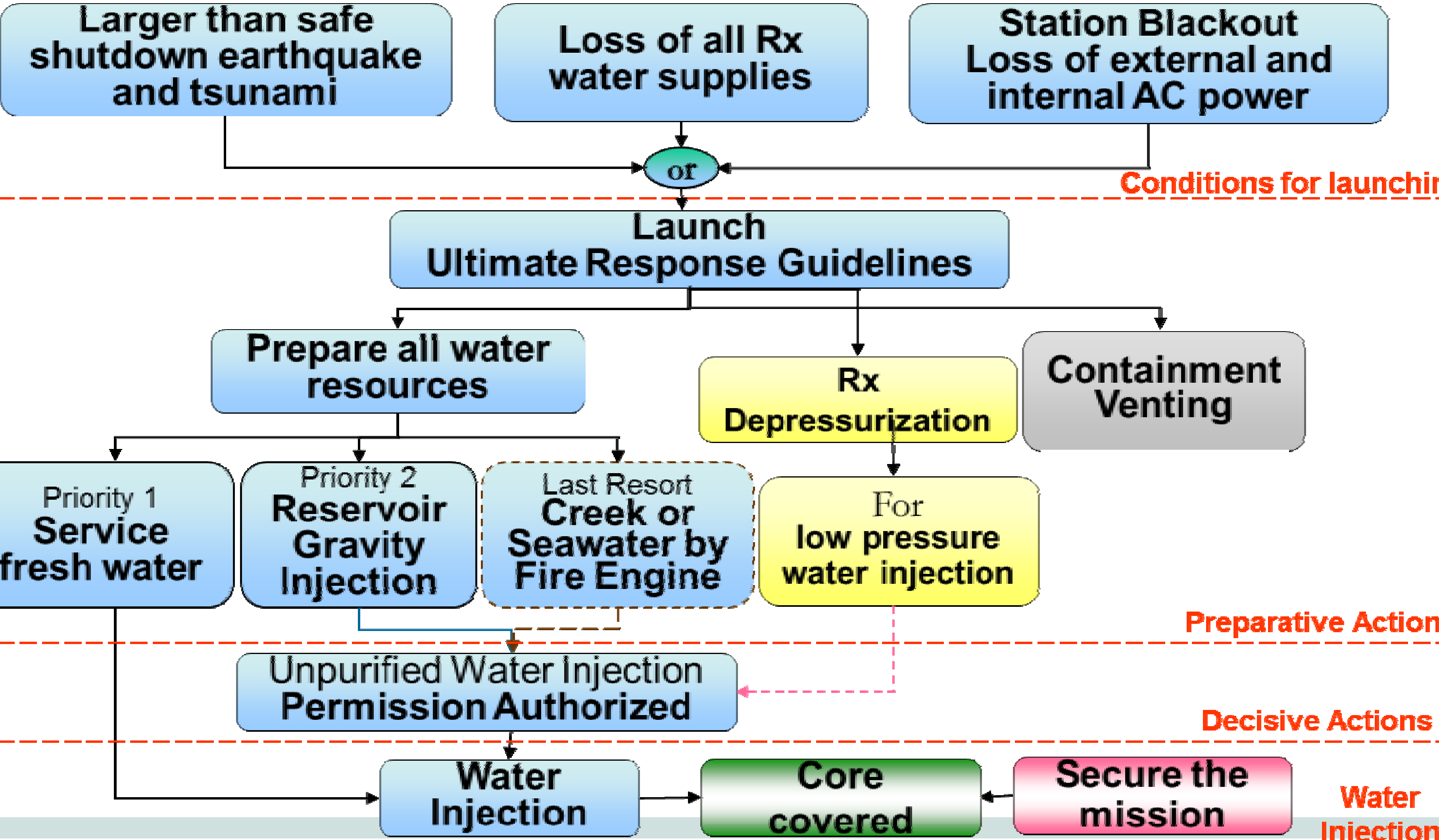
Safety Enhancements Against BDBA

Newly Developed Ultimate Response Guidelines -- BWR

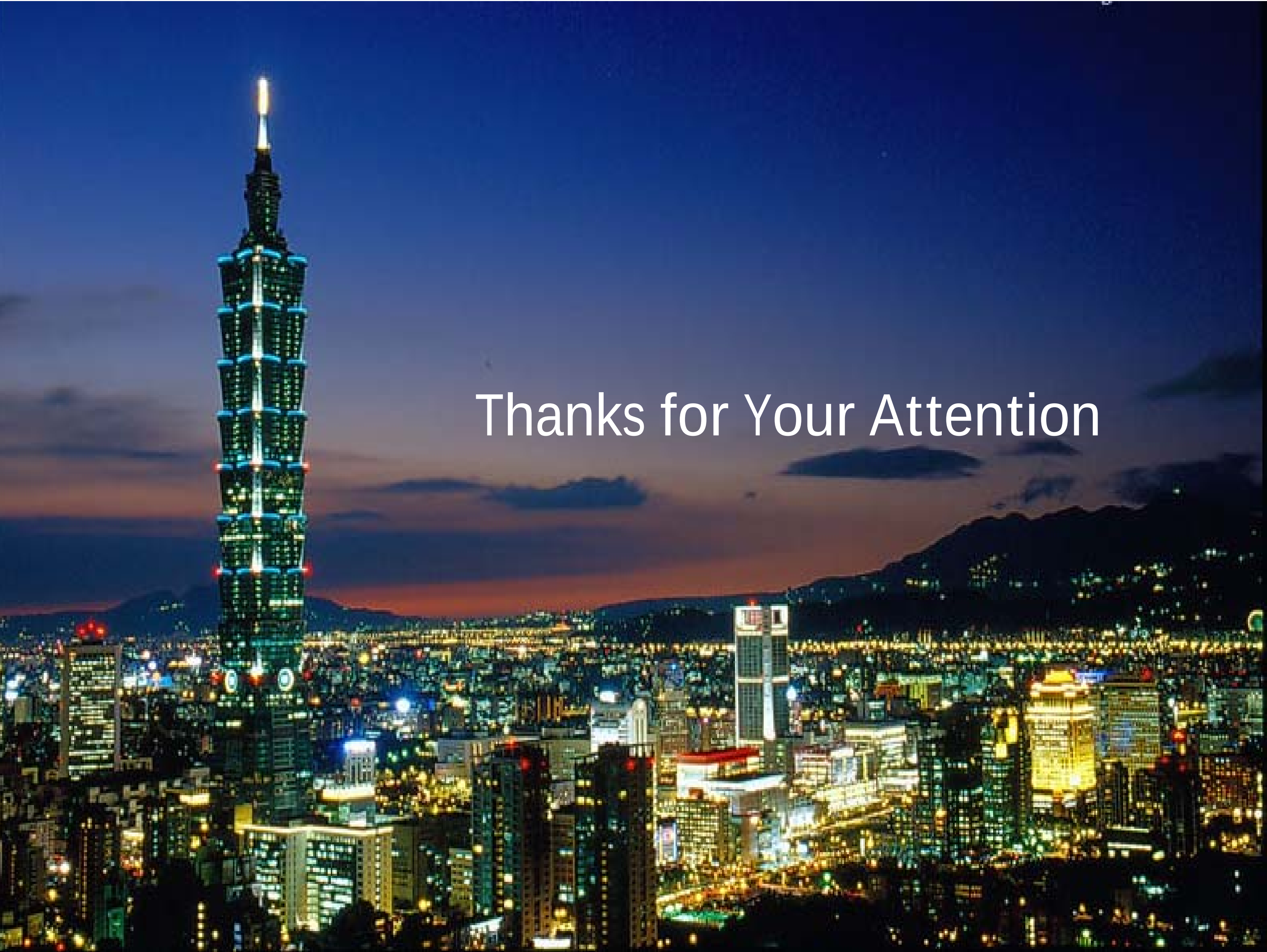


Safety Enhancements Against BDBA

URG -- Flow Chart



Independent Peer Review of Stress Tests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