Fukushima: Lessons learned and implications for the Czech Republic

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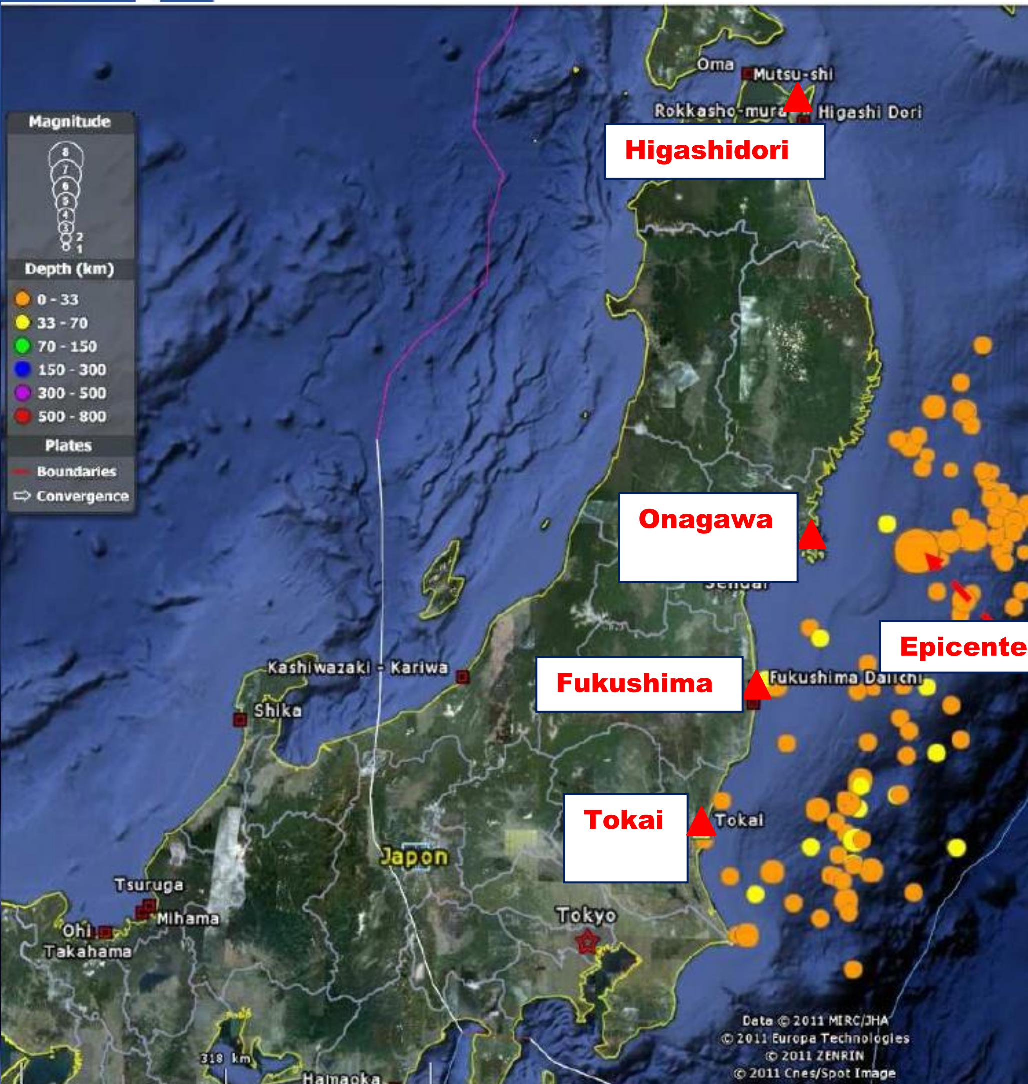
Content of the presentation

- ❑ Summary of the Fukushima accident
- ❑ Lessons learned from the Fukushima accident
- ❑ Impact of Fukushima on development of nuclear power
- ❑ EU and EC response to Fukushima
- ❑ Specific conditions and actions in Czech Republic
- ❑ Stress tests and their potential impact on CR
- ❑ Conclusions

Overview of Fukushima Daiichi Nuclear Power Station before accident

Earthquake impact on NPPs



Mostly affected NPPs			
NPP	Distance from epicenter (km)	Acceleration on the site (g)	Design acceleration* (g)
Onagawa	80	**0.80-1.0**	(0.375) 0.58*
Fukushima Daiichi	145	**0.32 - 0.56 ****	**(0.38) 0.60***
Tokai	255	0.20-0.40	(0.37) 0.60*
Higashidori	330	0.10-0.20	(0.38) 0.45*

*values updated in 2008

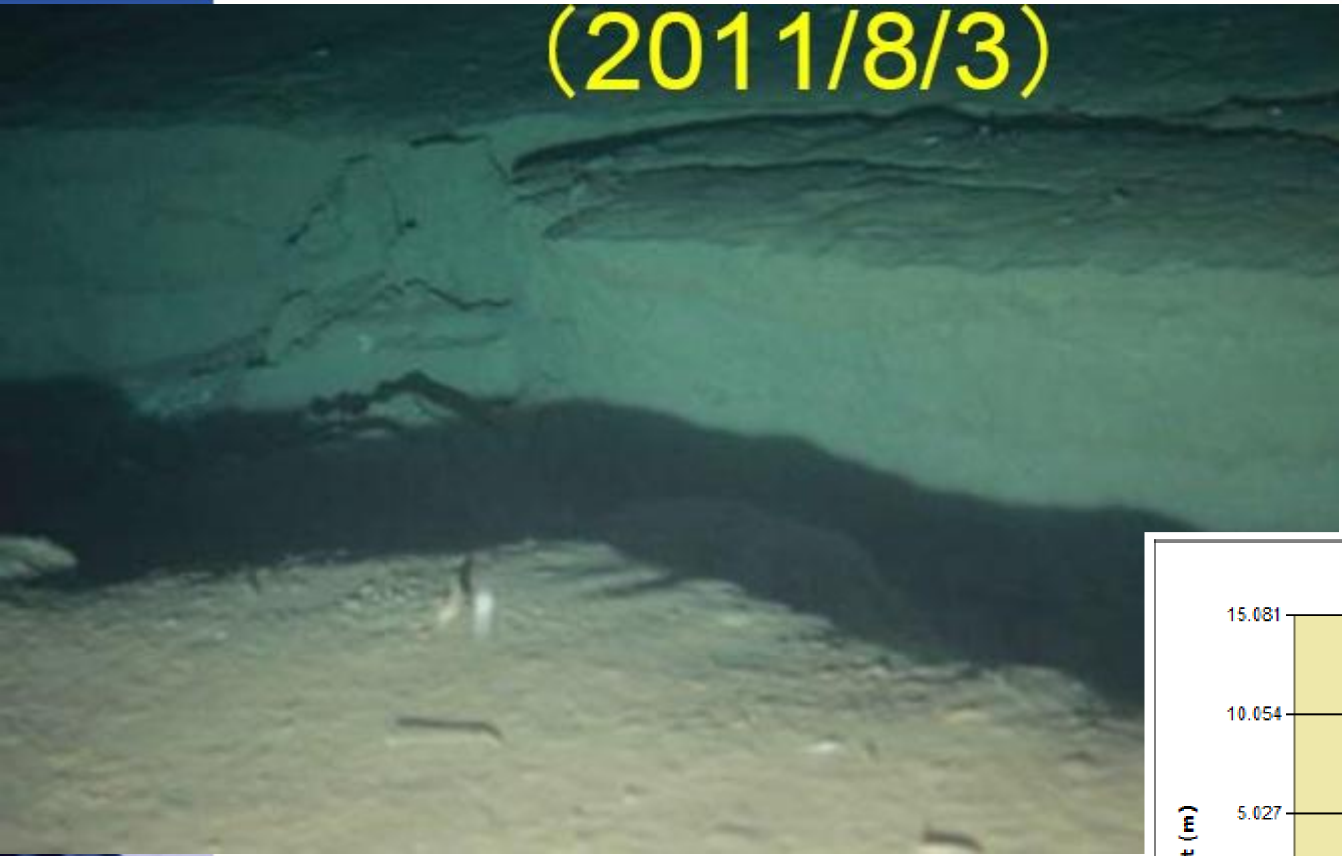
** values registered by 29 sensors on site

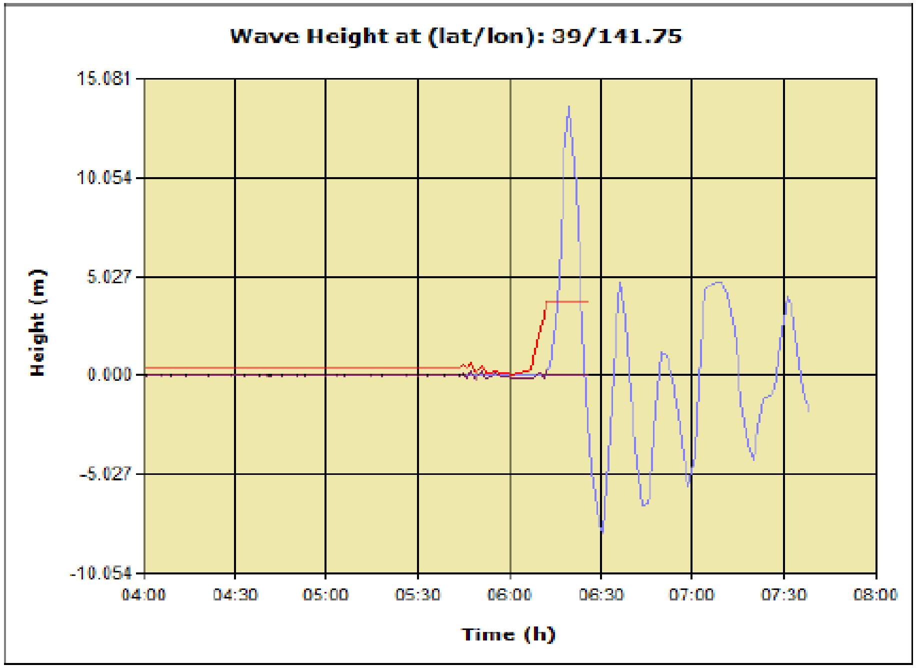
In Tokyo, PGA=0.17 g, 60 seconds

Fault - The driving force of tsunami

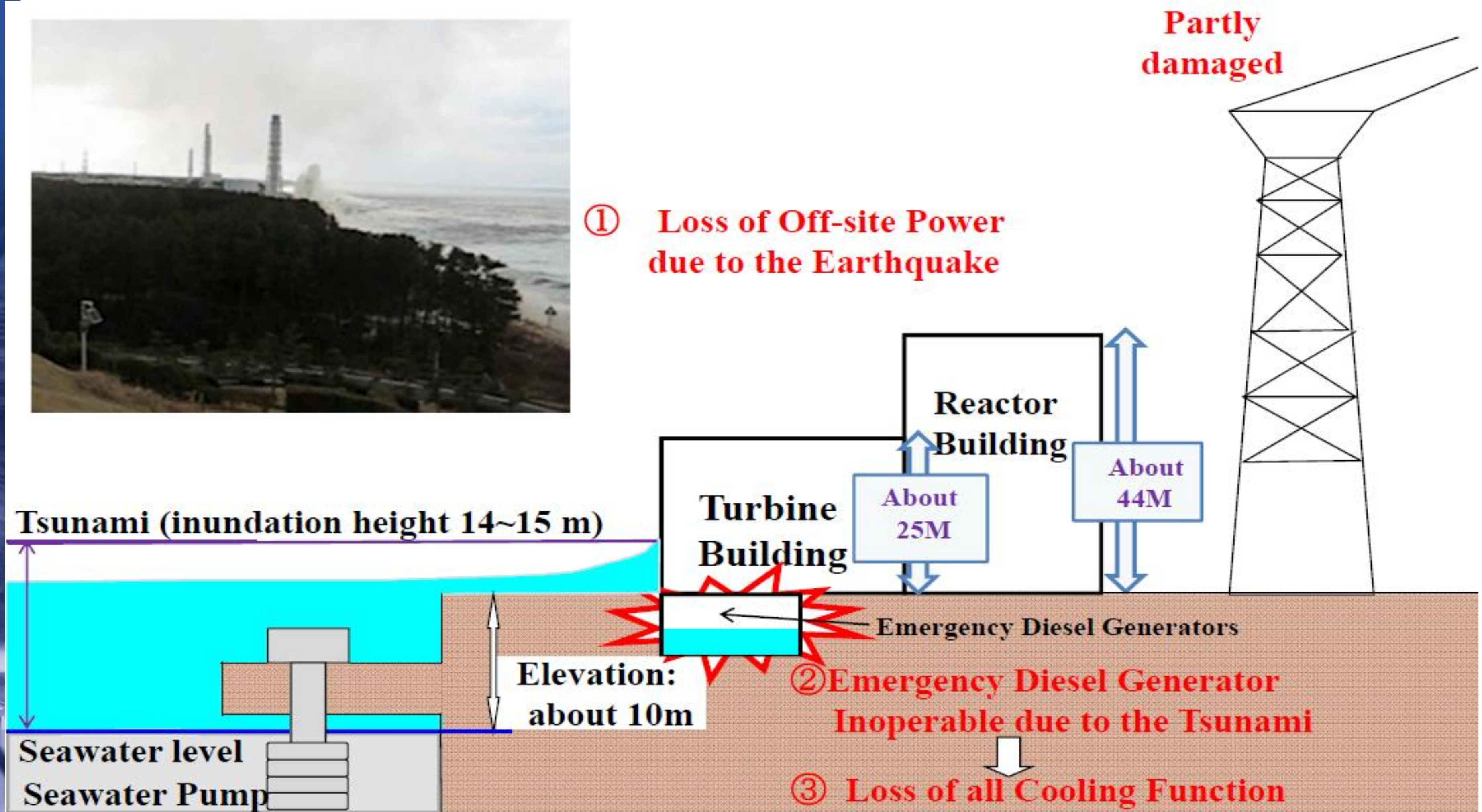
Total length of the fault about 500 km, displacement about 12 m

Height of tsunami wave on the site about 13 – 15 m

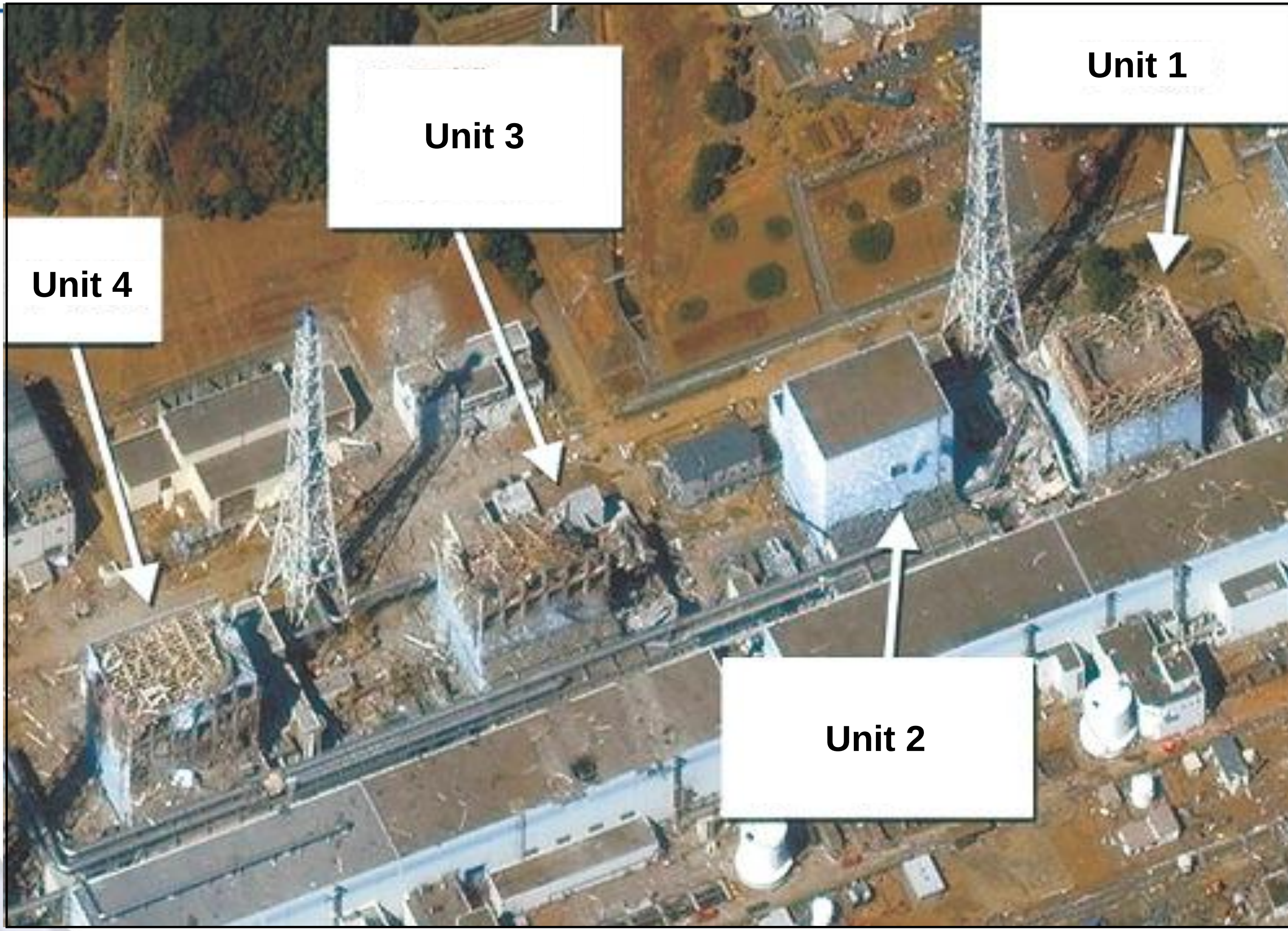




Causes of the accident and plant damages



Units 1 to 4 after Hydrogen Detonations



Sources: Areva NP, www.nirs.org

Situation with fuel pools after the accident

Unit 3

Unit 4

The fuel ponds of these reactor units were a major concern earlier in the Fukushima crisis. Unit 3 is using external power for top-up via the usual cooling and cleanup system, while unit 4 requires direct spraying from a pump truck.

Sources: Areva NP, www.nirs.org

Main accident sequence

Loss of external power supply due to earthquake

↓

Start-up of emergency power generation

↓

All emergency diesel power generators stopped except for one generator in Unit6 due to tsunami

(11 emergency diesel power generator stopped, and one generator(with air cooling)survived.)

↓

Loss of all AC power supply except for Unit6

(Unit 5 took power supply from Unit6 on 13 March).

↓

Core cooling system not using AC power

(Unit1:IC(isolation condenser), Unit2 (RCIC(reactor core isolation cooling system), Unit3: RCIC and HPCI (high pressure core injection system)

↓

Stop of core cooling system not using AC power

↓

Water injection from a fire extinguishing line

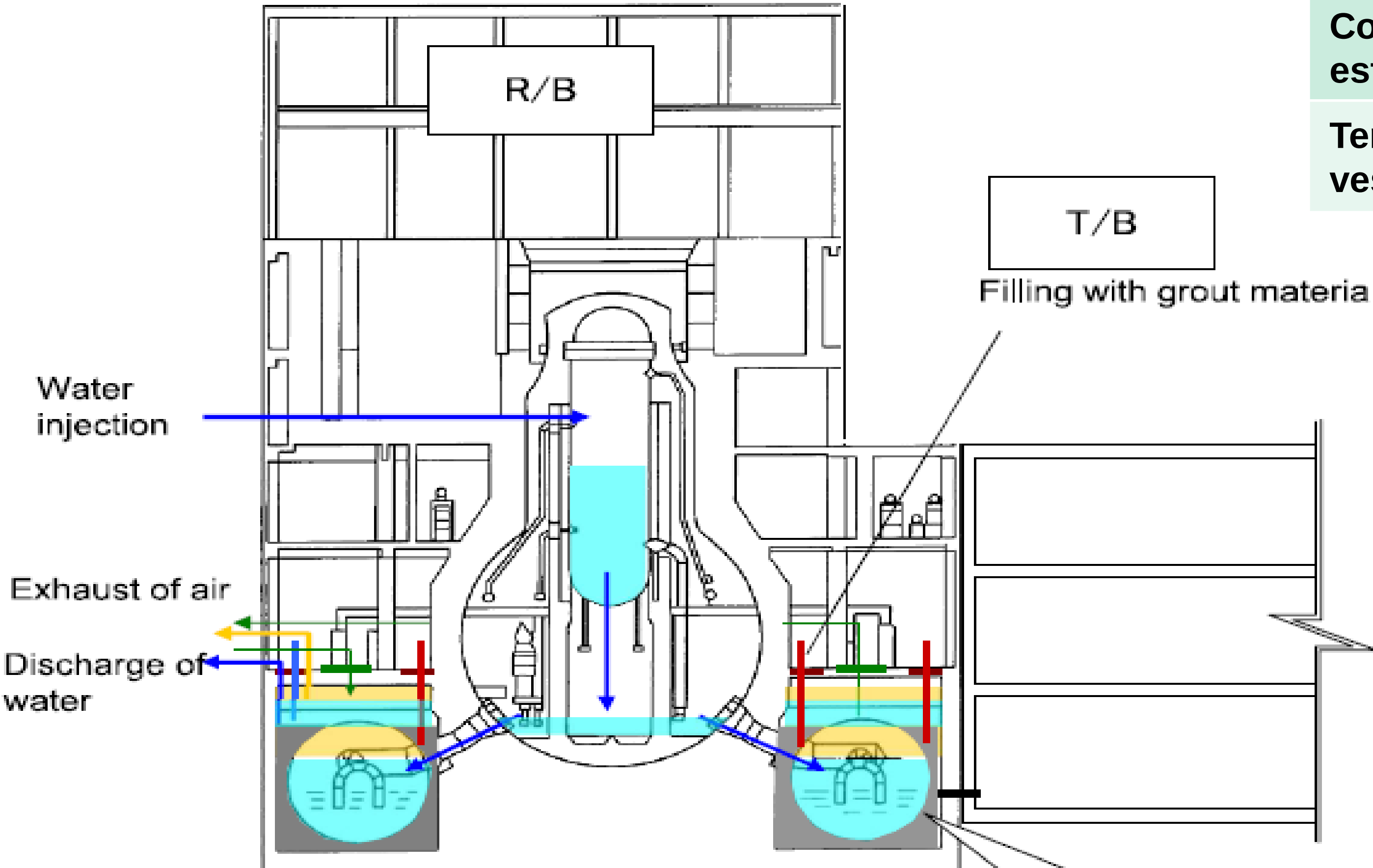
(Unit1:pure water->sea water, Unit2: sea water Unit3: pure water-> sea water)

↓

During this time without cooling, the fuel was exposed and core melt started, generating hydrogen

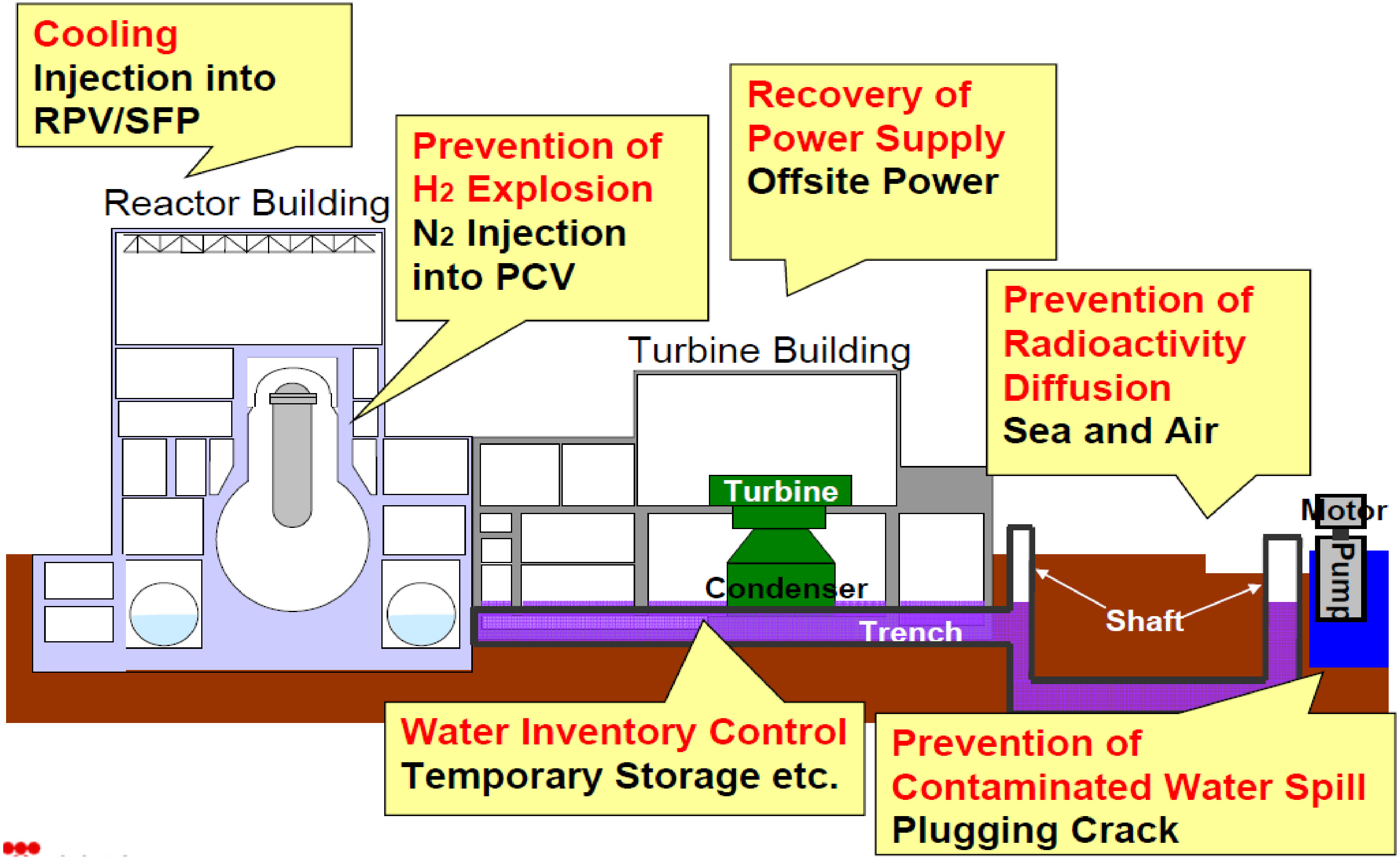
Damage of the reactor core – Current situation

Unit	1	2	3
Core damage estimate	55 %	35 %	30 %
Temperature at vessel nozzle	70 – 80 C		

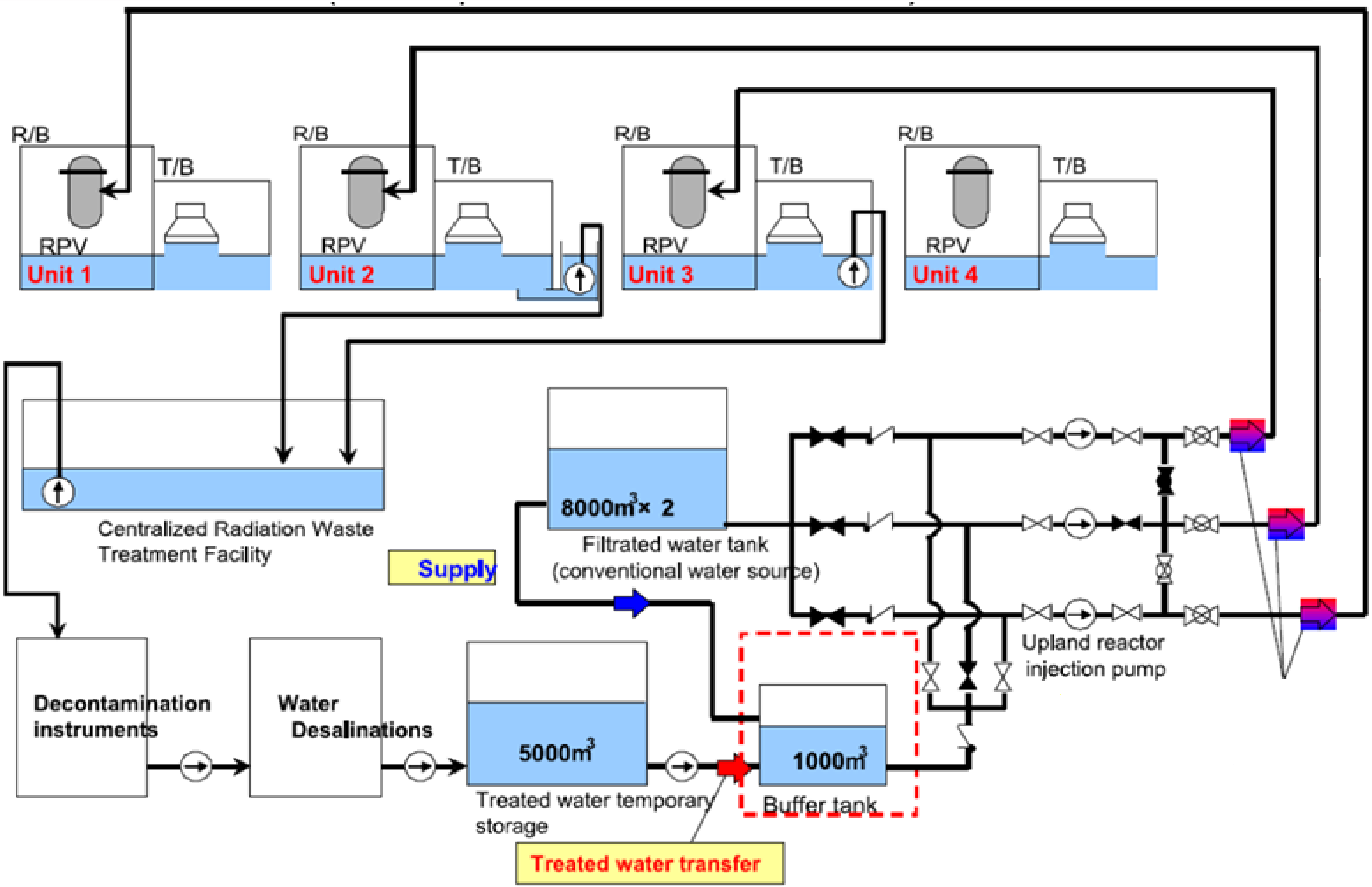


Final damage state of RPV and CV not exactly known
Injected water in all units leaked from RPV to CV and to basement of turbine building
Distribution of debris between the core, lower plenum or CV not known

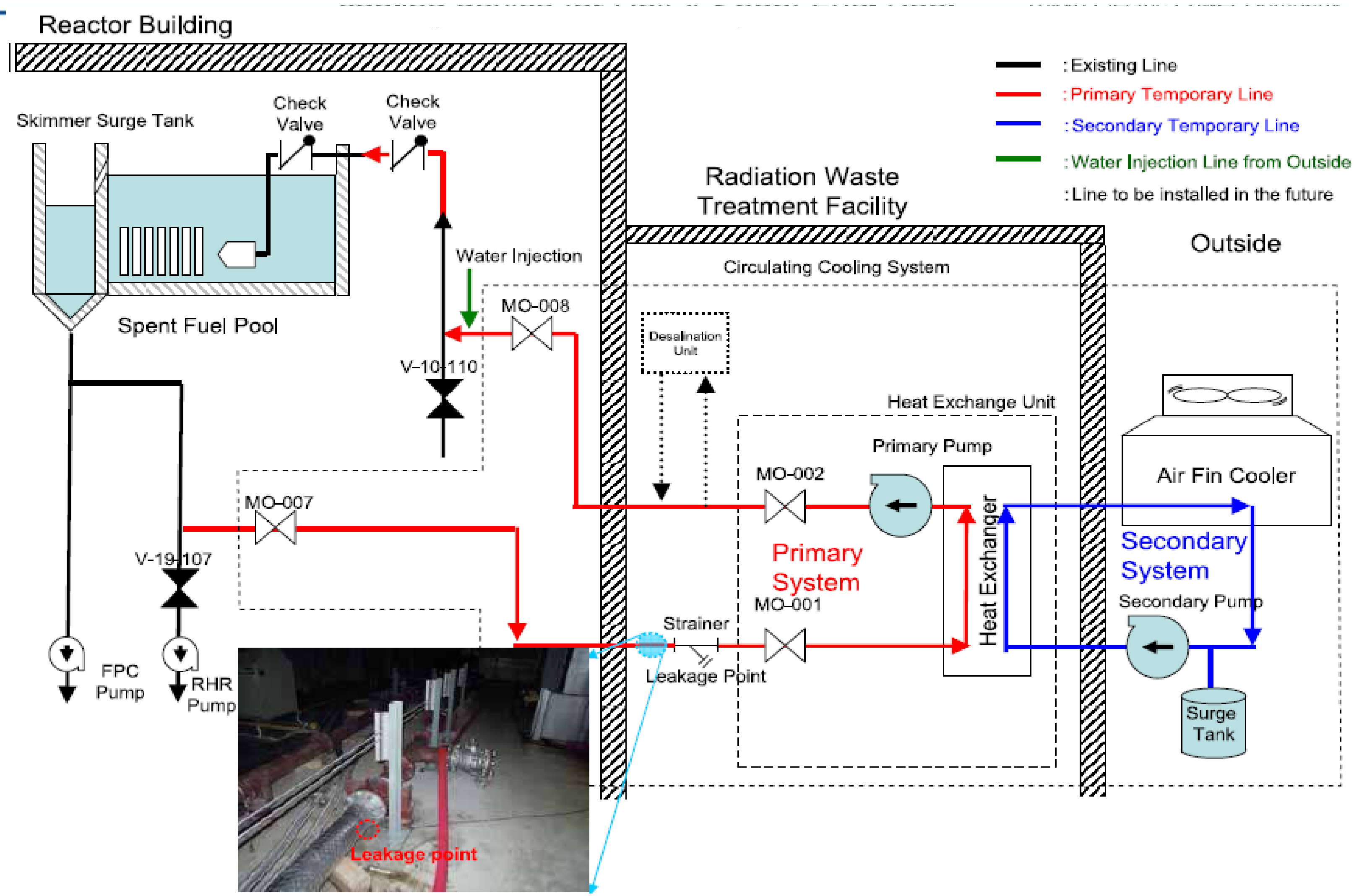
Overview of recovery actions
(by Tepco)



Core cooling system



SFP cooling system



Contamination of workers

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Dose limits

- Dose limits for normal operation: 20 mSv
- Dose limits for emergency (initially): 100 mSv
- Dose limits for emergency (revised in Japan): 250 mSv

Affected workers

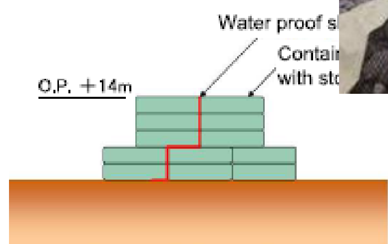
	Workers
100-150 mSv	77
150-200 mSv	14
200-250 mSv	2
Above 250 mSv	6

Overexposed workers: 6
On site victims of the accident (non nuclear): 3
Evacuated: about 80.000

Current radiological situation
Current total release rate from units 1 to 3 ~ 100 MBq/hour
Dose rate at the site boundary max. 0.2 mSv/year
Dust contamination by Cs-137 : 1.E-7 – 1.E-6 Bq/cm3

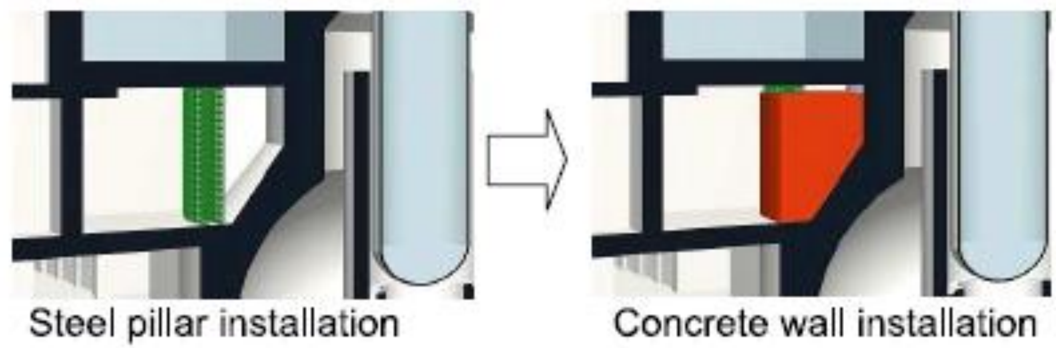
Measures against earthquake and tsunami

Barriers against tsunami
Placement of emergency DG on the hill
Positioning of trucks of firefighters on the hill
Placement of temporary barriers against high tide and tsunami



Support structure for the spent fuel pool of Unit 4

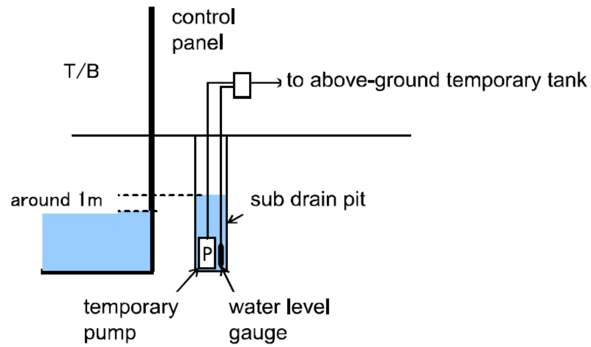
Installation of a support structure at the bottom of the spent fuel pool, damaged by the earthquake

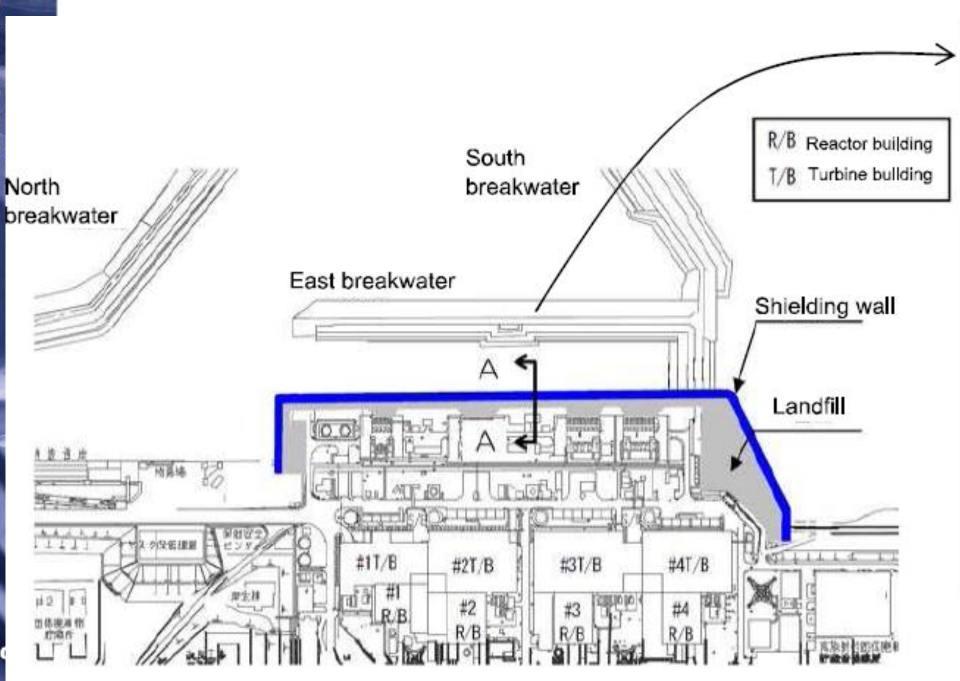


Control of contamination in groundwater

Mitigation of the subsoil contamination

- **closure of pits and trenches**
- **recovery of drainage system**
- **basic design of a wall for the shielding**





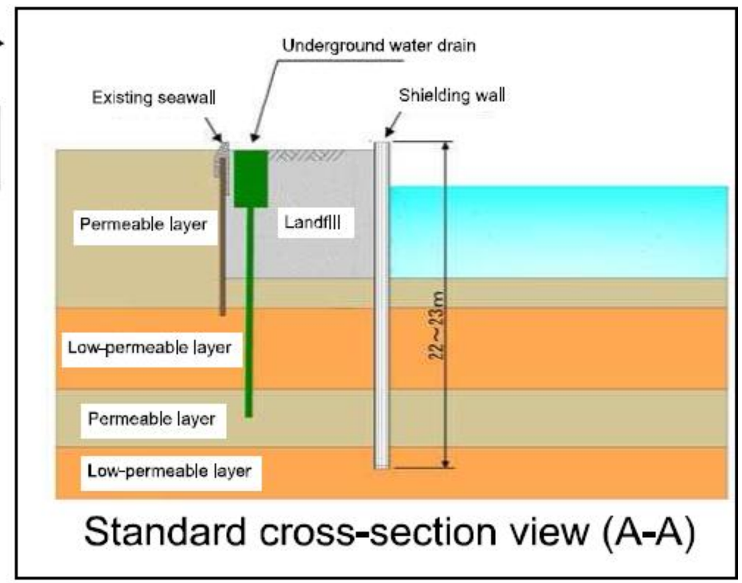


Figure of basic plan of shielding wall

Prevention of dust dispersion

Dispersion of resins to prevent the spread of radioactive material on the ground

Dispersion of inhibitors in the Power Station (slope)

Dispersion of inhibitors around buildings of Units 1 to 4 by crawler dump

After dispersion of inhibitors in the Power Station

Robotic removal of debris

Removal of debris

Before removal

Around the street at the ocean side
of T/B of Unit 1

After removal

Temporary storage tanks for contaminated water

Temporary covering of Unit 1 (42x47x54 m)

Sep. 9: Completion of steel-frame work (northwest side)

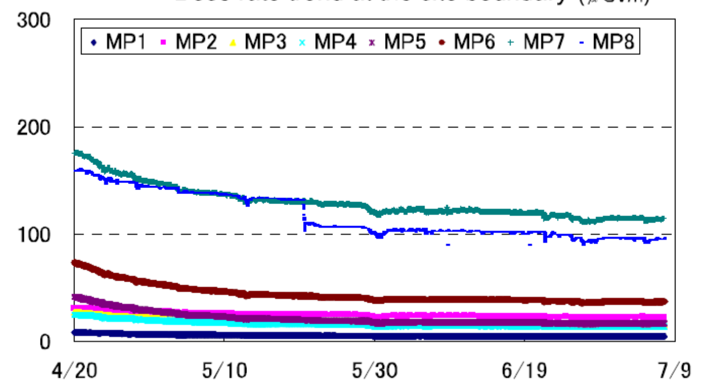
Sep 15: Status of wall panels (northwest side)

Plans of future activities

Objectives

STEP 1: Permanent decrease of doses; this step was reached on 19 July (in about 3 months)
STEP 2: release of radioactive material is kept under control and dose is decreased "significantly" (from 3 to 6 months after the STEP 1)

Dose rate trend at the site boundary (μSV/h)



Areas of intervention

I. Cooling	(1) Cooling the Reactors
	(2) Cooling the SFPs
II. Mitigation	(3) Accumulated water
	(4) Ground water
	(5) Atmosphere/Soil
III. Monitoring/ Decontamination	(6) Measurement, reduction, announcement of Radiation Dose in Evacuation Areas
IV. Countermeasures for aftershocks	(7) Tsunami reinforcement
V. Environment improvement	(8) Living/working environment
	(9) Radiation control/Medical care
	(10) Staff training/personnel allocation

Lessons learned

- Several organisation issued reports on “Lessons Learned”, leading to different numbers and grouping
- Key points are:
  1. Design considerations against natural hazards
  2. Design considerations against SBO and Isolation from UHS
  3. Completeness/effectiveness of SAM
  4. Emergency Management
  5. Safety regulation and safety culture
  6. Multiple unit installation
  7. Spent Fuel Pool design
  8. International aspects

Lessons learned from the Fukushima accident (1 of 4)

- Although existing NPPs are very safe, the accidents caused by certain hazards leading to common cause failures can not be completely eliminated
- Low likelihood of occurrence of any hazards only shall not be used as sufficient justification for elimination of the hazard from design considerations
- External hazards having the potential to generate consequential phenomena which can create severe common mode failures should be thoroughly investigated
- Initial natural event should be considered including their subsequent events, like earthquake+ tsunami, earthquake+aftershocks
- Effects of tsunami represent not only risk of inundation (flooding) but also risk of dynamic impact of the flooding wave

Lessons learned from the Fukushima accident (2 of 4)

- Quantified assessment of safety margins (such as SMA) should become an important component of the assessment
- Margins for protection against external hazards needs reconsideration using advanced methods based on historical data and latest hazard analysis including future projections
- Due to common cause failures several units on the same site can be affected at the same time and in such situation the interconnection between units does not represent a reliable back-up
- All NPP states (including shutdown regimes) and all sources of radioactive materials (including spent fuel pools) must be considered in the safety assessment and in accident management
- The capabilities to predict the cause and consequences of severe accidents are still limited: there are areas where level of knowledge require further improvements; uncertainties in severe accident predictions should be addressed more in detail

Lessons learned from the Fukushima accident (3 of 4)

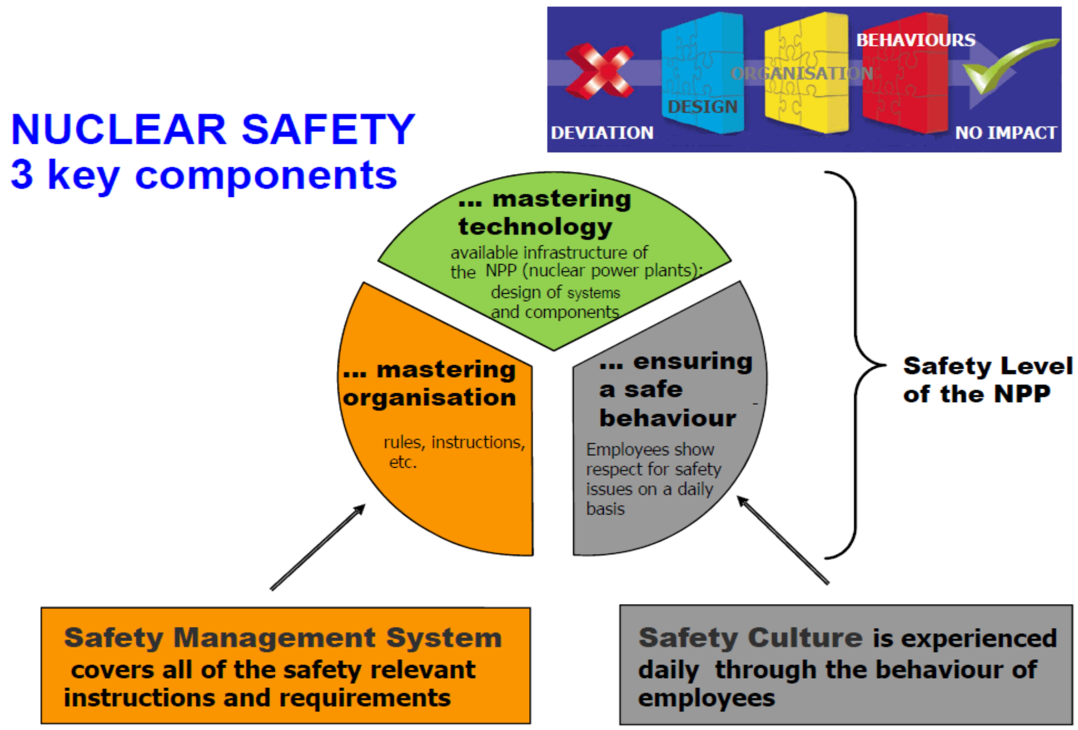
- Hydrogen production, transport, accumulation, flammability, explosions should be given high attention as a potential source of the safety barriers damage
- Accident management measures shall consider conditions of severely damaged infrastructure
- There is a need of advanced analytical resources capable to assist the crisis management
- Under station blackout conditions the timeliness in availability of recovery capability to ensure continued core cooling, spent fuel pool cooling and containment integrity is important
- Protection of containment integrity under post accident conditions including elevated pressure and hydrogen concentration is the issue of highest importance

Lessons learned from the Fukushima accident (4 of 4)

- Although the reactors should not necessitate filtered venting under certain conditions it may become an efficient way for protection against overpressurization
- Qualification/survivability of instrumentation under harsh conditions including high temperatures, high doses, high concentration of hydrogen, pressure waves is an important precondition for accident management (lack of information is a big issue)
- Behaviour of various structural materials under severe accident conditions requires further attention
- Some aspects of operational processes favourite for standard operation (top-down decision making) has turned into inefficient feature for the accident management
- Human/organizational factors under high stress and harmful conditions play essential role
- Open communication with the public is essential to keep emergency and recovery activitioes efficient

Priority on nuclear safety

- Before Fukushima, high attention paid to long-term safe operation and life time extension, on support to construction of Generation III reactors and on transition to sustainable nuclear power based on Generation IV reactors
- Currently, main focus on safety implications of Fukushima



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Measures to be taken- Report of the Japanese Government to the IAEA (1 of 4)

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1. Strengthen preventive measures against a severe accident

(1) Strengthen measures against earthquakes and tsunamis

(2) Secure power supply

(3) Secure robust cooling functions of reactor and containment

(4) Secure robust cooling functions of spent fuel pools

(5) Thorough accident management (AM) measures

(6) Response to issues concerning the siting with more than one reactor

(7) Consideration on placements of severe accidents in design

(8) Ensuring the water tightness of essential equipment facilities

Measures to be taken- Report of the Japanese Government to the IAEA (2 of 4)

2. Enhancement of response measures against severe accident

(9) Enhancement of prevention measures of hydrogen explosion

(10) Enhancement of containment venting system

(11) Improvement of accident response environment

(12) Enhancement of the radiation exposure management system at accident

(13) Enhancement of training responding to severe accident

(14) Enhancement of instrumentation to identify the status of reactors and containments

(15) Central control of emergency supplies and equipment and setting up rescue team

Measures to be taken- Report of the Japanese Government to the IAEA (3 of 4)

3. Enhancement of nuclear emergency response

(16) Response to combined emergency of both large-scale natural disaster and prolonged nuclear accident

(17) Reinforcement of environment monitoring

(18) Establishment of clear division of labor between relevant central and local organizations

(19) Enhancement of communication relevant to the accident

(20) Enhancement of response to assistance by other countries and communication to the international community

(21) Adequate identification and forecast of the effect of released radioactive materials

(22) Clear definition of widespread evacuation area and radiological protection guideline in nuclear emergency

Measures to be taken- Report of the Japanese Government to the IAEA (4 of 4)

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4. Reinforcement of safety infrastructure

(23) Reinforcement of safety regulatory bodies

(24) Establishment and reinforcement of legal structure, criteria and guidelines

(25) Human resources for nuclear safety and nuclear emergency preparedness and response

(26) Securing independency and diversity of safety system

(27) Effective use of probabilistic safety assessments (PSA) in risk management

5. Raise awareness of safety culture

(28) Raise awareness of safety culture

FUKUSHIMA – Reactions of EU Member States

- Additional assessments: EU "Stress Tests" *(all)*
- Closure of Nuclear Power Plants *(only Germany)*
- No return to nuclear *(Italy)*
- Continue with New NPP Builds *(United Kingdom, Czech Republic, Poland, France, Netherlands, Finland, Slovak Republic, Romania, Bulgaria, Lithuania)*

EC Response to Fukushima

- Solidarity and assistance to Japan
- Comprehensive safety & risk assessments ("Stress Tests") of nuclear installations in the EU – **Safety Track**:
  - Conducted on a voluntary basis in a 3-step process:
    - by licensees
    - by independent national authorities (regulators)
    - through peer reviews
  - Objective: to assess whether safety margins are sufficient to cover various unexpected events
  - Scope: Go beyond safety evaluations made during licensing process and periodic safety reviews
  - Main motivations:
    - contribute to the continuous improvement of nuclear safety
    - reinstall public trust which has been seriously affected following Fukushima *(Transparency of process & results: e.g. national reports)*)
    - BUT ALSO (by env. initiatives): to open public discussion about the future of nuclear industry

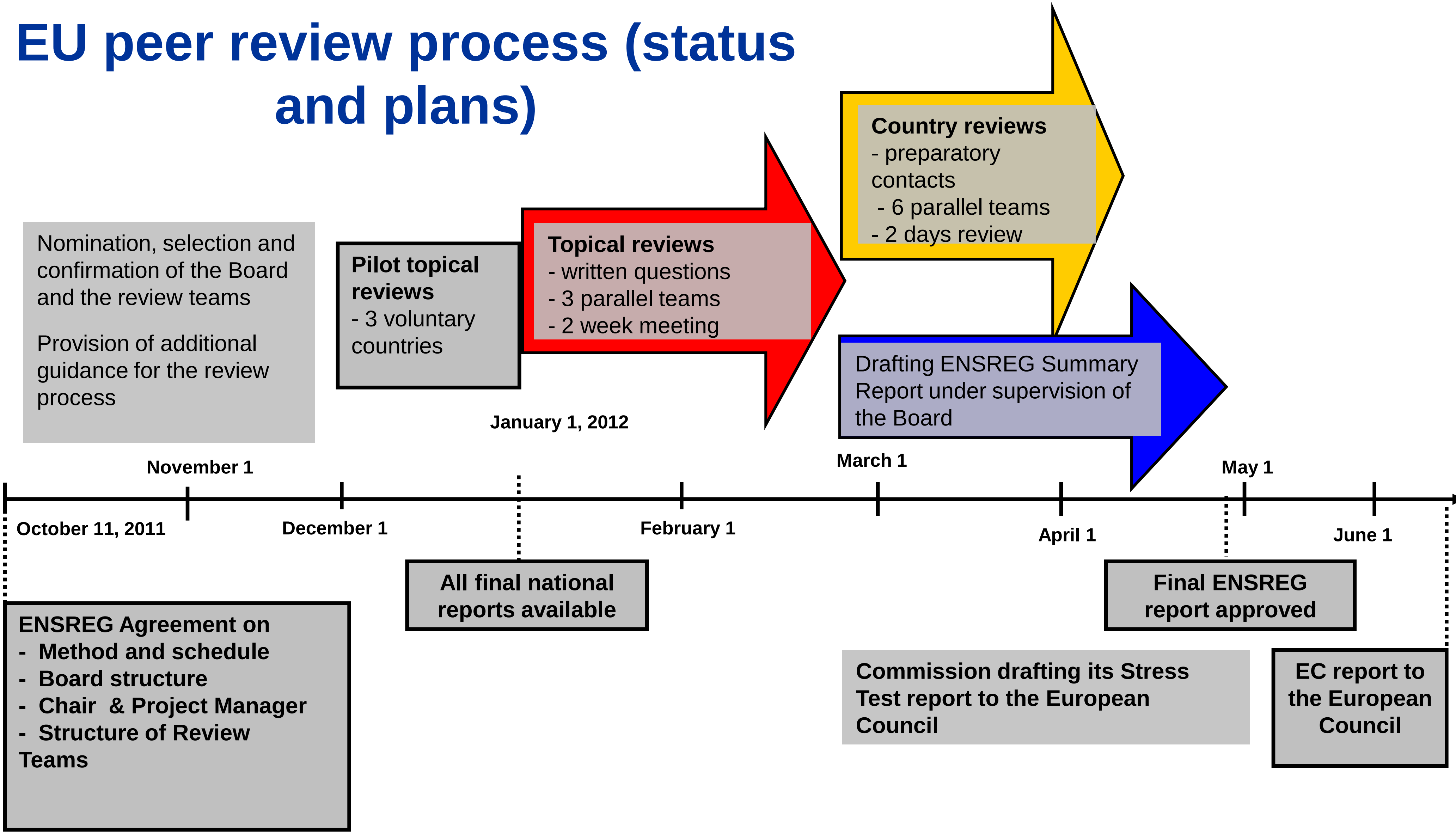
EU Stress Tests: timetable

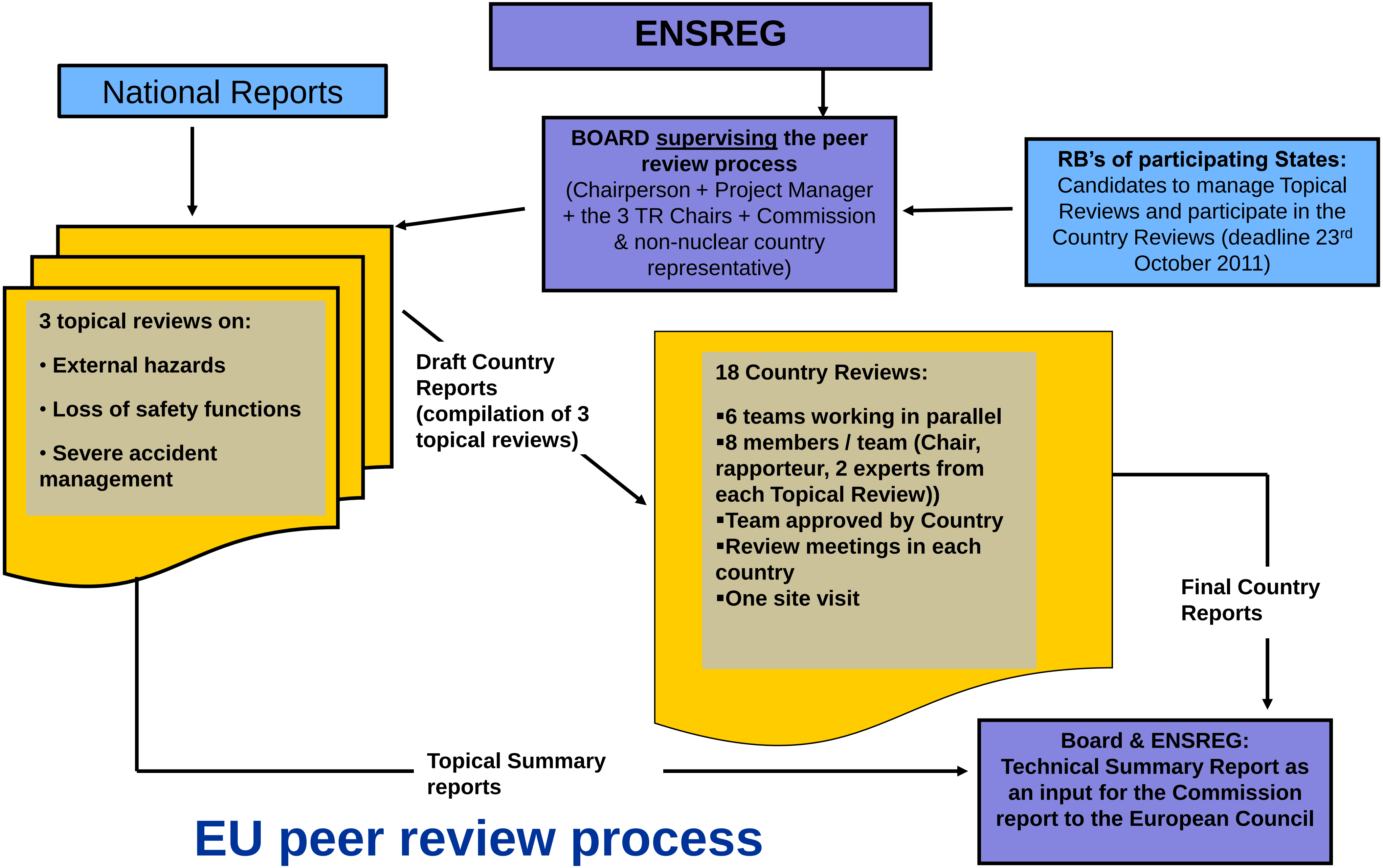
- 1 June 2011: national regulators initiate stress tests
- 15 August: operators carry out reassessments and submit progress reports to national regulators
- 15 September: regulators consolidate the data into national progress reports (from MS+NCs)
- 31 October: operators' final reports
- By 9 December: progress report from the Commission to the European Council
- 31 December: national final reports
- 1 January 2012: start of the peer review process
- 30 April 2012: completion of peer reviews
- June 2012: consolidated report from the Commission to the European Council

EU Stress Tests – (safety track) peer reviews

- **Objective:**
  - To confirm that the licensees have:
    - followed the agreed method,
    - addressed all topics listed in the specifications in sufficient completeness and technical quality, and
    - identified appropriate improvements (or given reasons if improvements are not considered necessary)
- **Approach:**
  - No review against given safety standards, but a comparison of what countries used as basis for decision making
  - Horizontal reviews of all national reports (MS+) – to ensure comparability - along the three topical areas defined in the stress tests specifications:
    - Initiating events *(earthquakes, flooding, bad weather conditions…)*
    - Consequential loss of safety functions from IEs *(SBO, loss of UHS)*
    - Accident management
  - Vertical reviews of all national reports – to ensure accountability
  - *Secretariat:* EC's Joint Research Centre

EU peer review process (status and plans)





EU peer review process (organization)

10.10.2011

Still a "Nuclear Renaissance" after Fukushima?

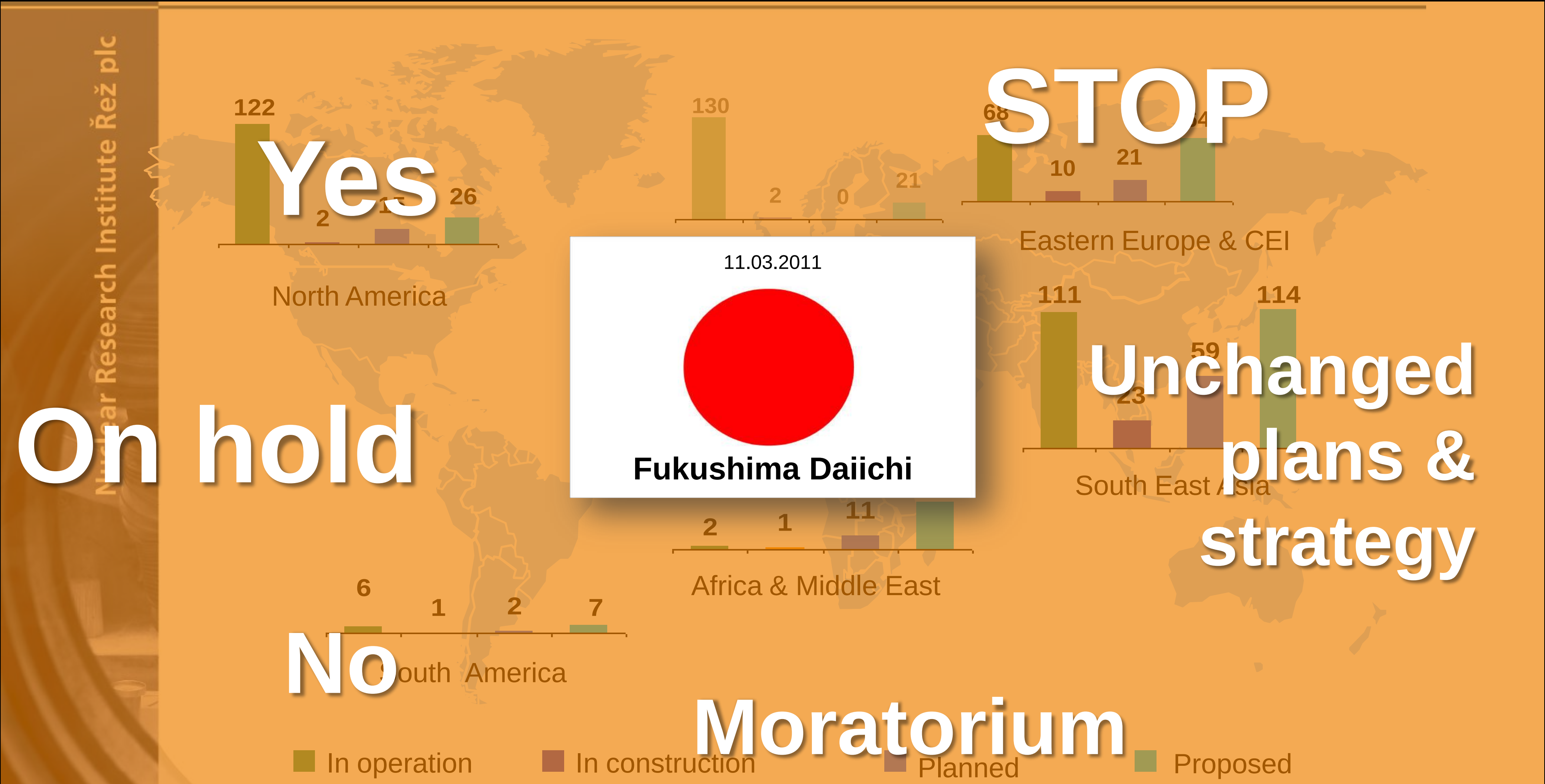
- **Drivers underlying pre-Fukushima "renaissance" persist:**
  - Growth in electricity demand
  - Energy security and affordability
  - Emissions / Global warming
- **Future of nuclear critically depends on:**
  - Successful implementation of post-Fukushima revised safety regimes:
    - Sufficient regulatory effectiveness *(independence …),*
    - Ensuring Sufficient Protection *(BDB-EE …),*
    - Enhancing Mitigation *(e.g. SBO, venting, H2 control, spent fuel pools),*
    - Strengthening AM and Emergency Preparedness *(long SBO, multiunit effects)*
  - Availability/economics/acceptability of the alternatives (wind, solar, grid, storage, CCS)
  - Trust of both private and institutional investors into new builds about the future operation without major events worldwide
  - In Europe it may depend upon keeping the public trust into nuclear
  - Commitment of Governments:
    - A responsible Government has a long-term energy planning and commits to it.
    - However, public opinion also counts

Stress tests follow-up

- EU Safety Legislation:
  - The European Council called on the Commission to review the EU legal framework for nuclear safety
  - December 2011: proposals for possible improvements put forward in the Commission progress report to the Council
  - Mid-2012: the Commission will present a proposal for the review, which may include:
    - governance issues (e.g. enhancing independence of regulators),
    - financial aspects
    - technical aspects

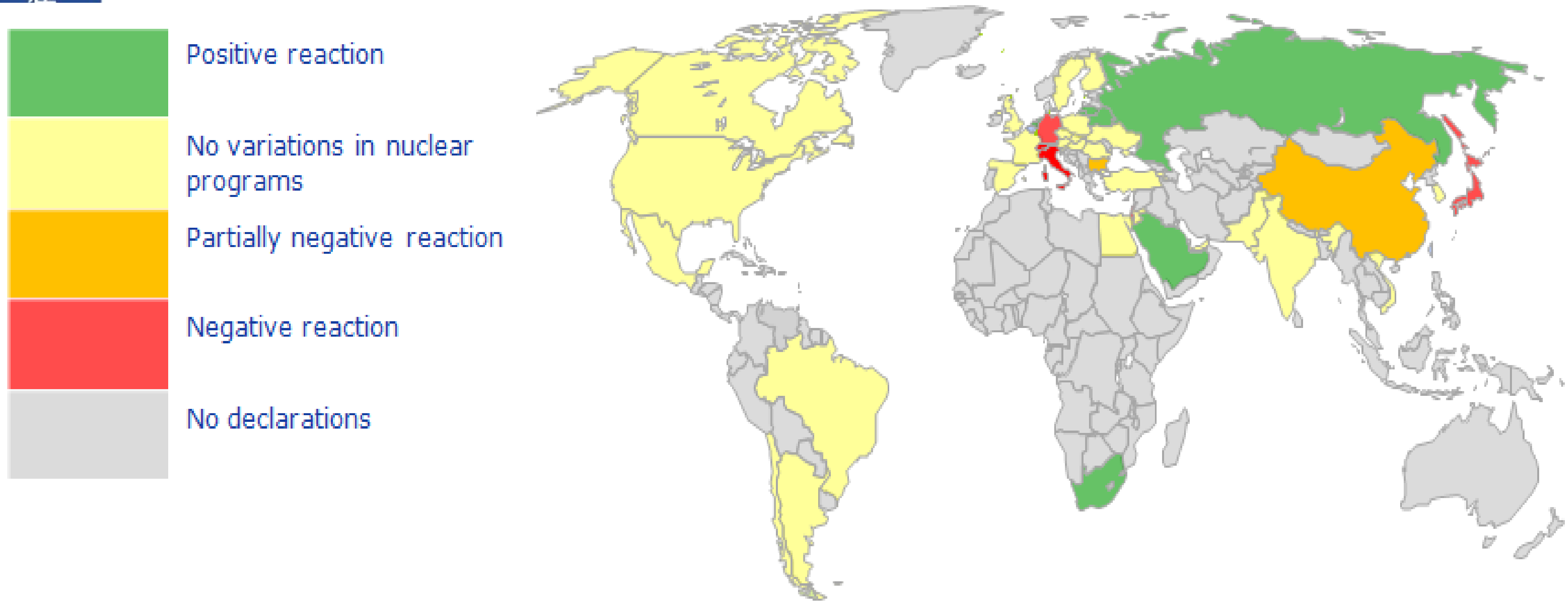
- Application of Euratom Treaty Art.41/43 Procedure on Communication of Nuclear Investment Projects (e.g. new NPPs):
    - Use of Stress Test Type of “Criteria” for Future EC Viewpoints ?

After Fukushima, is there any future for nuclear energy?



Source: WNA, 30.11.08

International reactions to Fukushima accident



Impact of Fukushima on development of nuclear power till 2030 (IAEA projections 2011)

- The Fukushima-Daiichi nuclear accident will slow growth in nuclear power but not reverse it
- The world's installed nuclear power capacity will grow in 2030 from present 367 GWe to
  - 501 GWe (low projection), down 8% from 2010
  - 746 GWe (high projection), down 7% from 2010
- The number of reactors increases (mainly in countries that already have operating NPPs) from the current 433 reactors in 2030 by about
  - 90 (low projection)
  - 350 (high projection)

Impact of Fukushima on development of nuclear power till 2030 (IAEA projections 2011)

- Projected growth is greatest in the Far East.
  - From 81 GWe at the end of 2010, capacity grows to 180 GWe in 2030 in the low projection and to 255 GWe in the high projection
  - These levels are, however, lower than last year's projections by 17 GWe and 12 GWe respectively
- Western Europe shows the biggest difference between the low and high projections.
  - In the low projection, nuclear capacity drops from 123 GWe at the end of 2010 to 83 GWe in 2030.
  - In the high projection, nuclear power grows to 141 GWe, but that is 17 GWe below the growth projected in 2010

Impact of Fukushima on development of nuclear power till 2030 (IAEA projections 2011)

- In North America from 114 GWe at the end of 2010
  - the low projection shows a small decline to 111 GWe in 2030
  - the high projection shows an increase to 149 Gwe, 17 GWe below 2010projection
- Other regions with substantial nuclear power programmes are Eastern Europe, which includes Russia, and the Middle East and South Asia, which includes India and Pakistan. Nuclear power expands in both regions in both the low and high projections - to only slightly lower levels than projected last year. The same is true for regions with smaller programmes - Latin America, Africa and South East Asia

Nuclear power – national policies post Fukushima

Changes in Government Policy Toward Nuclear Energy Following Fukushima in Countries Using or Intending to Use Nuclear Energy	
Existing nuclear installations	
Use of nuclear power in principle is not being affected	Argentina, Brazil, Belgium, Bulgaria, China, Czech Republic, Finland, France, Hungary, India, Japan, the Netherlands, Romania, Russia, Slovakia, South Africa, South Korea, Spain, Sweden, Switzerland, Ukraine, United Kingdom, United States
Use of existing nuclear power is being rejected	Germany
Construction of new nuclear installations	
Construction projects in principle are not being affected	Brazil, China, Czech Republic, Finland, France, Hungary, India, the Netherlands, Poland, Russia, Slovakia, South Africa, South Korea, Sweden, Turkey, Ukraine, the United Arab Emirates, the United Kingdom, the United States, Vietnam, Saudi Arabia, Jordan
Basic assessment of extension of nuclear power	Japan
Construction precluded	Germany, Switzerland, Italy, Venezuela

Areas requiring additional consideration in the design due to Fukushima (1 of 2)

- Selection of extremely unlikely external hazards as a part of the design basis (In the end it will be always a ballance between level of hazards taken into account and economy of the project)
- Enhanced robustness of design against external hazards and security threats including malevolent actions
- Sequence of (in)dependent external hazards
- Need to obtain historical data of sufficient age and reliability
- Combination of external hazards with internal initiating events
- Prevention, identification and mitigation of severe accidents associated with spent fuel pools
- Enhanced requirements on plant autonomy (independence on external support)

Areas requiring additional consideration in the design due to Fukushima (2 of 2)

- **Enhanced independence and diversity of provisions at different levels of defence, in particular at level 4 aimed at prevention and mitigation of severe accidents**
- **Accessibility and feasible ways of utilizing mobile sources of power and coolant**
- **Availability of additional sources of cooling media on the site**
- **Availability of instrumentation and other hardware tools for management of severe accidents**
- **Reconsideration of needs for filtered containment venting**

Specific conditions in the Czech Republic

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Unfavourable situation regarding primary energy resources and potential for use of renewable power sources:

1. Negligible resources of oil and natural gas
2. Coal resources sufficient depending on selected energy strategy and breaking down the mining limits are sufficient until 2030 – 2070; enormous impact on the landscape
3. Use of renewable power sources:
   - potential for use of hydro power nearly exhausted
   - limited possibilities for efficient use of wind power and solar power due to given climatic conditions
4. There are certain resources of uranium, but mining reduced from 3000 t U/year to 300-400 t U/year, total resources being about 130 kt
5. Significant amount of uranium in spent fuel storages and in resources of depleted uranium as potential secondary power source

Czech Republic nuclear profile

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- 50 years of nuclear experience
- Background in research, education, design, fabrication of heavy components, plant construction, operation
- Favourable public opinion
- ~33 % of electricity produced in NPPs
- Existing country energy strategy relying on significant role of nuclear power in the energy mix
- Design of all operational NPPs Czech made
- ~80 % of components for existing power plants fabricated in CR
- Capabilities for design and fabrication of all major components still available, engineering and industry can effectively participate in implementation of reactors
- CEZ – major state owned utility interested in further expansion of its nuclear fleet

Report of Independent commission for evaluation of energy needs for the CR (2008)

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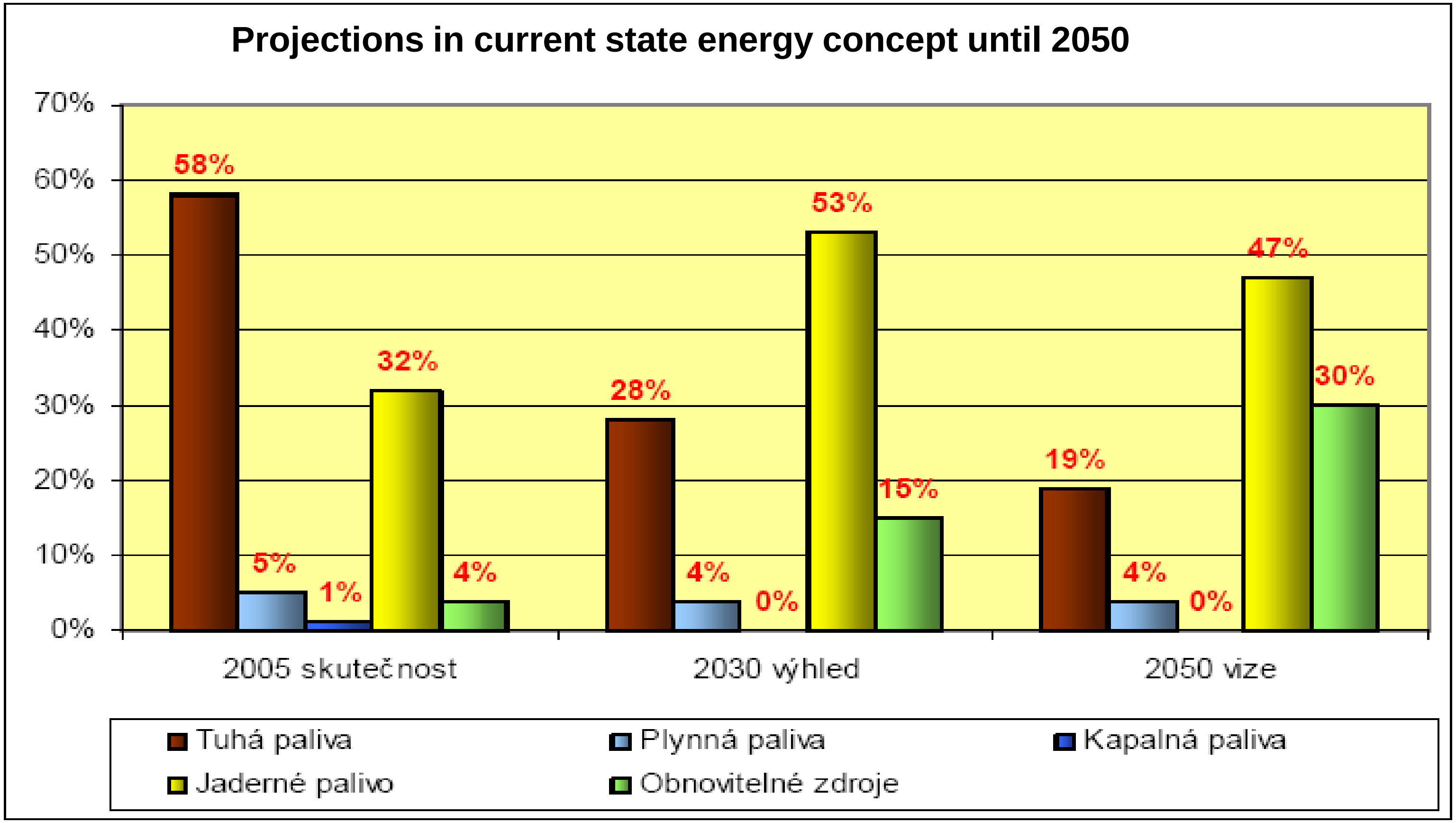
- Coal reserves will be drastically reduced in next 25 years to about 20 % of current status, and in less than 50 years there will be no more coal reserves
- Essential role of nuclear energy confirmed
- Needs for transition to fast breeders after 2040 recognized
- Use of nuclear energy to non-electric applications identified (central heating, industrial needs, production of hydrogen)
- Lack of primary fuel for central and distributed heating identified as one of the largest risks in mid-term future

State energy concept of the Czech Republic of 2010 – Role of nuclear energy

- Increasing role of nuclear power
- Long term operation of existing units up to 50-60 years
- Accelerate construction of new units, generation III, III+ and generation IV with high level of passive safety and load following capability
- Ensuring sufficient resources of nuclear fuel, development of technologies utilizing plutonium cycle
- Extended use of centralized heat supply from existing and newly built NPP in the time horizon 2030 (including large cities like Brno, Jihlava, Ceske Budejovice, Strakonice)
- In long term horizon (after 2030) considering replacement of existing coal firing sources for central heat supply by small underground nuclear sources with high level of nuclear safety, standardization and pre-fabrication

Projection of electricity production in the CR until 2060



Zdroj: ČSÚ, ERÚ, MPO

- **Updated energy concept currently under preparation (until 2060) considers increase of nuclear share from the current 33,3 % up to 90 %, with newly built 14 to 21 GWe installed power**

Will Czech NPPs pass the "stress tests"?

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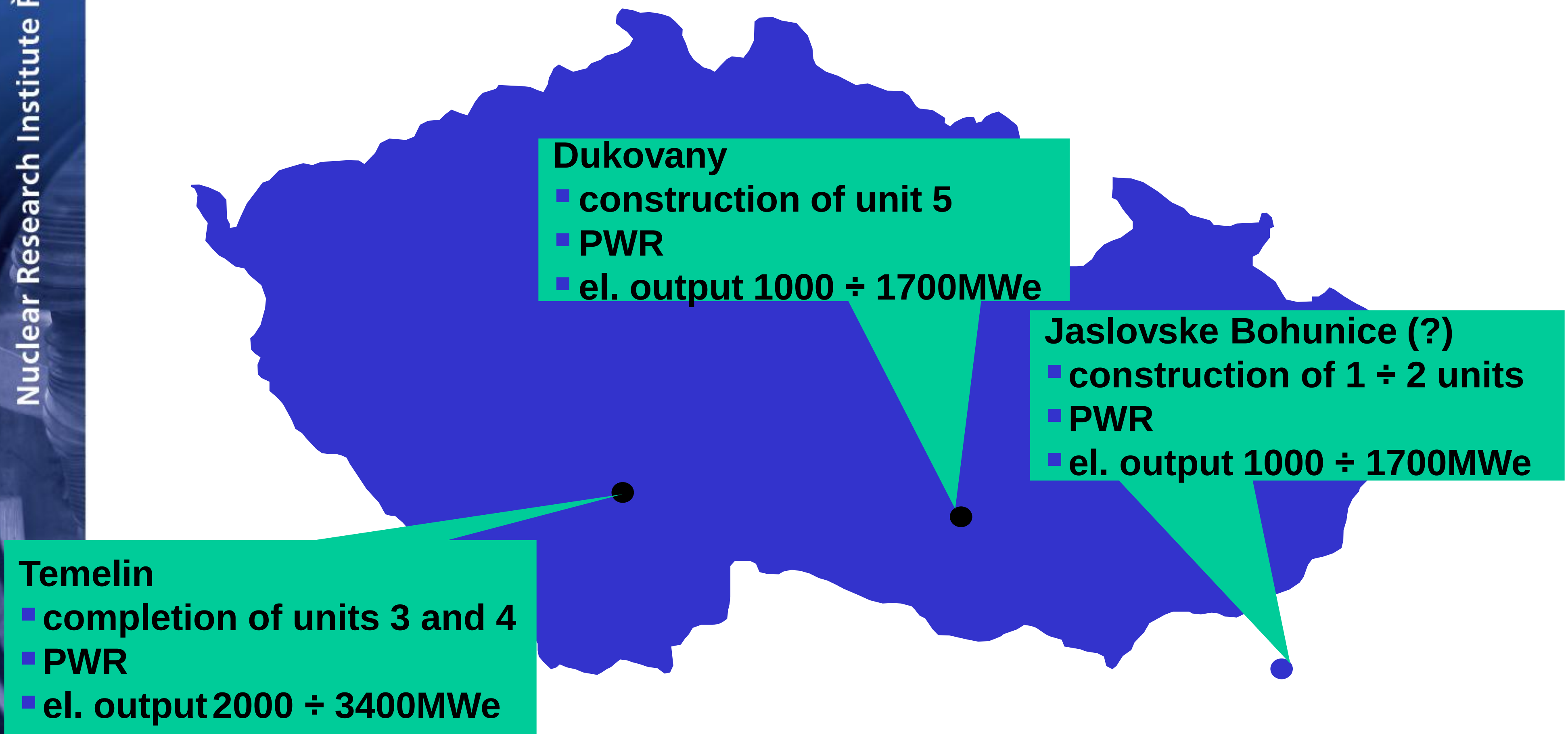
- Technically irrelevant question, there are no acceptance criteria; however, very sensitive political issue
- The objective is to determine which level of severity of an external hazard the NPP can withstand without severe damage of the nuclear fuel or without significant releases of radioactive materials into the environment and to propose measures beyond the current design basis which would address identified issues
- All NPPs if properly designed have safety margins due to conservatism embedded in the design; stress tests should quantify the margins
- The final objective of the actions should not be a confirmation that the safety level is satisfactory, but rather should lead to identification of measures for further safety improvements
- In addition to short term actions there should be long term activities towards enhanced safety
- An important aspect of stress tests is to strengthen safety culture by creating safety related initiatives of operators beyond the current design basis

Current plans of nuclear projects of CEZ, a.s.



Candidate projects for new builds in CR

Westinghouse

MITSUBISHI HEAVY INDUSTRIES, LTD.

AREVA

ATMEA

АСЭ·ASE

KHNP

Conclusions

- The Fukushima accident did not change the reasons for maintaining/enhancing the role of nuclear energy in energy mix as sustainable, safe and low carbon source
- The Fukushima-Daiichi nuclear accident will slow growth in nuclear power but not reverse it
- In spite of the Fukushima accident, NPPs represent the safest way of electricity production, but safety should remain an issue requiring continuous improvements
- Fukushima accident should be used as an opportunity to address our understanding of coping with external hazards and events of extremely low probability
- Stress tests can not be used on categorization of NPPs as good or bad; there is no basis for decisions on shutdown of NPPs based on the stress tests

Conclusions

- Stress tests were found to be a useful exercise offering to assess more deeply the safety level of nuclear power plants for potential hazards caused by extreme natural events
- Lessons learned from Fukushima should result in identification and implementation of improvements, preferably harmonized
- Nuclear energy should remain a part of the energy mix as safe, sustainable and economically affordable energy supply for CR
- There is large potential for involving Czech energy industry in construction of new NPPs