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Monitoring of the EU Stress test improvement actions in neighbouring countries

Public Workshop:
Five Years Fukushima, Thirty Years Chernobyl

26th February 2016

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Approach

Review & monitoring of post Fukushima safety improvements

- All safety deficiencies/proposed measures addressed
- Detailed concept/safety solutions reviewed
- Assessment of adequacy/understanding of solutions
- Status of the implementation

Issue papers (country & topic specific) in 2013/2014

- Safety measures collected, evaluated, ranked (importance)
- Clarifying questions raised; Activities proposed

Update of Issue papers 2015/2016 (content, schedule)

Comparison of similar issues (across countries)

Update of Issue papers

Consideration of current status

NAcP reports & Workshop; Bilateral meetings; 6th RM of CNS; IAEA missions; ENSREG & WENRA

Verification & update of status of safety issues

Level of completeness; Implementation schedule; Change in approach; Method/focus; etc.

Three/four categories of issues

Topic 1: Initiating events (earthquake, flooding, extreme weather)

Topic 2: Loss of Safety Systems

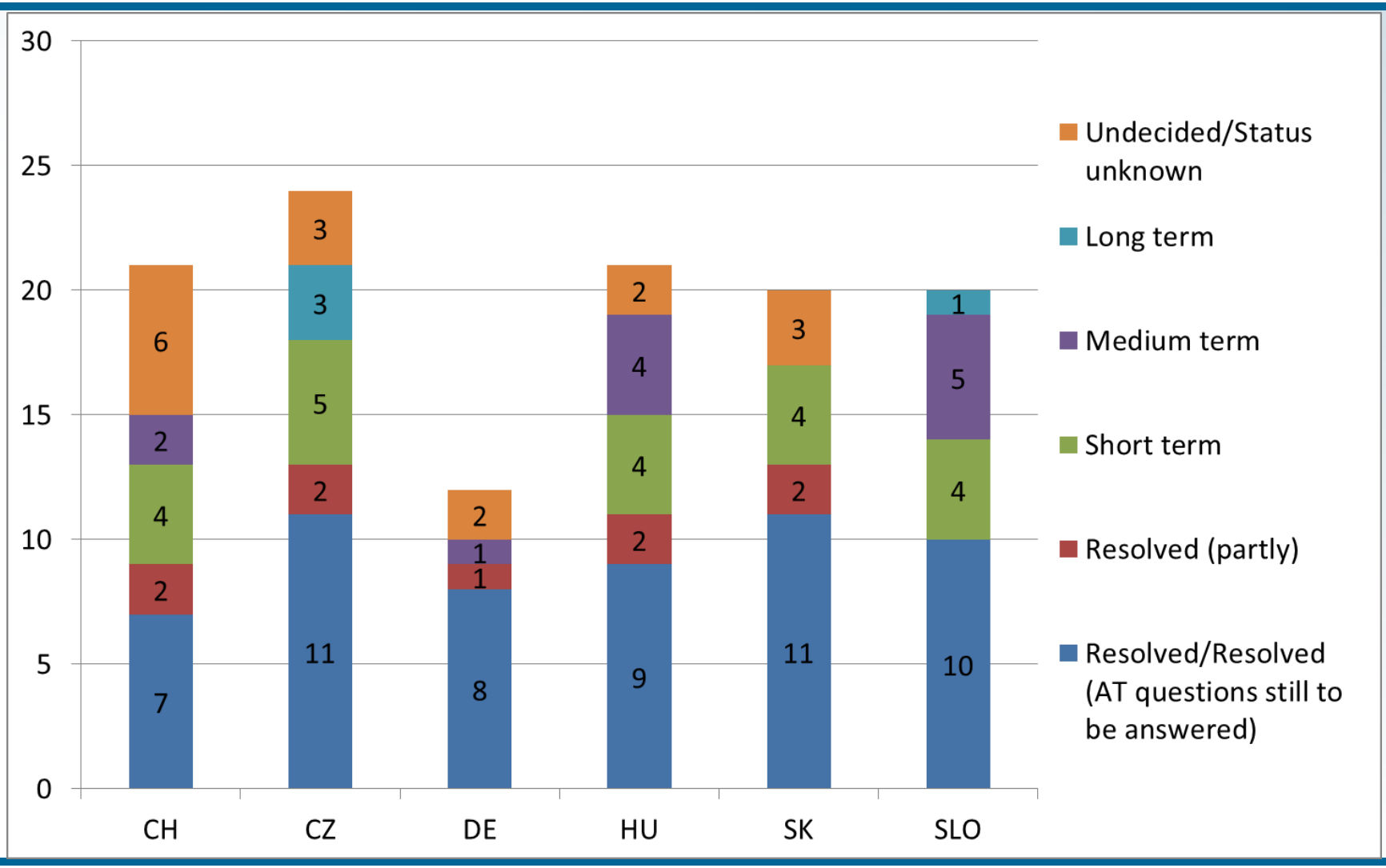
Topic 3: Severe Accident Management

Topic X: Other issues *(beyond Topics 1-3)*

Example of an Issue

Topic 2: Loss of safety systems	
Title	Additional water source for the diesel-driven fire water pumps
Content	Modifications to enable uptake 2x2000 m^3 water from discharge canal ….
Safety relevance	Fire water pump, when ESW non-operational, supply 100 m^3 of water..
Background (2014)	The fire water system can be primarily considered as a water source….
Assessment 2015	Work has commenced…. It also indicates that according to the task schedule development, the proposed deadline can be met.
To be discussed	Question from the last Issue Paper is still relevant: Engineering consideration in relation with availability of water reserve during a seismic event.
Safety importance	High
Expected schedule	Medium term
Follow-up	Dedicated presentation

Results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Undecided/Status unknown
Long term
Medium term
Short term
Resolved (partly)
Resolved/Resolved (AT questions still to be answered)

Comparison of similar issues across countries

Topic 1:	Natural hazard assessments (seismic, extreme weather)
Topic 2:	Power supply
	Spent Fuel Pool (SFP) cooling
Topic 3:	Hydrogen management
	Stabilisation of molten core (VVER-440/213)

Topic 1: Initiating events (earthquake, flooding, extreme weather)

Switzerland: Topic #1 Overall

New seismic hazard assessments (PEGASOS and Pegasos Refinement Project) show that the revised hazard levels exceed the original seismic design basis of all plants.

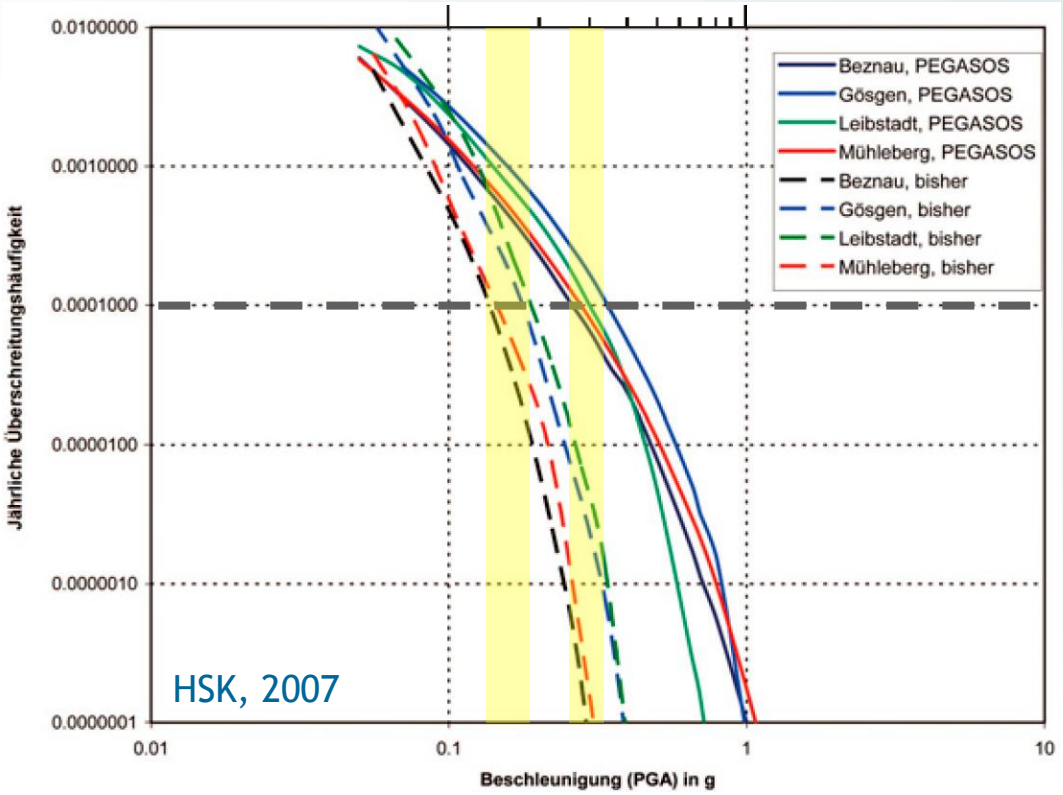
New design basis values have not been defined yet although hazard revisions started in 1990ies.

The main topics: hazard levels, seismic safety margins, and plant upgrades are addressed by three issues.

Other topics:

Adequate protection of all plants against extreme weather

Switzerland: Topic #1 Details



PEGASOS hazard assessment outdated the seismic design basis of all plants in 2004.

Updated design basis values have not been defined yet. Instead, the Pegasos Refinement Project was launched in 2008 (project ongoing).

Stress tests indicate that existing safety margins do not meet the requirements of the new hazard levels.

Czech Republic: Topic #1 Overall

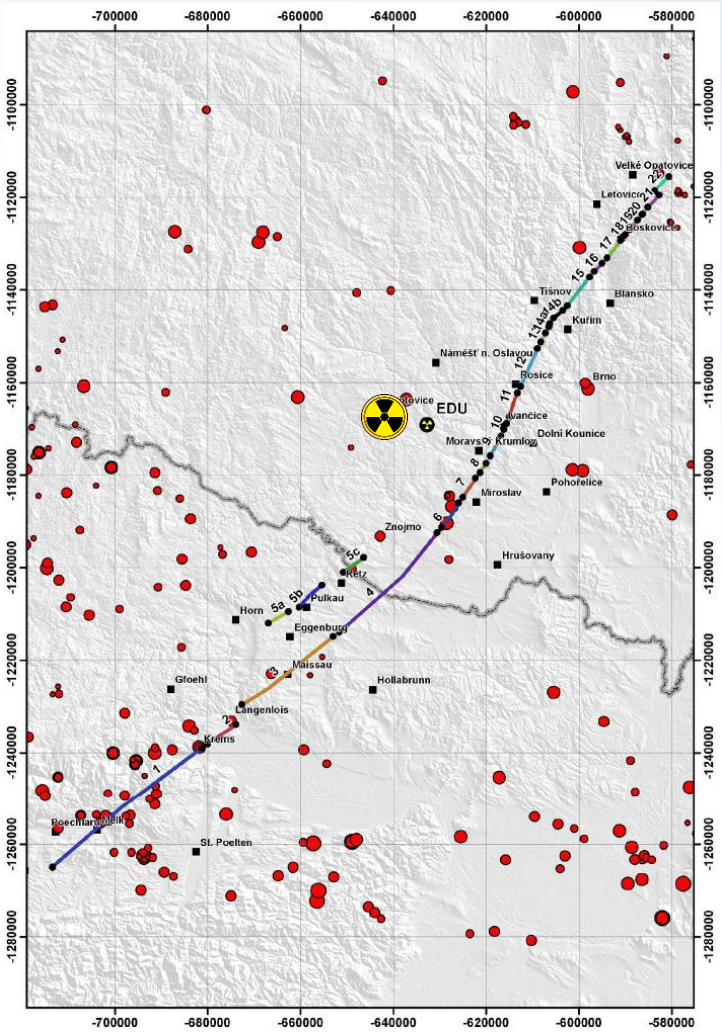
Main topics:

Upgrading of Dukovany's cooling towers to resist storm and earthquakes (Issues 1.2 – 1.4)

Seismic hazard assessment – NPP Dukovany: implementation of new scientific findings from the Diendorf-Boscovice Fault (CZ and AT results)

Seismic hazard assessment – NPP Temelin: implementation of AIP / CIP results (Issue 1.7: mostly resolved)

Czech Republic: Topic #1 Details



NPP Dukovany

Update of seismic hazard assessment in progress

Assessment should account for the hazard contribution of the active Diendorf-Boskovice Fault (15 km distance from the site)

CZ geoscientists strive for cooperation with AT for the assessment of the Austrian part of the fault

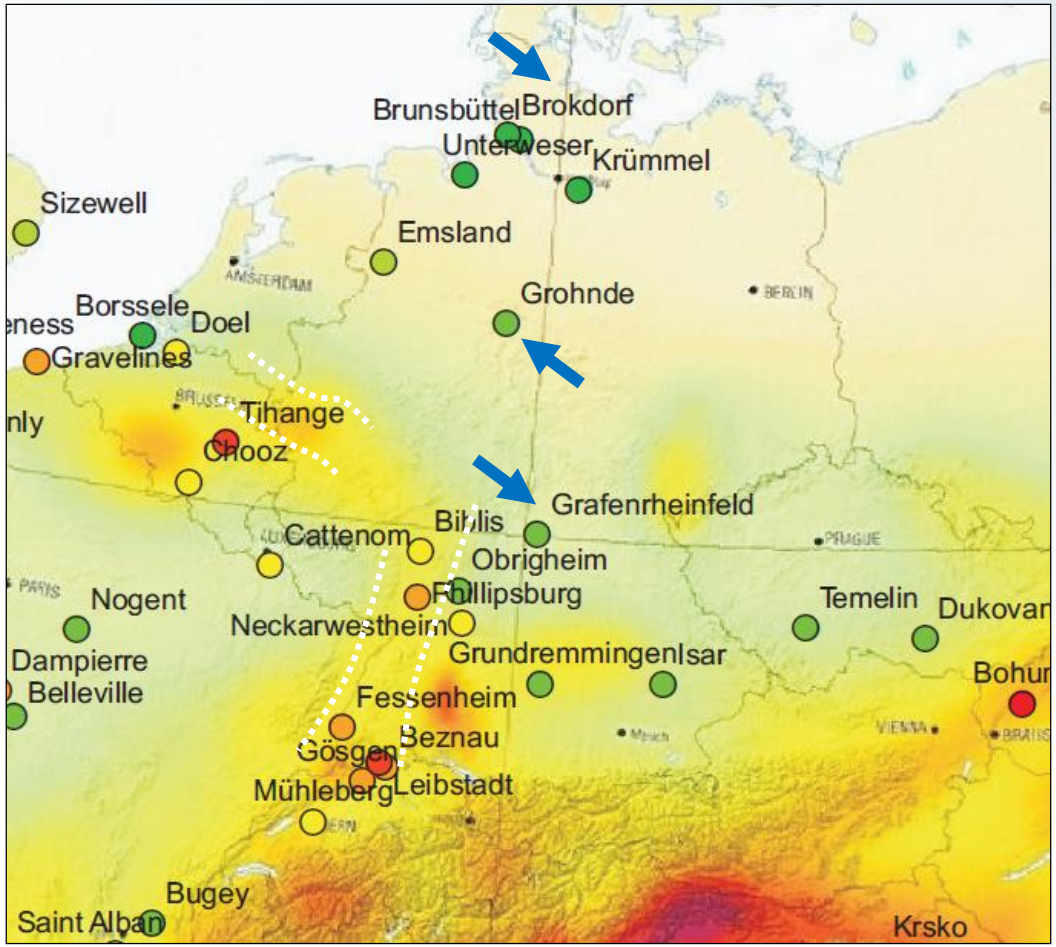
Germany: Topic #1 Overall

The EU Stress tests revealed that the design basis of several German NPPs is below IAEA's suggested minimum of 0.1 g PGAh.

This value has recently been confirmed as a common minimum by the WENRA Reference Levels for Existing Reactors.

New geological data further suggest that the seismic hazard for German (and French) sites near the Rhine Graben may be underestimated.

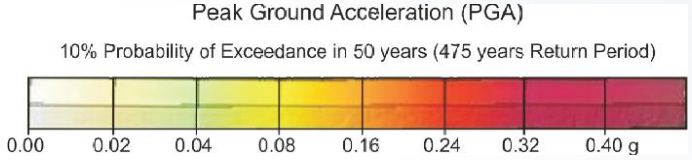
Germany: Topic #1 Details



NPP Design Base

PGA hor

- 0.0000 - 0.0600
- 0.0601 - 0.1000
- 0.1001 - 0.1430
- 0.1431 - 0.1700
- 0.1701 - 0.2100
- 0.2101 - 0.2800
- 0.2801 - 0.3440



Hungary: Topic #1 Overall

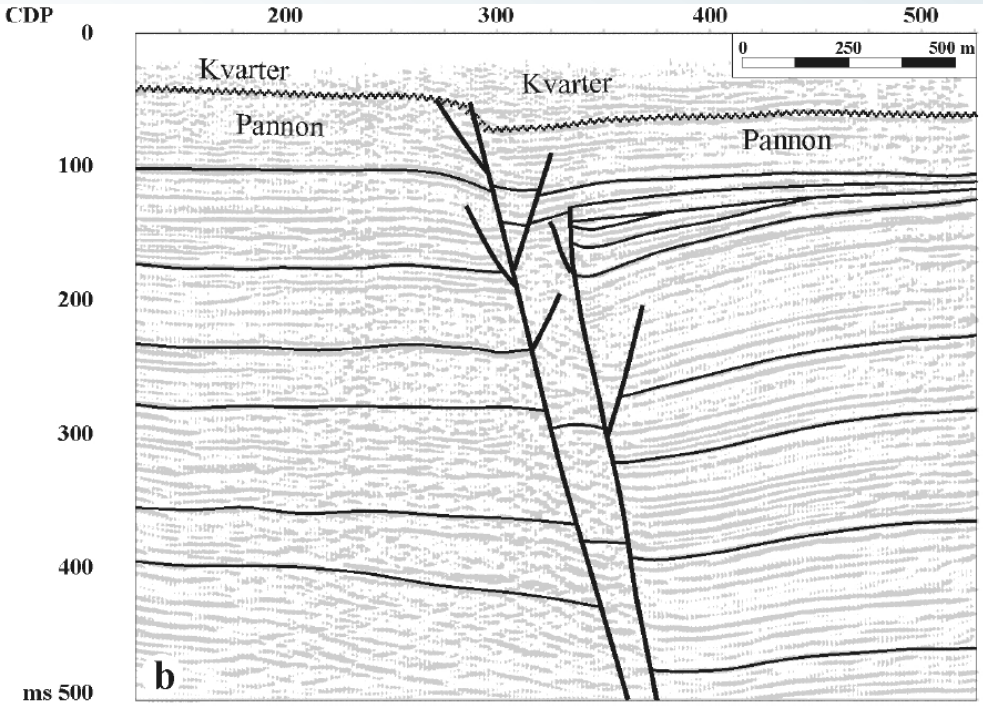
Priority issue:

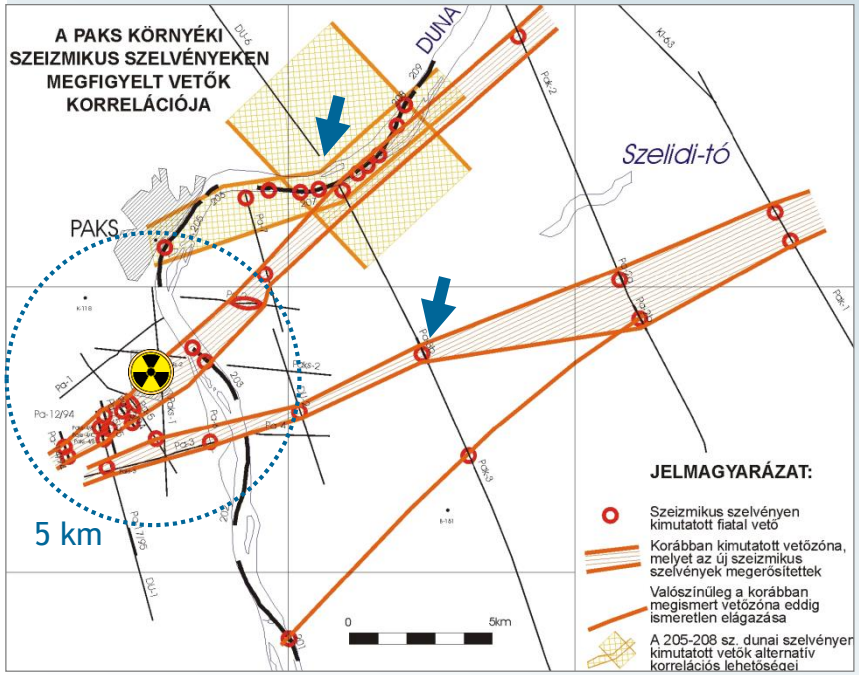
Reflection seismic (Tóth, 2003) identified several active faults near Paks. These faults offset young (Quaternary) sediments and need to be considered in seismic hazard assessment (Issue 1.2)

New seismic hazard assessment for the siting of Paks 5 and 6 should address this issue

Open issue of the bilateral dialogue since 2010

Hungary: Topic #1 Details





Quaternary faults in the near-region and site-vicinity of the plant shown in reflection seismic

Capable faults in the site vicinity are site exclusion criteria according to IAEA

Slovakia: Topic #1 Overall

Priority issues:

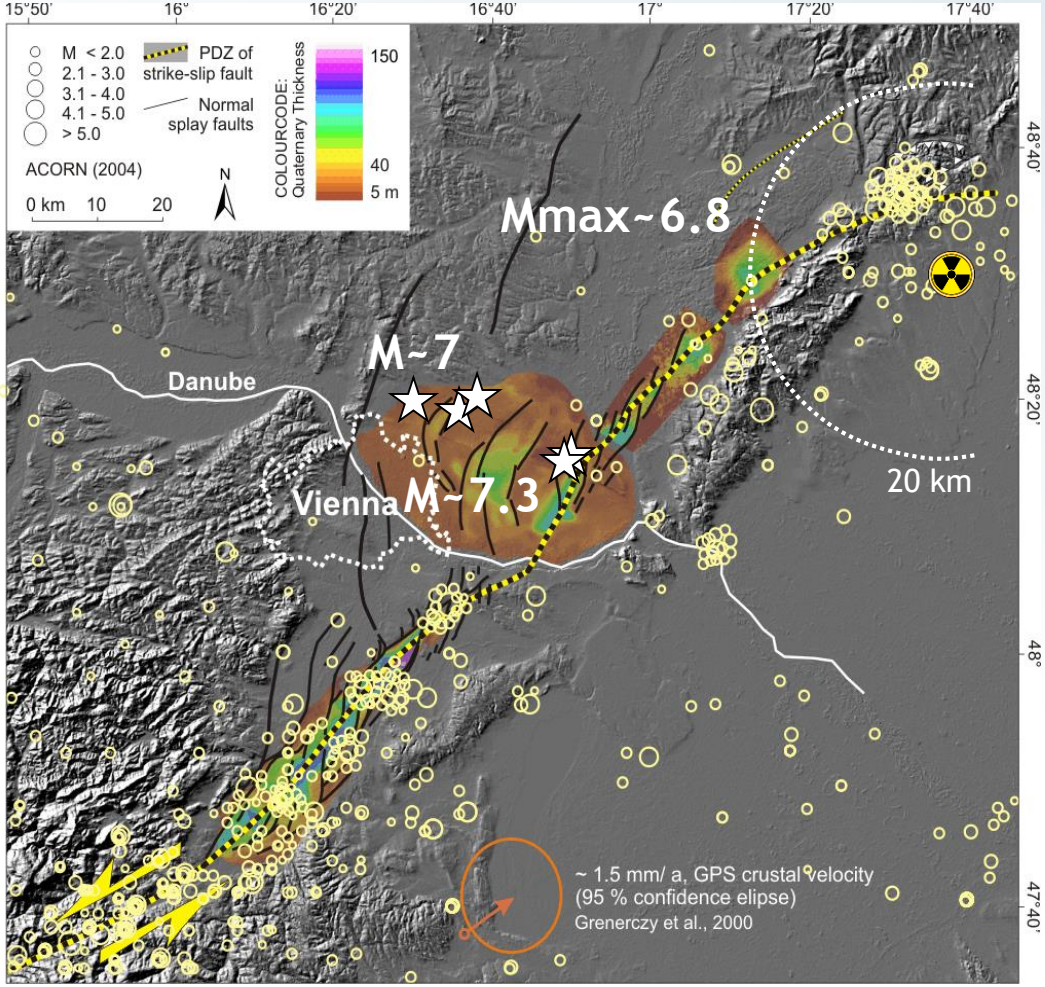
Seismic hazard NPP Bohunice: new evidence from the Vienna Basin Fault Zone not covered by previous hazard assessments (Issue 1.1)

Seismic hazard assessment for NPP Mochovce: clarify open questions remaining from the bilateral meeting in 2010 (Issue 1.3)

Other topics to be discussed:

Extreme weather, NPP Bohunice (Issues 1.6 and 1.7)

Slovakia: Topic #1 Details



NPP Bohunice

Design basis: PGAh=0.34 g

Safety margin for containment integrity: PGAh=0.35 g

New: Vienna Basin Fault System extends along the Male Karpaty Mountains. The fault can produce earthquakes with M up to M~7

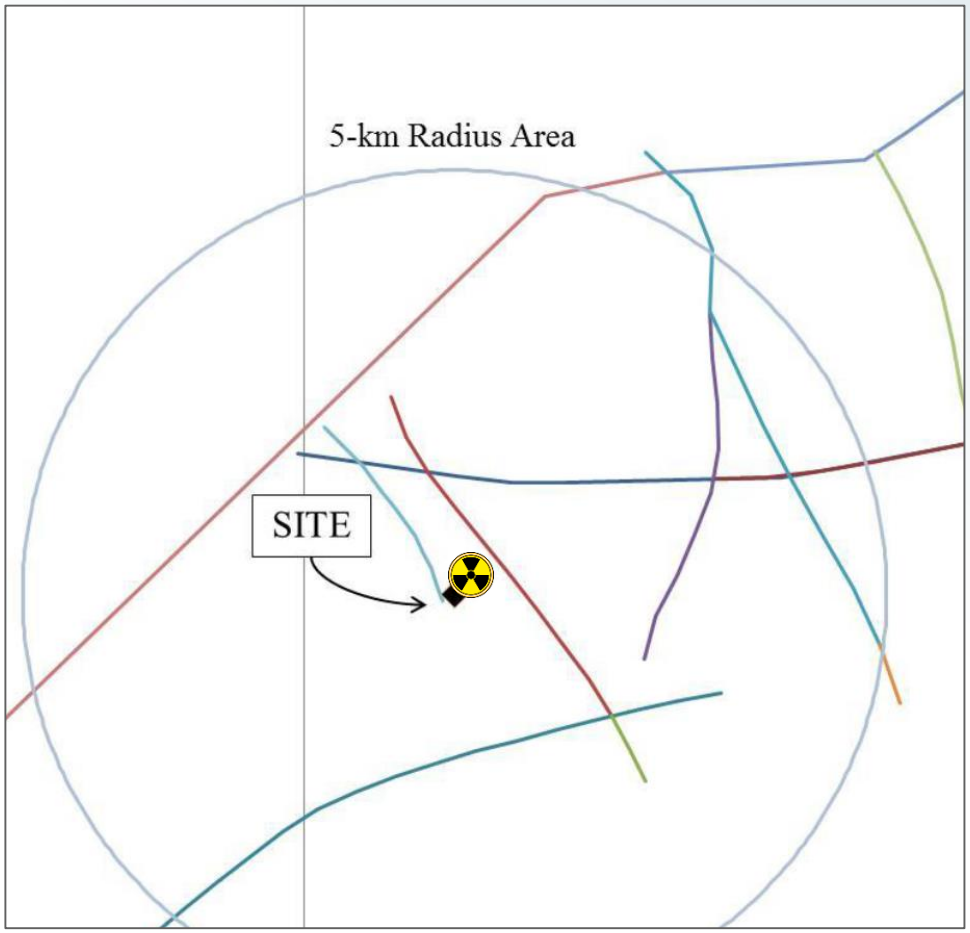
Slovenia: Topic #1 Overall

Priority issues:

Slovenian regulator published evidence for a capable fault in the vicinity of NPP Krsko. This is of utmost importance for the seismic safety of the existing plant and the siting of “Krsko II” (Issue 1.1 to 1.3)

Seismic hazard assessment for the site increased hazard from 0.3 g to 0.56 g. It is claimed that the safety margins above the original design basis are sufficient to accommodate the new hazard value (Issue 1.4 and 1.5)

Slovenia: Topic #1 Details



Cline et al., 2015

NPP Krsko

Slovenian Geological Survey excavated a capable fault in the site vicinity

PFDA by Rizzo (2015): 5 active faults, 5 faults with probabilities of being active 0.5; fault slip rates 0.04 to 0.1mm/y; Mmax ~ 6-7

No significant hazard for ground displacement at the site

Contribution to ground shaking hazard not quantified

Comparison of issues: Topic #1 Initiating events

Stress test findings:

Many hazard assessments were completed during the siting of the plants (sometimes in the 1970ies and 1980ies) and not updated since

Due to their age these assessments could not benefit from advances in science and new data

For extreme weather hazard assessments were often not available, a design basis was not established, or the design of facilities was based on building codes for ordinary structures

Comparison of issues: Topic #1 Initiating events

Western European
WENRA RHWG
Nuclear Regulators Association

Report
WENRA
Safety Reference Levels for Existing Reactors
–

UPDATE IN RELATION TO LESSONS LEARNED FROM TEPCO FUKUSHIMA DAI-ICHI ACCIDENT

24th September 2014

19
Issue T: Natural Hazards

Design basis events for non-exceedance frequency 10^{-4}/y

Design basis may change during the lifetime of the plant

Protection against design basis events shall apply conservatism providing safety margins in the design

Events more severe than the design basis event shall be considered ("DEC analysis")

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Comparison of issues: Topic #1 Initiating events

Western European WENRA RHWG Nuclear Regulators Association

Position paper

on Periodic Safety Reviews (PSRs) taking into account the lessons learnt from the TEPCO Fukushima Dai-ichi NPP accident

–

Study by

WENRA Reactor Harmonization Working Group

March 2013

"As part of the PSR process, the safety justification against external hazards shall be re-evaluated at least every ten years if not specifically addressed otherwise."

"Concerning the scope of PSR, it is recognized that natural hazards should be more systematically reviewed during PSR"

Covered by WENRA Reference Levels (2014) Issue P, Periodic Safety Review.

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Comparison of issues: Topic #1 Initiating events

All countries except Germany updated hazard assessments and seismic design bases during the lifetime of the plants.

In four countries hazard reviews are driven by the siting of new reactors at locations close to existing ones (Dukovany, Paks, Mochovce, Krsko) rather than by the striving for increased safety for existing reactors.

Previous hazard revisions were not linked to a formalized periodic process such as PSR.

Periodic hazard revisions (e.g., in the context of PSR) as recommended by WENRA and ENSREG were so far not required.

Topic 2: Loss of Safety Systems

Switzerland: Topic #2 Overall

4 NPPs in Switzerland: world's oldest but massive improvements over the time

Safety issues

- Cooling system for Mühleberg NPP
- SFP cooling (all plants)
- AC power supply (KKB, KKG)
- Primary pump seal system (KKB)

5 safety issues identified

- 4 issues **resolved**
- 1 issue resolution in **medium term** *(SFP cooling)*

Switzerland: Topic #2 Details

Cooling of Mühleberg NPP in case of extreme flooding

NAcP 2012: alternative UHS independent from Aare river (protected well fed by Saane river)

Now: KKM permanent shutdown (2019)

Reinforcement of dam at HPP Mühleberg

Additional cooling water supply

- REWAG pumping station (additional mobile DG)
- Connections for mobile pumps

Resolved (AT questions still to be answered)

Czech republic: Topic #2 Overall

Dukovany & Temelin NPP: highly redundant safety systems

Safety issues: deficiencies/enhance capabilities in BDBA

- Heat removal from RCS/SFP/I&C (EDU&ETE)
- AC/DC power supply and cooling (EDU&ETE)
- Containment isolation valves (ETE)

8 safety issues identified

- 5 issues **resolved**
- 2 issues **partly resolved**
- 1 issue resolution in **long term** *(Containment isolation valves)*

Czech republic: Topic #2 Details

AC power supply & battery backed power supply

EDU

- Additional SBO DG
- Alternative mobile devices
- No reinforcements of off-site connections needed
- *Measures to ensure long term DC power supply (2016)*

ETE

- Additional SBO DG
- Alternative mobile devices
- Measures to ensure long term DC power supply

Resolved (partly; not at Dukovany)

Germany: Topic #2 Overall

Focus on 8 NPPs in operation (except SFP issues)

Only 3 issues: rectify specific vulnerabilities

- Emergency power supply (some NPPs)
- Residual heat removal capability (Brokdorf NPP)
- SFP cooling (all NPPs)

Resolved (AT questions still to be answered)

Hungary: Topic #2 Overall

Issues connected to power supply/cooling

- AC power supply (DG, cross-connections, to water wells)
- Black start of nearby gas turbine
- EDG cooling
- SFP cooling

For Paks NPP 9 issues identified

- 3 issues **resolved**
- 2 issues **partly resolved** (regulatory body approval needed)
- 2 issues resolution in **short term**
- 2 issues resolution in **medium term**

Hungary: Topic #2 Details

EDG cooling in case of loss of essential water system

ESW cooling EDGs

LOOP: EDG supply ESW

Solution: equipment for cooling water supply to EDG from fire water system

Resolved (AT questions still to be answered)

Slovakia: Topic #2 Overall

Issues connected to power supply/cooling

- Emergency power supply during BDBA
- AC/DC power supply
- Cooling capability
- Loss of ultimate heat sink

5 issues identified (4 EBO & EMO, 1 EBO)

- 4 issues **resolved**
- 1 issue resolution in **short term**

Slovakia: Topic #2 Details

Increase resistance and reliability of EPS for BDBA

SBO: loss of SG feedwater → no heat removal from RCS

SBO: no RCP seal cooling → RCS coolant leakage

New 6 kV SBO-DG for (EBO & EMO)

- Increased reliability of EPS in BDBA
- Physically independent from original safety systems
- Seismically qualified
- To prevent CD and for SAM

Resolved (AT questions still to be answered)

Slovenia: Topic #2 Overall

Issues connected to power supply and cooling of RCS/SFP

- AC power supply
- RCS and SFP cooling
- Connection points for mobile equipment
- Loss of UHS

9 safety issues identified

- 5 issues **resolved**
- 2 issue resolution in **medium term**
- 2 issue resolution in **long term**

Slovenia: Topic #2 Details

Dedicated safety bunker, Alternative UHS

Safety bunker: dedicated water sources, HP safety injection pump, SG feed pump, containment spray pump

Alternative UHS (air cooled)

Plant's owners ordered cost-benefit study

Future of the projects unknown (yet)

After 2020

Long term

Comparison of issues: Topic #2 AC power supply

The following issues deal with AC power supply:

CH 2.3, CH 2.4	HU 2.1, HU 2.2, HU 2.4
CZ 2.4	SK 2.1, SK 2.2
DE 2.1	SLO 2.1, SLO 2.3

Before Fukushima

Fixed DGs (all NPPs): the number and capacity vary

Mobile DGs: available in all NPPs except in Gösgen (CH), Emsland & Brokdorf & Gundremmingen (DE), (CZ), (SK)

Off-site/other means of power supply:

- House load operation, interconnection between units (all NPPs)
- Connection to different offsite grid voltage levels (all NPPs, not Paks)
- Dedicated connection to nearby gas or HPP (several NPPs)

Comparison of issues: Topic #2 AC power supply

After Fukushima

Fixed DGs:

- CZ, SK, SLO: additional DGs installed
- HU: new DG planned (2018)

Mobile DGs:

- CZ (1 DG), DE (1-2 DGs), SK (1 DG): provided after Fukushima

Off-site/other means of power supply:

- NPP Beznau (CH): supply from onsite HPP replaced by 4 DGs
- Paks NPP: black start of gas PP enabled, connections between DGs and consumers from different units under implementation

Comparison of issues: Topic #2 SFP cooling

The following issues deal with SFP cooling:

- CH 2.2 Enhancement of cooling (all NPPs)
- CZ 2.1 Enhancement of heat removal from RCS and SFP, NPPs EDU and ETE
- DE 2.3 Enhancement of SFP cooling
- HU 2.7 External source for the make-up of spent fuel pool (SFP)
- SLO 2.8 Alternate cooling of SFP
- SLO 2.9 Mobile heat exchanger

General comparison → redundancy and diversity of SFP cooling

Before Fukushima: all NPPs redundancy; some diversity

After Fukushima: increase robustness of SFP cooling

Topic 3: Severe Accident Management

&

Topic X: Outside of Topics 1-3

Switzerland: Topic #3 + X Issues - Overall

Topic 3:

Containment hydrogen management

Strategy for deployment of mobile equipment

Power supply of instrumentation for accident management (KKM, possibly also other NPPs)

KKM: Systematic assessment of availability of AM measures

KKM: Operability of pneumatic valves under accident conditions

Cliff-edge effect in shutdown phases

1 issue **resolved**, 1 **resolved (AT questions pending)**, 2 **partly resolved**, 2 resolution in **short/medium term**

Switzerland: Topic #3 + X Issues – Overall

Topic X: NPP Mühleberg (going to permanent shut down in 2019)

Cracks in the reactor core shroud

Overfilling of reactor pressure vessel

1 issue resolution in **short term**, 1 in **medium term**

Switzerland: Topic #3 - Details

2 issues partly resolved

Power supply of instrumentation necessary for AM measures – resolved for KKM, situation at other NPPs unclear.

Safety improvements concerning cliff-edge effect in shutdown phase – some analyses performed by licensees. Status of review by ENSI and possible plans for further analyses unclear.

2 issues to be resolved in short/medium term

Containment hydrogen management – mostly performed, some measures still needed at KKB, KKG and KKL (until end-2017).

Operability of pneumatic valves under accident conditions at KKM – might not be needed because of other measures; status unclear.

Czech Republic: Topic #3 + X Issues – Overall

Topic 3: Dukovany and Temelín

Stabilization of molten core

Avoid long-term containment over-pressurization

Hydrogen management

Upgrade of PSA level 2

Common VVER support center

3 issues **resolved (AT questions pending)**, 1 resolution in **short/medium term**, 2 resolutions in **long term**

Topic X: Temelín

2 issues concerning materials, both **resolved (AT questions pending)**

Czech Republic: Topic #3 - Details

Topic 3: 2 issues to be resolved in the long term.

Both concern Temelín NPP, and are connected:

Stabilization of molten core – ex-vessel cooling of the corium to be implemented by 2022 (possibilities of in-vessel cooling are also investigated, but still in R&D-phase).

Avoid long-term containment over-pressurization in case of severe accident – decision against filtered venting. Some measures for spraying into containment atmosphere are already implemented. Additional measures to be introduced together with ex-vessel cooling.

Germany: Topic #3 + X Issues – Overall

Topic 3: Concerning operating NPPs

Availability of AM measures in case of natural hazards

Development of AM measures for load drop, flooding

Measures to improve reliability of ultimate heat sink

Topic 3: Concerning NPPs in shut down

Vulnerability of SFPs at KKB, KKI-1 and KKP-1

4 issues **resolved (AT questions pending)**, 1 **partly resolved**, 1 resolution in **medium term**

Topic X: Gundremmingen

1 issue on seismic design of ECCS **resolved (AT questions pending)**

Germany: Topic #3 - Details

Topic 3: 1 issue to be resolved in the medium term

Vulnerability of the spent fuel pools at the smaller BWRs of type SWR 69 (KKB, KKI-1 and KKP-1) – no safety reason is seen in Germany for accelerating the transfer from SFP to dry storage. In the course of the decommissioning, pools will be emptied anyway (expected to be completed in 2018 at KKI-1).

Topic 3: 1 issue partly resolved

AM measures in case of internal flooding of the annulus in the reactor building of German PWRs – mostly completed, but regulator is still checking in KKE.

Hungary: Topic #3 + X Issues - Overall

Topic 3:

Stabilization of molten core

Long-term over-pressurization of containment

Hydrogen generation and distribution

Containment bypass via steam generator

SAMGs for multi-unit accidents

4 issues **resolved (AT questions pending)**, 2 resolution in **medium term**

Topic X:

Reactor pressure vessel integrity **resolved (AT questions pending)**

Ageing management resolution in **short term**

Hungary: Topic #3 - Details

Topic 3: 2 issues to be resolved in the medium term

Avoid long-term over-pressurization of containment in case of severe accident – spray system with active cooling to be installed by end of 2018.

SAMGs to manage multi-unit accidents and simultaneous accidents in reactor and spent fuel pool – development of guidelines, introducing appropriate organization and personnel capacity, training and exercises, development of simulator. Final deadline end of 2017.

Slovakia: Topic #3 – Overall

Topic 3:

Stabilization of molten core

Hydrogen management in containment and for SFP

Alternative coolant systems for PC, containment, SFP

Long-term over-pressurization of containment

SAMGs for multi-unit accidents

Improve containment integrity in case of severe accident

Extension of post-accident monitoring

1 issue **resolved**, 4 **resolved (AT questions pending)**, 1 **partly resolved**, 1 resolved in **short/medium** and 1 in **short term**

Slovakia: Topic #3 – Details

Topic 3: 1 issue to be resolved in the short/medium term

SAMGs to manage multi-unit accidents and simultaneous accidents in reactor and spent fuel pool – analyses of severe accidents in all units completed, plan for implementation of measures delayed (was to be completed by end of 2014, not completed by mid-2015).

Topic 3: 1 issue partly resolved

Measures to support containment integrity in case of a severe accident – additional line for depressurization of PC and vacuum-breakers already installed; verification of leak tightness of containment penetrations still to be examined.

Slovenia: Topic #3 - Overall

Topic 3:

Filtered containment venting

Hydrogen management in containment, and presence of hydrogen in unexpected places

Access to NPP site by emergency staff

Implementation of emergency control room

Full scope PSA level 2

1 issue **resolved**, 3 **resolved (AT questions pending)**, 1 to be resolved in **medium term**

Slovenia: Topic #3 – Details

Topic 3: 1 issue to be resolved in the medium term

Implementation of emergency control room – at present, the only backup for the main control room are three shutdown panels. Complexity of project and complicated procurement led to delays: In 2013, implementation was planned for end of 2016; now, it is planned for end of 2018.

Comparison of issues: Topic #3 Hydrogen Issues

The following Issues are dealing with hydrogen management:

CH 3.1 Containment hydrogen management

CZ 3.3 Hydrogen management by passive autocatalytic recombiners

HU 3.3 Study of hydrogen generation and distribution in the reactor hall

SK 3.2 Containment hydrogen management by passive autocatalytic recombiners
SK 3.6 Severe accidents in the SFP – hydrogen generation and MCR accessibility

SLO 3.2 Hydrogen management by passive autocatalytic recombiners, and presence of hydrogen in unexpected places

To complete the comparison, information for Germany was also evaluated (from National Stress test Report and post-Fukushima National Action Plan).

Important aspects: H_2 management inside containment
Management of H_2 from SFP, if outside containment
Migration of H_2 to unexpected places

Comparison of issues: Topic #3 Hydrogen Issues

Hydrogen management inside the containment, for severe accidents:

DE and HU: Planned and (mostly) installed pre-Fukushima

Other countries: Only for DBAs pre-Fukushima, for severe accidents installed post-Fukushima

Management of hydrogen from SFP, if outside the containment:

DE: Installed pre-Fukushima (only 1 NPP concerned)

HU: Analyses performed with the result that hydrogen production from SFP could be high and is to be avoided. Additional cooling pipeline installed.

SK and SLO: Analyses planned, no results provided so far.

CH and CZ: No specific activities reported. In CZ, severe accident in SFP is to be practically eliminated.

Comparison of issues: Topic #3 Hydrogen Issues

Migration of hydrogen to unexpected places:

DE: Studied pre-Fukushima, but no details available.

HU: Analyses performed for reactor hall.

CH, SK and SLO: Analyses have been planned, no results provided so far.

CZ: No specific activities reported.

→ **Regarding hydrogen management in the containment, all six countries have reached the same standard post-Fukushima.**

→ **Regarding management of hydrogen from the SFP, and migration of hydrogen to unexpected places, differences between the six countries are apparent (different stage of work, different approaches).**

Comparison of issues: Topic #3
Stabilization of Molten Core for VVER-440/213

Reactors of this type are in operation in the Czech Republic (Dukovany 1-4), in Hungary (Paks 1-4) and in Slovakia (Bohunice 3+4, Mochovce 1+2); and under construction in Slovakia (Mochovce 3+4).

The Issues CZ 3.1, HU 3.1 and SK 3.1 are dealing with stabilization of molten core (in-vessel retention) for reactors of the type VVER-440/213. All the three neighbouring countries with reactors of this type consider this topic as important and have implemented corresponding measures. For the demonstration of feasibility, they rely to a considerable extent on the same experiments.

Important aspects: Time of implementation of in-vessel retention
Demonstration of feasibility
Considerations for the case of RPV failure

Comparison of issues: Topic #3
Stabilization of Molten Core for VVER-440/213

Time of implementation of in-vessel retention:

Implementation of the measure had been completed in SK in 2010 (EBO 3+4) and 2012 (EMO 1+2), in Hungary in 2014 and in the Czech Republic in 2015.

Demonstration of feasibility:

For all three countries, the demonstration of feasibility is based mostly on work which has been performed in Hungary, in particular in the CERES test facility.

This test facility simulates the gap between RPV and biological shield, for different gap configurations.

Simulations with the code ASTEC have also been performed.

Comparison of issues: Topic #3
Stabilization of Molten Core for VVER-440/213

Considerations for the case of RPV failure:

Failure of the strategy is considered very unlikely in all three countries.

It appears that investigations of RPV failure have already been performed in HU and SK, with the result that consequences are limited if the cavity is already flooded at the time of vessel failure. In CZ, investigations are planned.

Little is known about the details of the investigations performed or planned, and about their depth.

→ **All three countries have implemented the measure, based on the same experiments and calculations.**

→ **Considerations for the case of RPV failure are mentioned by all three countries, but little is known about the details.**

Discussion

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