

Post-Fukushima Safety Margins-and Safety Upgrade Program at NPP Krško



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Topics:

- Introduction (about NPP Krško)
- Periodic Safety Review
- B.5.b response and EU Stress tests
- Post Fukushima Safety margin
- Safety Upgrade program - SUP
 - Requirements/Design Extended Conditions – DEC
 - Main components of SUP
 - Economic evaluation of SUP and consequences
- Conclusions/closing remarks



Nuclear Power Plant Krško in brief

- **Owner..... GEN-Energija- 50%**
HEP -50%
- **Operator Nuklearna elektrarna Krško**
- **NSSS supplier..... Westinghouse**
- **Reactor type..... PWR**
- **Construction permit..... 1975**
- **Commercial operation... 1983**
- **Operating license..... 60 years**
- **Number of employees.... ~600**
- **Gross plant output.....727 MW**

more:

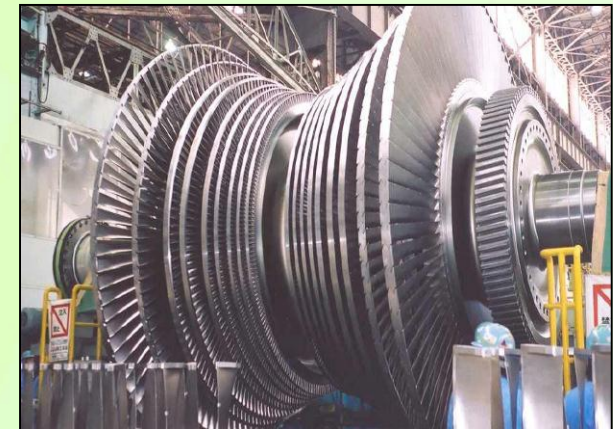
http://www.nek.si/en/about_nuclear_technology/technical_data





Power evolution

Power(MW)	Design 1983	SGR update 2000	New LP TU 2006
Reactor Thermal Power	1876	1994	1994
NSSS Thermal Power	1882	2000	2000
Gross Plant Electrical Output	664	707	727
Net Electrical Output	632	676	696



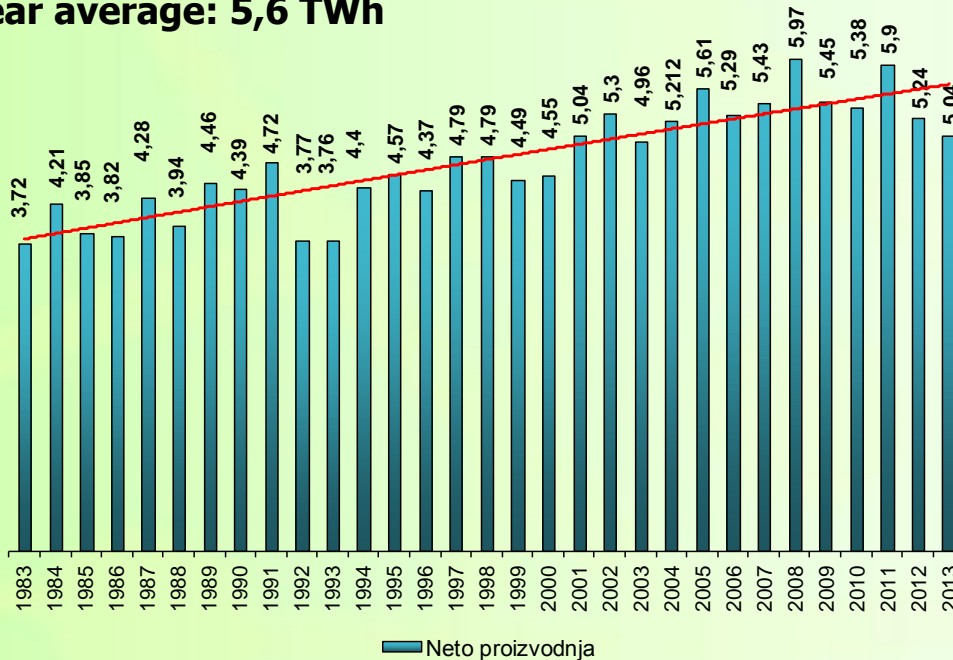
Production trend in NPP Krško



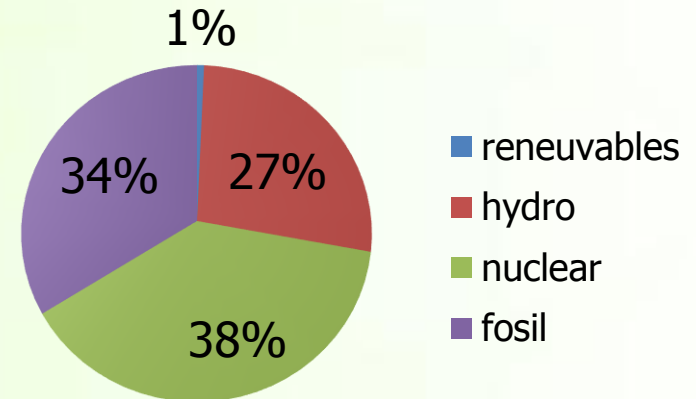
NPP Krško production 2013 5,04 TWh

Cumulative : 149,04 TWh

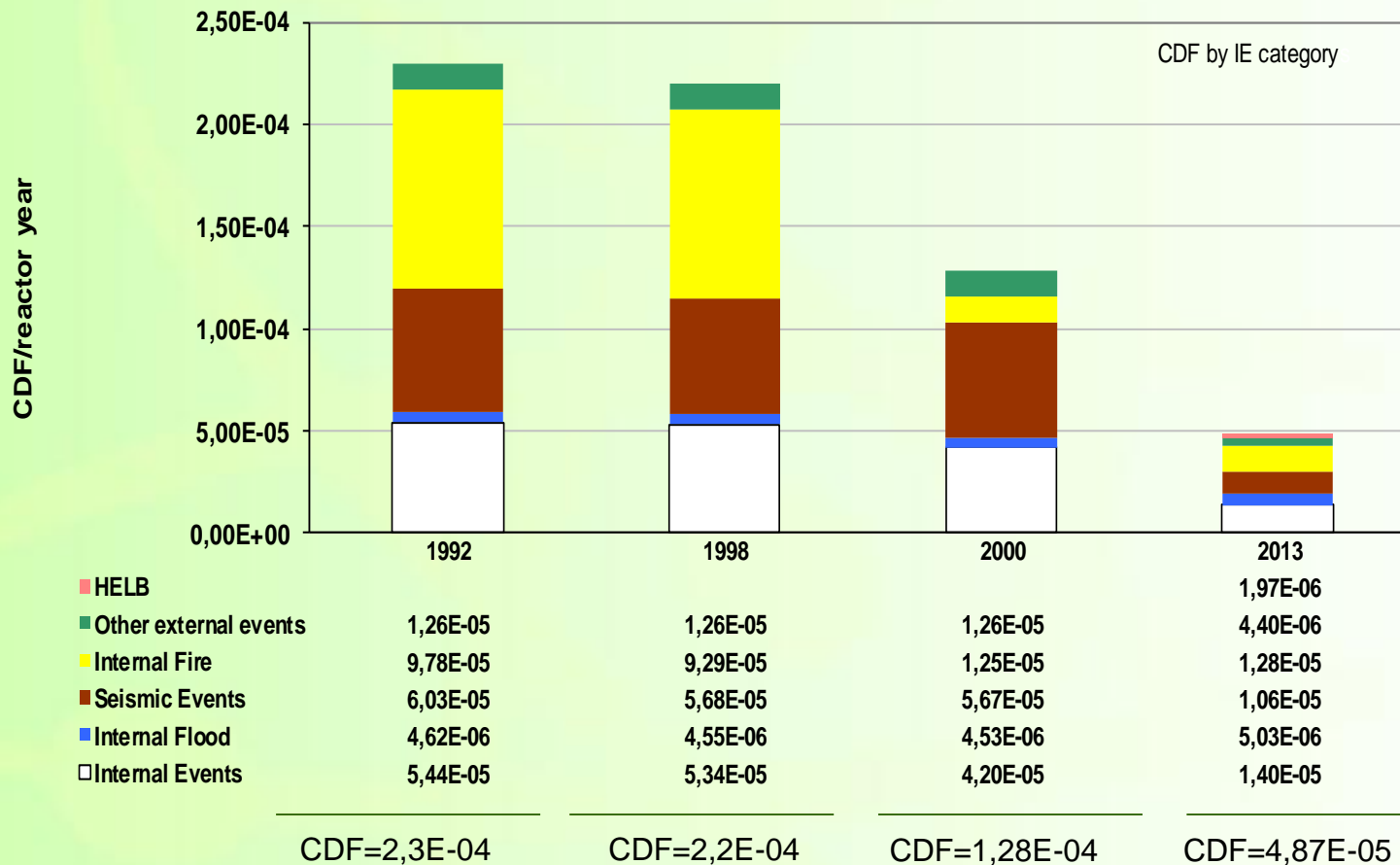
3-year average: 5,6 TWh



Production in SLO by sources



Safety evolution - Core Damage Frequency (CDF)



CDF= Core Damage Frequency

IE=Initiating Event

Periodic Safety Review – positive contribution to safety



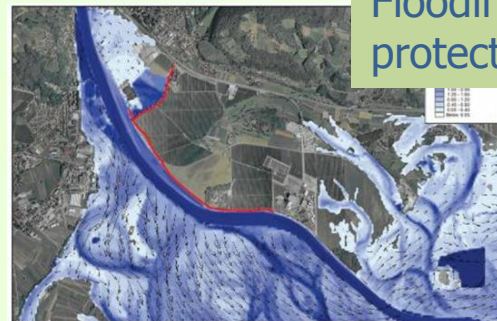
- In Slovenia, **Periodic Safety Review is practice (since 2000) and requirement** („Nuclear Law“ since 2004)).
- In 2003 PSR **two major findings caused significant plant safety upgrades** in the area of:

- **AC power supply**
- Upgrade of **external flood protection** due to PMF* increase

* Probable Maximum Flood



3rd diesel
generator



Flooding
protection





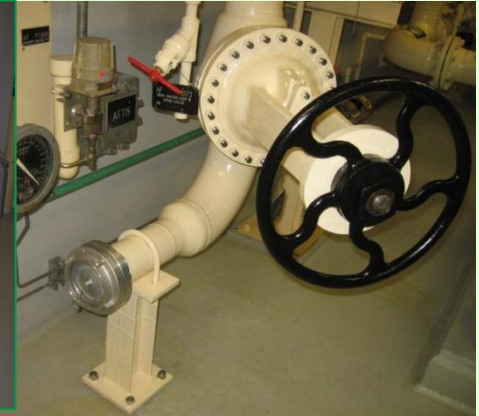
International cooperation – positive contribution to safety

- After 9/11 terrorist attack, the **SNSA (end 2008)** took note of the American B.5.b approach; a secret document at first (Agreement between the Governments of the Republic of Slovenia and the USA)
- The **SNSA issued a decision (2009)**, requiring from the plant to prepare an analysis regarding an impact of aircraft crash on the plant, **carry out preventive actions, purchase equipment and provide necessary material and human resources** for such case.
- Krško NPP prepared an action plan with a target completion date in 2012.
- After the Fukushima accident, the Krško plant decided to expedite implementation of actions **most of which were resolved up to the end of June 2011.**

Mobile equipment and quick connection points



- two different solutions for every function





Stress tests – positive contribution to safety

- Different approach was introduced – **margin to cliff edge, design parameters connected** with **return periods** of natural disasters
- Based on the work performed before (design per US codes and standards, PSR/B.5.b action plan implementation) we have been able to show:
 - that **significant margins** have been **build in the original design**
 - that with additional safety upgrade investments performed in the past the **return periods** of natural events that would **caused cliff edge** effect are in the order of **1E5 – 1E6 years**.
 - that with **additional mobile equipment** and Severe Accident Management plant **can cope with the accident for days without** external support and that potential **plant releases** can be **delayed/minimized**
- But we also recognized that **additional plant improvements** can and shall be performed **to further decrease the probability for severe accident** and in case that it happen, **minimize plant releases** and assure that the **core/fuel** can be cooled



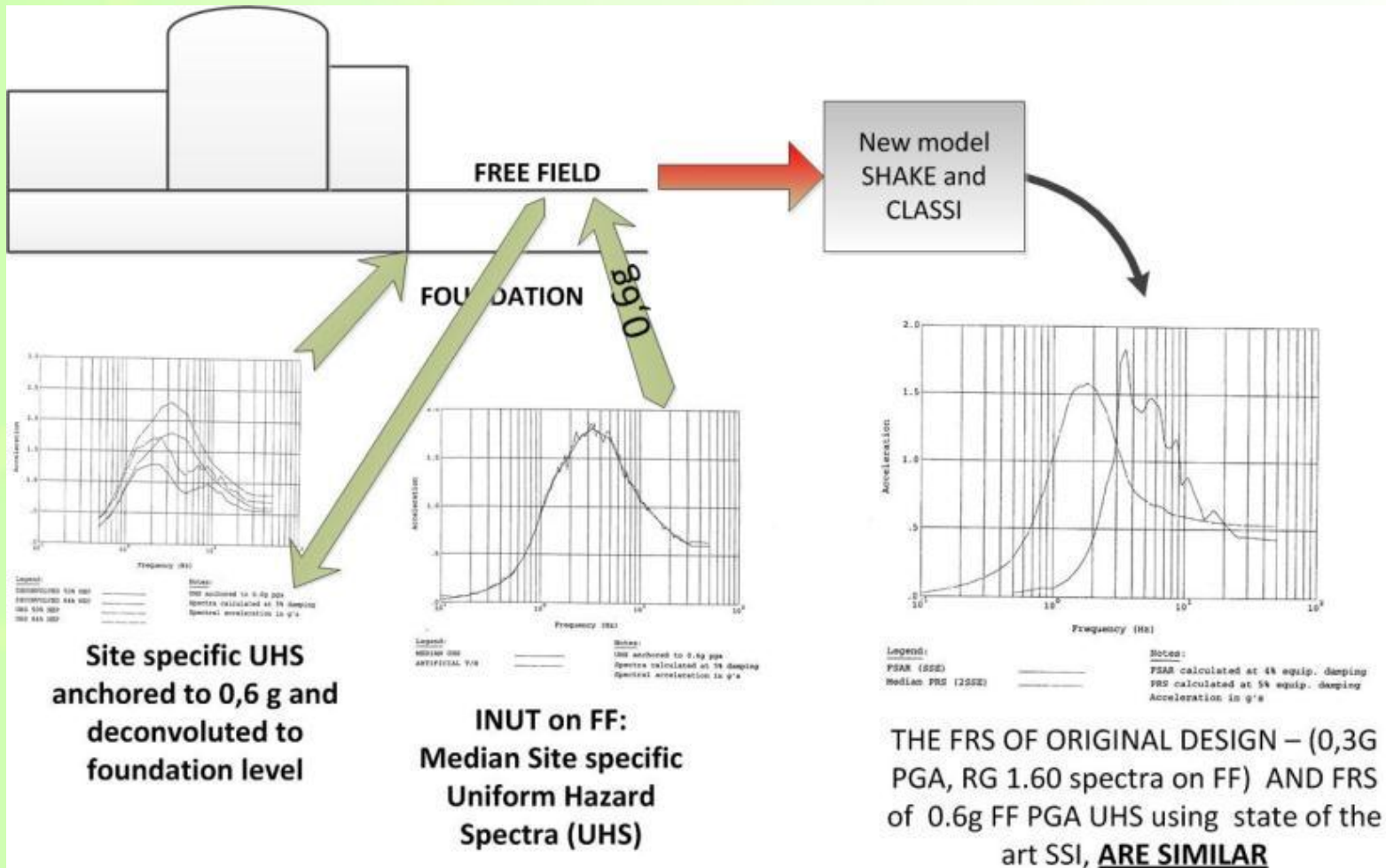
Post Fukushima Safety margin

	Before	After
Seismic	1 x SSE (0,3 g PGA)	2 x SSE (0,6 g PGA)
Flooding	157,1 m.a.s.l.	157,5 m.a.s.l.
Temperature	-28 ⁰ C/+40 ⁰ C	-33 ⁰ C/+46 ⁰ C
Controls	4 Local station	Centralized ECR
High winds	<150 m/s	tornado (<270 m/s)

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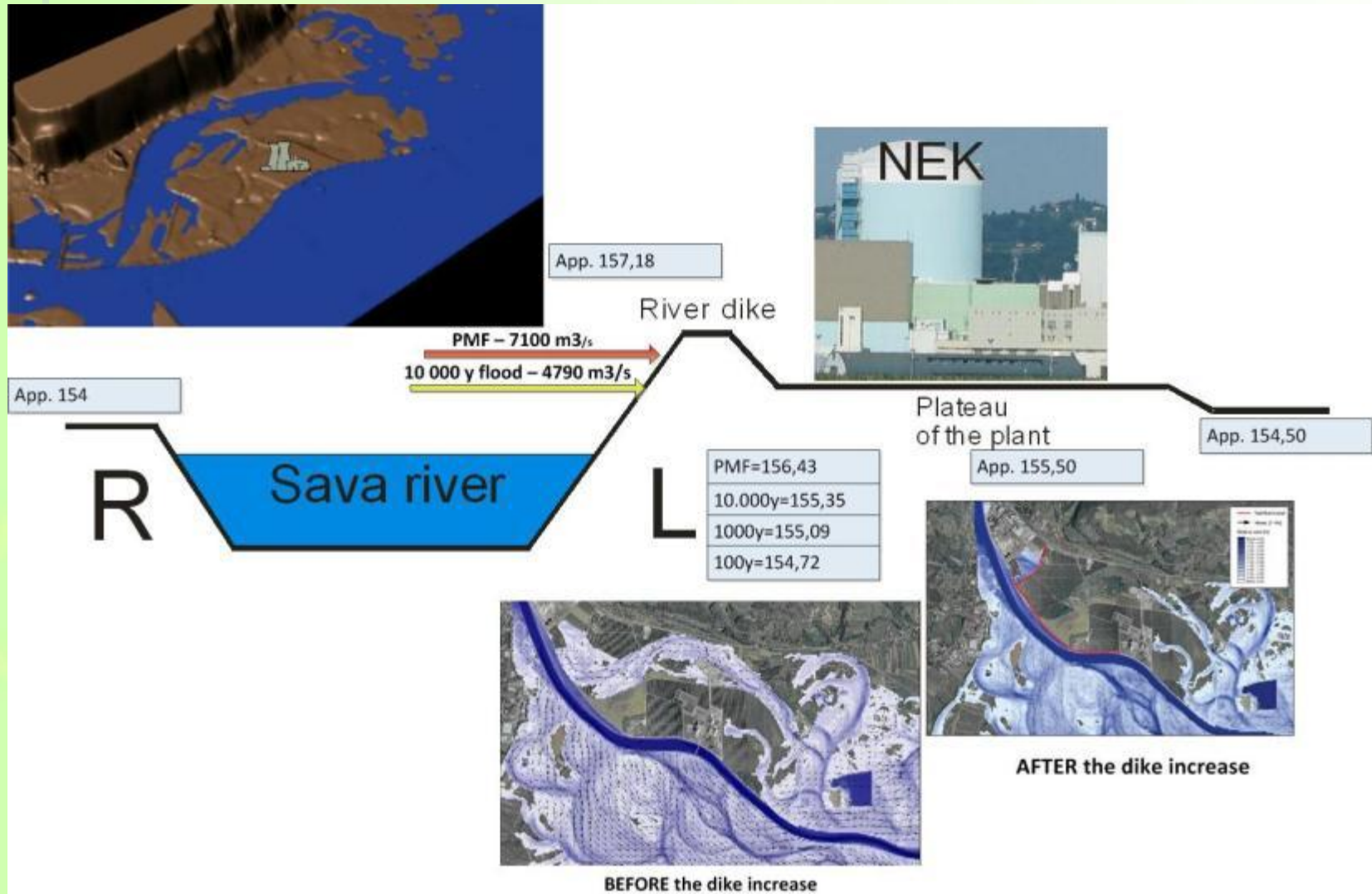
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Seismic



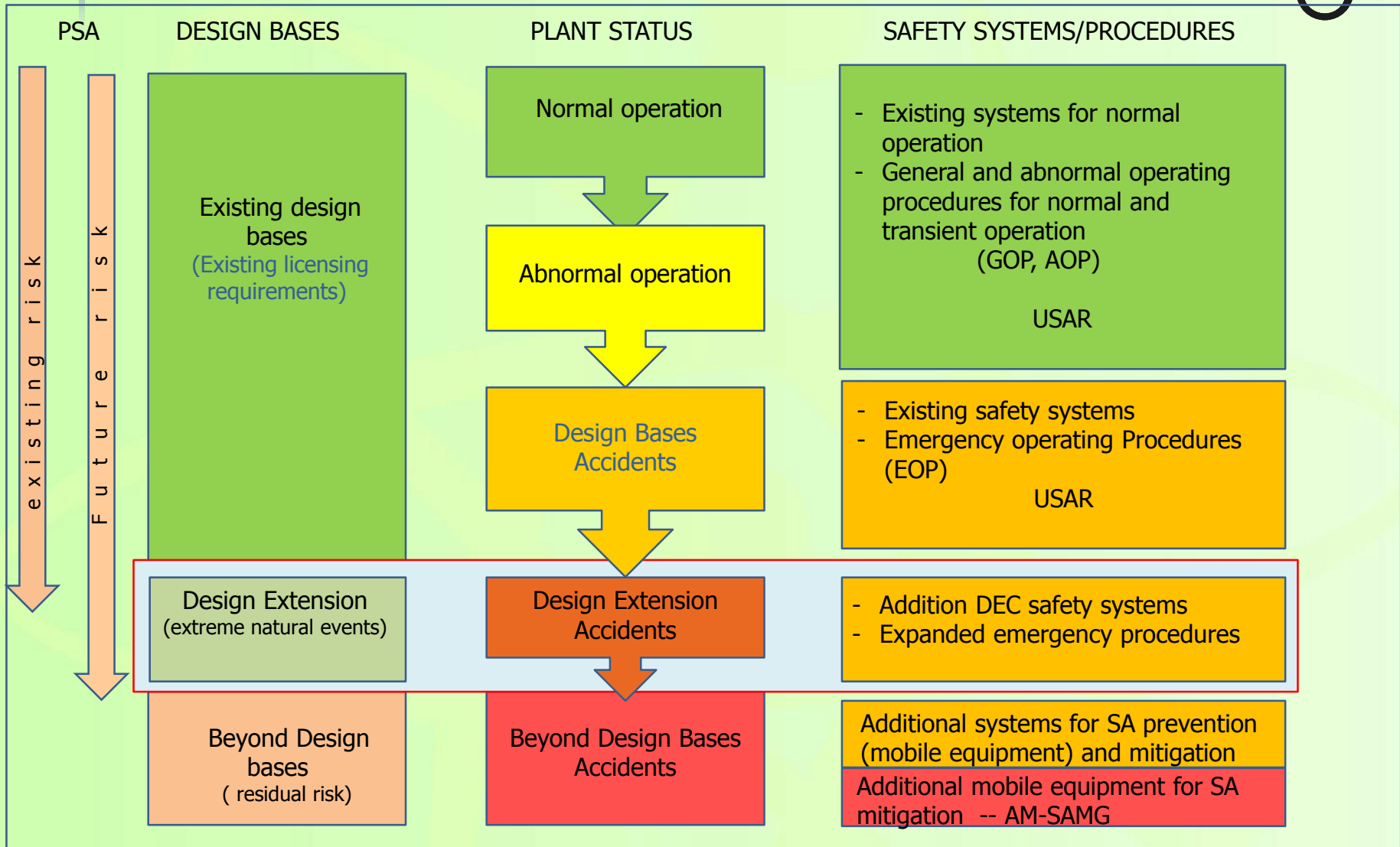
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Flooding



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Concept of Safety Upgrade Program





Design Extension Conditions - DEC

- Design Extension Conditions (DEC) is derived on the basis of **engineering judgment, deterministic assessments and probabilistic assessments** based on reference IAEA SSR-2/1 document¹, NEK IPE evaluation and NPP Krško Analyses of Potential Safety Improvements. There are some combinations of events that are more severe than design basis accidents and are considered as design extension requirements are:
 - Combination of **seismic event** (PGA up to 0,6g), consequentially caused **SBLOCA and Station Blackout (SBO)**,
 - Combination of **seismic event** (PGA up to 0,6g) and **external flooding**.
 - Combination of **seismic event** (PGA up to 0,6g), **loss of Ultimate Heat Sink (UHS) and SBO**.
 - Combination of **large commercial aircraft crash and fire**.
- **All other combinations** of events /accidents are considered as Beyond Design Bases including complete loss of SFP cooling, loss of Component Cooling etc. and will be addressed **by mobile equipment** .

1- IAEA Specific Safety Requirements, SSR-2/1, January 2012.



Design Extension Conditions – DEC - cont.

- The assumed **time duration** of the before mentioned conditions are the following:
 - Loss of off-site power (**LOOP**) for **7 days**,
 - Station blackout (**SBO**) for **72 hours, valid for DB equipment** emergency power supply with assumed DEC equipment available and DB equipment is not available,
 - Loss of ultimate heat sink (**UHS**) for **30 days**,
 - **Loss of the UHS combined with SBO 72 hours**, assuming that DEC equipment is available,
 - **flooding water will retain for 7 days.**

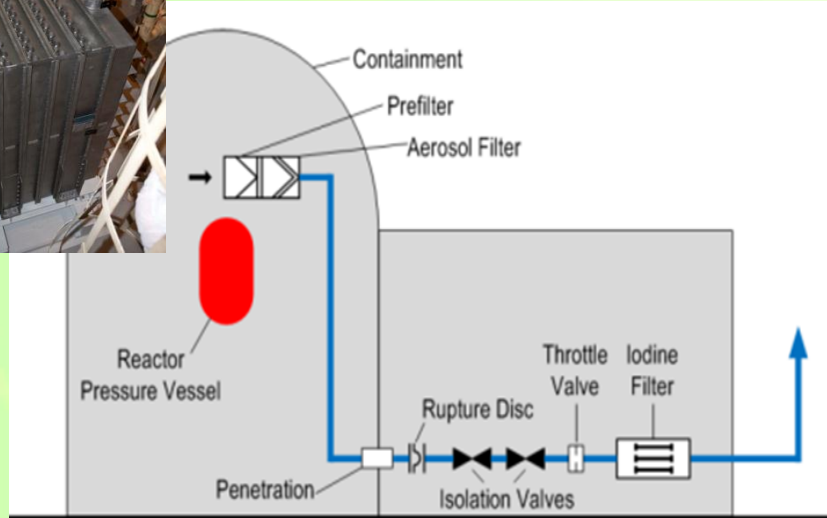


Projects of SUP

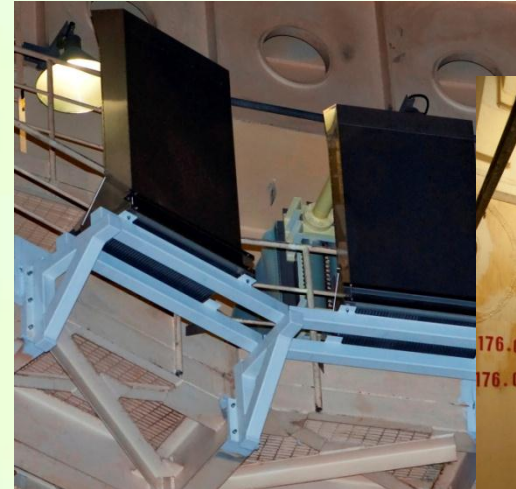
- **CFVS and PAR** - ensuring containment integrity – passive pressure & hydrogen control → **Phase 1**
 - **Upgrade of NSSS flood protection** - ensuring flood safety even in the case that plant site would be flooded
 - **Upgrade of the OPC** – upgrade of the existing operation support center to assure safety atmosphere and food for all required personnel during severe accident
 - **BB1** – Upgrade/relocation of Emergency Control Room and Technical Support Center
 - **New Independent system for RCS depressurization,**
 - **SFP alternative cooling** (installation of permanent spray and pipes to allow quick connection of mobile Hx)
 - **RCS/CNT alternative long term cooling** (additional alternative RHR pump being able to recirculate primary coolant form RCS/CNT via mobile Hx)
 - **BB2 – Bunkered additional underground pond of water, additional safety systems - injection into RCS & CNT, and SG,** → **Phase 3**
- Phase 2

Control Containment pressure (CFVS) & hydrogen (PAR)

- Installation of **Passive** containment **filtering system** (dry method with **DF over 100 000**) and PAR
- **Status:** Implemented in 2013



CFVS – Containment Filtering Vent System



PAR – Passive Autocatalytic Recombiners

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NSSS flooding protection and Operational Support Center Upgrade Status: Under implementation



Passive approach – door replacement, penetration sealing

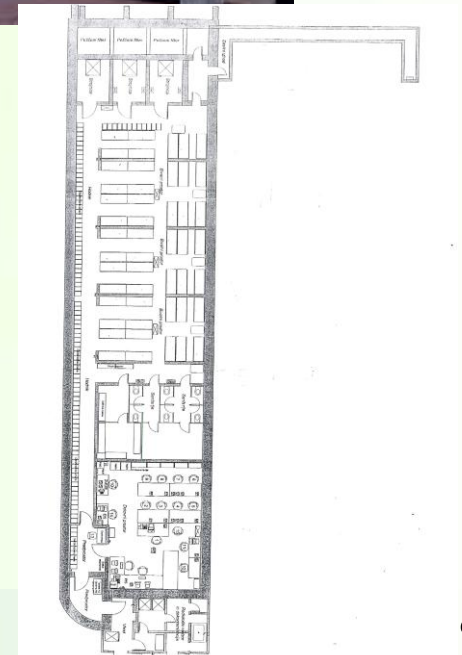


Active approach – door mobile protection sets



Expand capability of the existing underground shelter to assure:

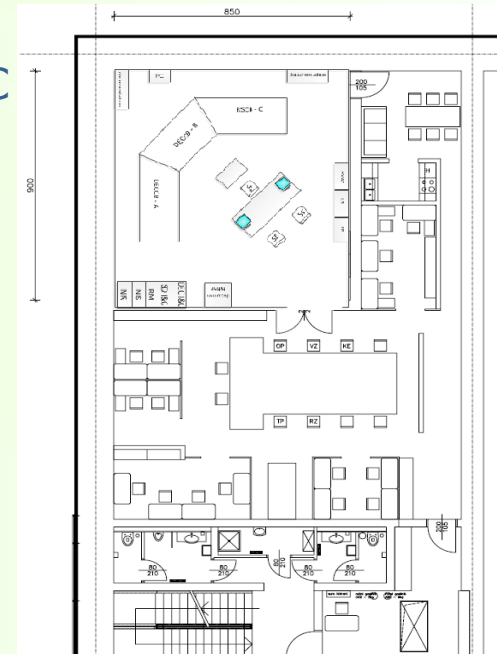
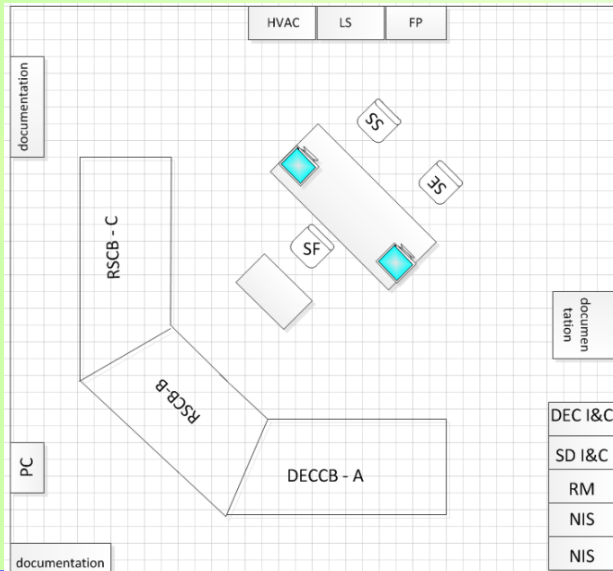
- **Increase the capacity**
- **Independent power supply** (powered by new DG)
- **Long term habitability** condition for the SAM crew located at the site (additional air filtering units,...)



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Emergency Control Room and Technical Support Center - PLANNED

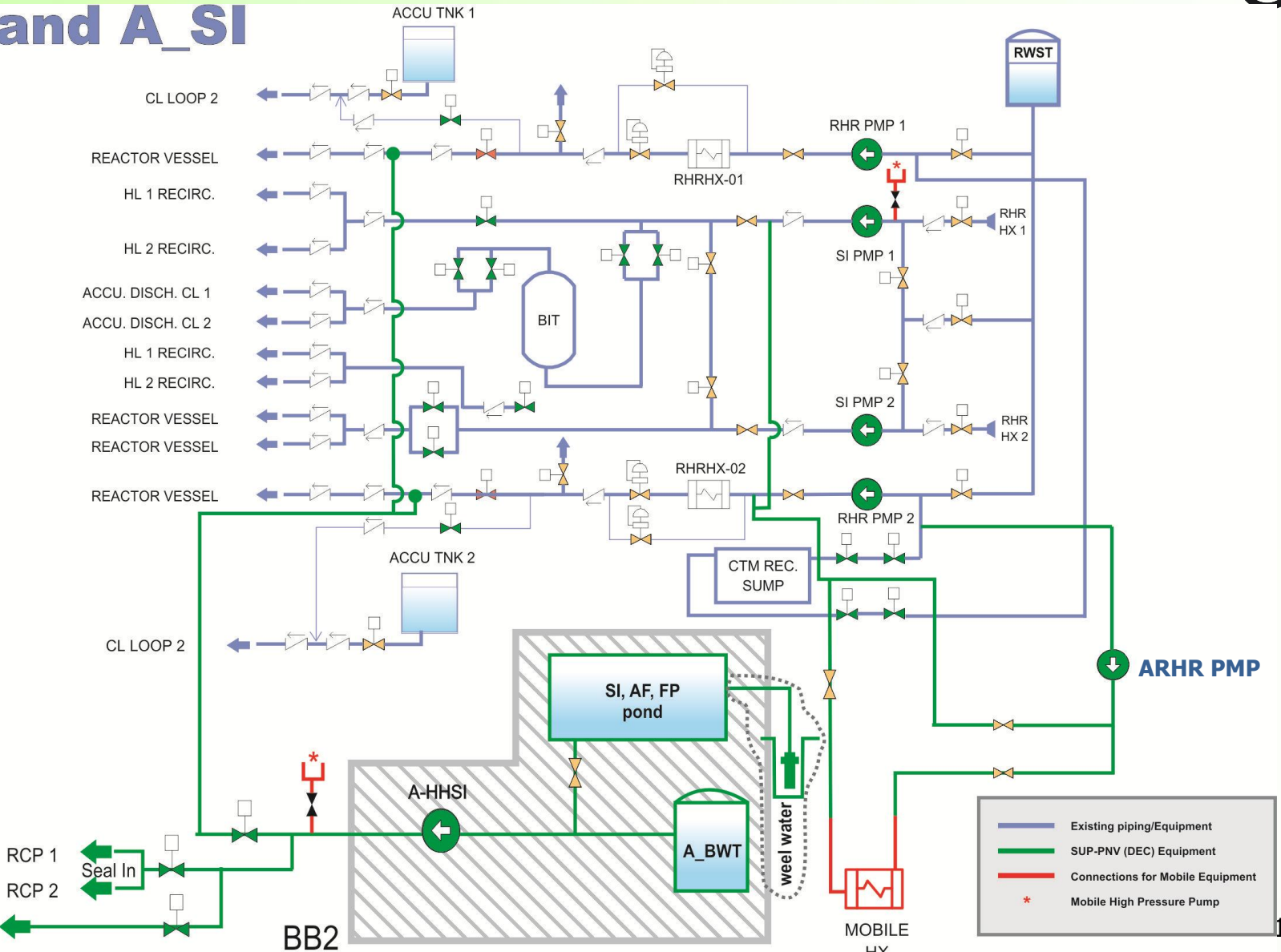
- **Relocation/integration of present shut-down panels and their functional extension** to enable the plant to cool, reach and maintain safe cold shut-down from the Alternate Shut-down Panel, also for a long-term period.
- At the same location, ensure **separate, special instrumentation for control of severe accidents and an option for control of all additionally installed equipment**. It shall be possible to control and manage all additionally installed equipment, supplied independently of existing sources.
- **Relocate** to the same **bunkered building TSC**



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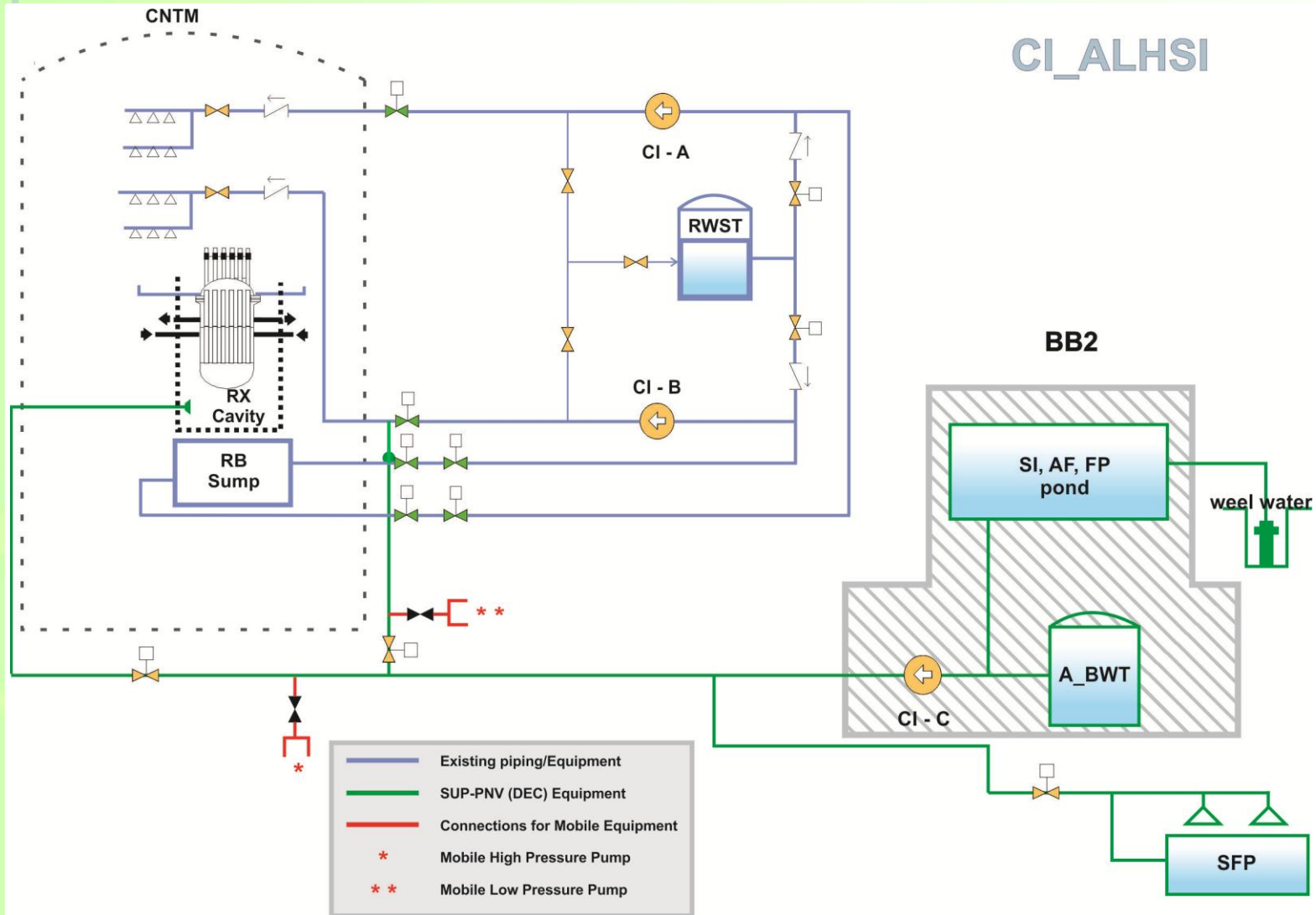
Bunkered additional underground pond of water, additional safety systems - injection into RCS & CNT, and RCS/CNT long term cooling - **PLANNED**

SI and A_SI



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Injection to CNT and SFP - PLANNED





Economic evaluation of SUP and consequences

- It was **requested and planned** to complete SUP until the **end of 2018**.
- After conceptual design approval and economic analyses/ evaluation of the costs influence on plant economics – it turned out that this additional investment package alone would cause **increase of the production price for next five years for cca 20%**.
- With the **historically low prices** of the electricity **this can jeopardize plant economics** (having in mind that we need to invest to other areas as well to assure availability/capacity, dry storage for the spent fuel).
- As a consequence **SUP implementation will need to be prolonged from 5 to 8 years - from 2018 – 2021** (remains to get for that plan **green light** from the **regulator**).



Conclusions/closing remarks

- **We all have to be aware that Safe and Reliable** operation of all operating nuclear facilities (including „my plant“) worldwide is an important precondition for the future of nuclear energy.
- **Continuous investments** in safety improvements based on new findings is required to achieve higher level of safety and to **prevent severe accident** and in the case that it happened to **prevent public exposure and long term land contamination**.
- We have to **increase safety margin** in **all areas** including **natural phenomena** and taking into account **climate changes**.
- **Further improvements** are required:
 - **international cooperation** in the area of research, operating and regulatory experience (example of bad practice B.5.b) – particular important for the countries with small nuclear program,
 - **Unifying regulatory requirements across the world but in EU in particular**.



Thank you!

Questions?