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"Results of the national and EU post-Fukushima safety analysis for NPPs - conclusions and requirements" considerations for German PWR*

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*note: on the following pages, German NPPs means PWR, the German BWR fulfill the same safety requirements, but have other technical solutions

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   - **Design against external events**
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   - **Emergency Measures**
   - **Filtered venting System**
   - **Passive Autocatalytic Recombiner (PAR)**
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Key factors, contributing to the accident or preventing mitigation

- **Wrong definition of design earthquake/design tsunami**
  - *Fukushima Tsunami had a probability occurrence of 10^{-2} to 10^{-3} /a*
- **Weak protection of Emergency Diesel Generator (EDG), Batteries, cooling water pumps**
  - *Cliff edge effect on EDG, some Batteries, cooling water pumps*
- **No PAR in reactor building**
  - *Autocatalytic recombiner reduce the H2 concentration and prevent or minimize hydrogen explosions*
- **No filtered venting system**
  - *Containment pressure release led to significant release of radioactive material*
- **Efficient organization of manual emergency measures**

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Design earthquake/flooding

Flooding

- Design flood for German NPP: occurrence frequency 10^{-4}/a. Conservatively, all upstream dam failures need to be taken into account.
- Further margin in all NPPs (typically 0,5 to 1 m), before e.g. EDG are flooded, but even the loss of these four D1-EDG do not lead to SBO, because German NPPs have a second set of four D2-EDG.
- The second set of D2-EDG is located in a bunkered hazards protected building with four physical separated safety trains. Further essentials of the layout are direct diesel driven emergency feedwater pumps and the autarky (at least 10h, best estimate with load shedding even 72h).
- Therefore even for higher flooding no cliff edge effect like Fukushima are expected.

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Design earthquake /flooding

Earthquake

- Design Earthquake for German NPP: occurrence frequency 10^{-5}/a
- Strongest earthquake, what can be expected concerning scientific analyses (this includes historic experiences, but goes further and therefore create more safety margin) up to 200 km distance has to be considered
- To ensure conservatism of the calculations, it is assumed that all earthquakes in the same seismogenic zone as the NPP site take place in the immediate vicinity of the plant. The earthquakes occurring in the neighbouring seismogenic zones are assumed to take place at the border of the zone as close to the site as possible.

Other external events

- Plants are designed to withstand e.g. Airplane Crash (fast military airplane), blast wave, lightning.
- Due to the extreme robust design specially against Earthquake and APC, the designated SSC are considered to have high safety margins for other possible external events as well.

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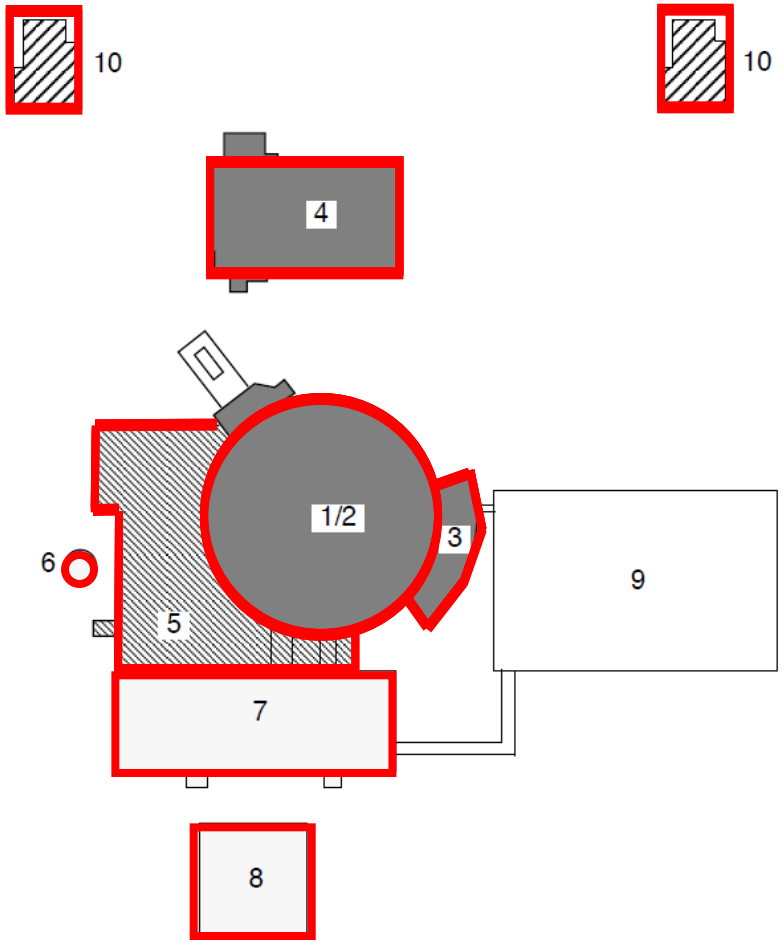
Design against external events



1/2 – reactor building/annulus
3 – Main steam and feedwater valve compartment
4 – Emergency feed building
5 – reactor auxiliary building
7 – switchgear building/control room
8 – emergency diesel generator building
9 – turbine hall
10 – secured service water intake

Against Earthquake

Earthquake and blast wave

APC (partly), blast wave, earthquake

APC, blast wave, earthquake

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Emergency Feedwater Building, Example KONVOI

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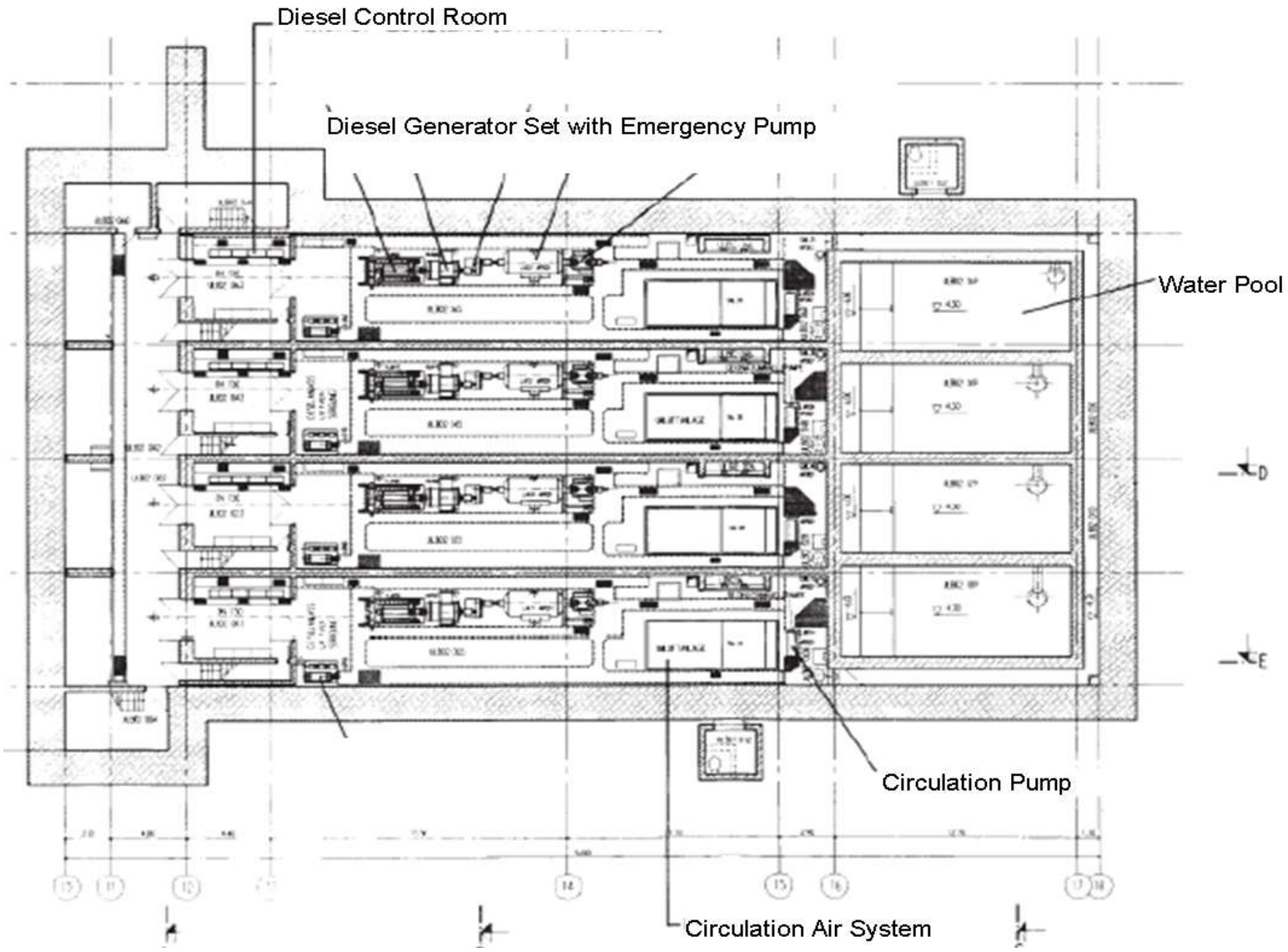
Emergency Feedwater Diesel Generator D2 system

- **Accommodated in a bunkered building with following safety functions:**
  - **Emergency feed water supply of the steam generators (divers water source for ultimate heat sink)**
  - **Back-up emergency power supply (EPS) in case of loss of the primary EPS system (called D1) as a 4x50% system**
  - **The Back-up EPS system (called D2) permits the operation of:**
    - Emergency feed water system
    - Spent fuel pool cooling system
    - Emergency residual heat removal system
    - Extra borating system
    - Necessary I&C (emergency control room) and HVAC
  - **Automatic start and autarkic operation at least 10h (real around 24h), with load shedding and other optimizing measures (external water supply) up to 72h.**
  - **Designed against following impacts:**
    - External: flood, earthquake, explosion waves, land terror attack, air plane crash
    - Internal: flooding, fires

Existing Experience in German NPP



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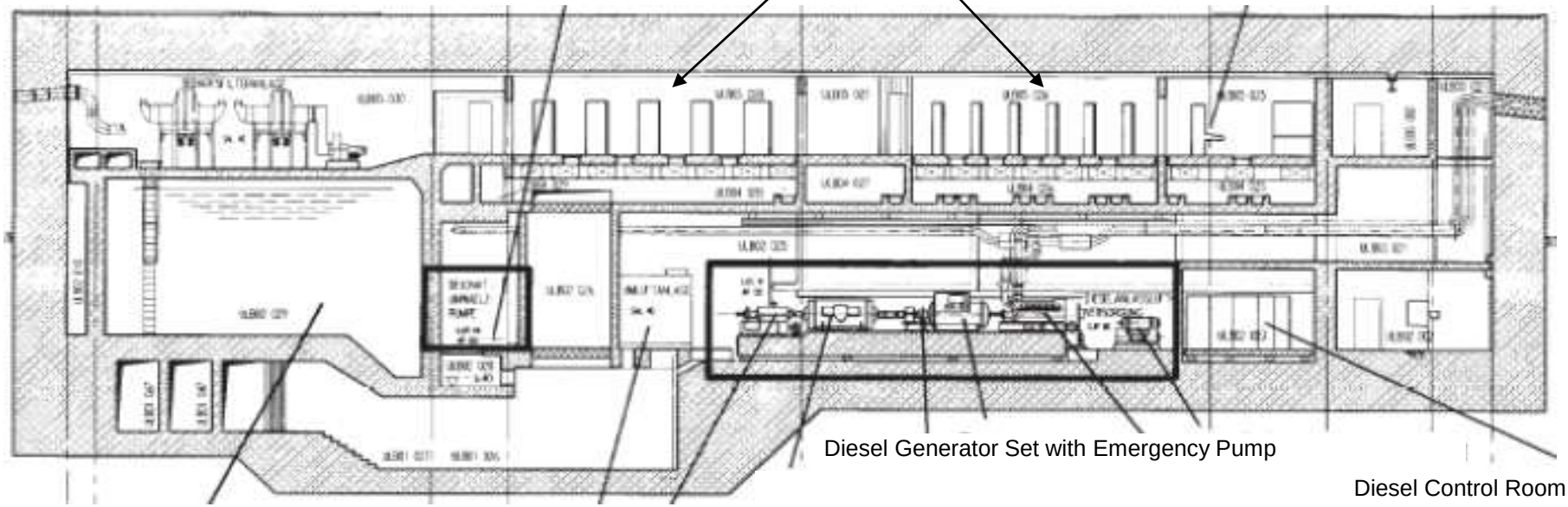

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Autocatalytic Recombiner

- Safety Objective: Avoid Damage of the barrier “Containment” by detonation of Hydrogen (mainly from zircon-water reaction)
- Therefore it is important to minimize Hydrogen concentration to avoid DDT (deflagration to detonation transition)
- Passive hydrogen control during:
  -Design Basis Accident (DBA) &
  -Beyond Design Basis Accident (BDBA)

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Autocatalytic Recombiner international testing

- Very extensive PAR qualification finalized
- Results of International PAR-Severe Accidents Qualification in frame of EC/IRSN Core Melt Program PHEBUS (2007-with real molten core).
  - AREVA PAR: Best performance
    - **very fast start-up**
    - **highest efficiency**
    - **absolutely constant hydrogen depletion rates**
  - Others : Some industrial competitors failed!
- This enveloping real severe accident tests represents
  - the new international PAR qualification standard and
  - finalized the PAR qualification successfully!

All German PWR have autocatalytic recombiner installed
AREVA has delivered more than 100 PAR Systems to plants all over the world

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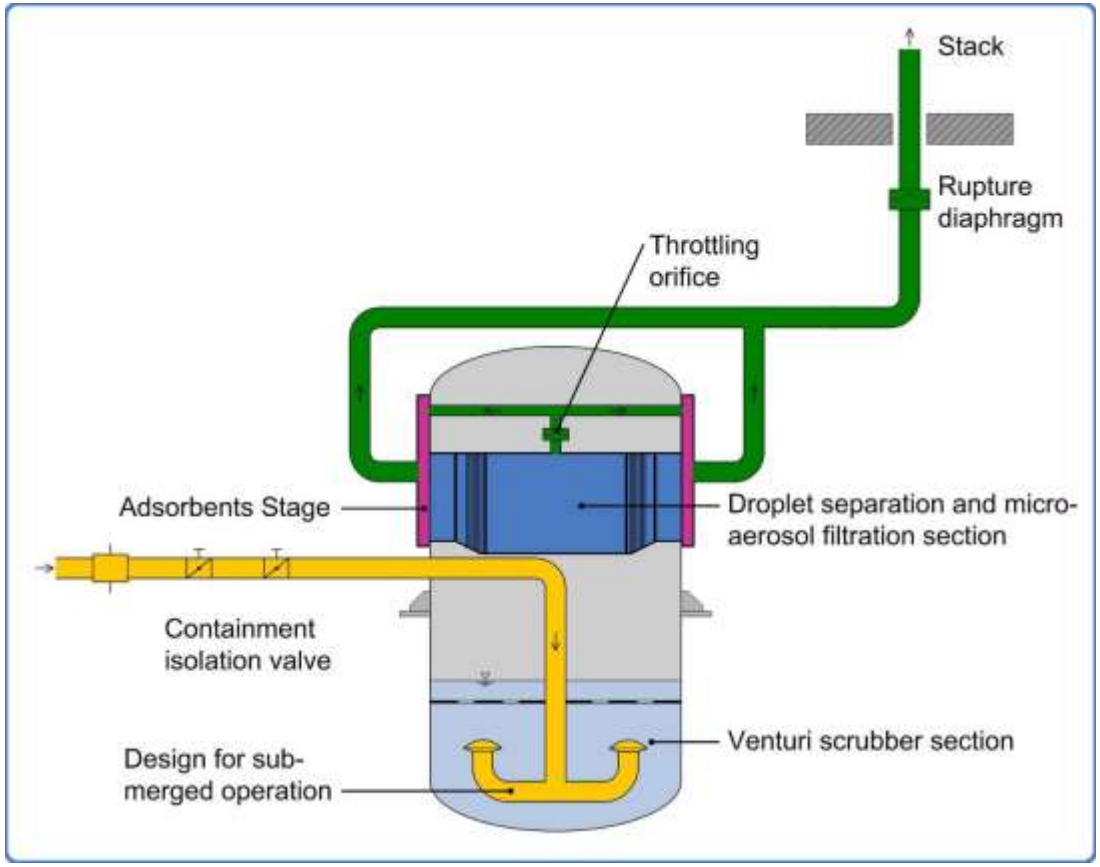
Filtered Venting System

- **Objective Filtered Venting system concerning safety are:**
  - Keep the integrity of the containment (overpressure protection)
  - Retention of activity to avoid long-term land contamination

- **Some general design examples and requirements:**
  - Max. pressure can be limited to the test pressure
  - Pressure reduction e. g. by a factor of two
  - Operation time : day's, or even > 1 week

Filtered Venting System
AREVA´s Standard Plus



1.Filtration stage: Venturi Scrubber

- Most aerosols retained
- Most elemental iodine retained (mid term)
- Large quantity of organic iodine retained (mid term)

2. Filtration stage: Metal Fibre Filter

- Large pre and fine filter surfaces
- Penetrated Fine Aerosols retained
- Re-suspension Aerosols captured

3. Sorbents Section

- Retaining of remaining and re-volatilized iodine (Elemental & Organic)

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Filtered Venting System
AREVA´s Standard Plus

Decontamination factor for Aerosols:

- **Fine Aerosols > 10.000**
- **Large Aerosols > 100.000**

Decontamination factor for Iodine

- **Aerosol Iodine > 1.000.000**

Under Verification:

- **Elemental Iodine > 1000**
- **Organic Iodine > 50 to 100**

Molecular Sieve Test facility of TÜV
Organic Iodine Retention Test

References:

During the last 10 years AREVA technology has been retrofitted to 37 reactor units (including German NPP)

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Efficient organization of emergency measures (EM)

- **According to the principle, that prevention is always better than mitigation, EM to prevent core melt have to be prioritized**
- **All German NPP have introduced preventive EM, but also some mitigative EM:**
  - Secondary Bleed with MS safety or MS release Valve
  - Secondary Feed with mobile fire fighting pump
  - Primary feed with dedicated release valves
  - Containment filtered venting
  - Passive autocatalytic recombiner
- **Further Development of consistent mitigation strategies (SAMG) is under way**
- **More details: see presentation of Dr. Steinrötter (GRS),** "*Existing Severe Accident Management Measures for German NPP and Current Activities for Improvement as Consequence of the Fukushima Accident*"**, Wednesday 4th July, Technical Session 1**

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Results of RSK- and EU-Stress tests

- **The German experts (e.g. RSK), German authorities (BMU) and the international peer reviewers (of the stress test) did not identify weak points that need fundamental design modifications of German NPP:**
  - *"The peer-review process identified that the design concept where the plants need to be resistant against an aircraft crash is a strong safety feature, because it offers additional level of protection for other external hazards including seismic events. A strong safety feature is also the availability of fully autarkic and protected (bunkered) buildings containing redundant diesel generators with fuel supply, feed water pumps with stored water supply as well as housing the emergency controls. …"**
- **Other Countries, e.g.: some authorities defined a requirement of a so called "hardened core", which includes all vital safety functions for SBO, hardened against external loads, and including:**
  - **Electricity supply**
  - **Cooling water (divers source)**
  - **I&C systems**
  - **Emergency control room and so on**

Most relevant parts of these requirements are already included in the design of the emergency feed water building for German PWR

* from: peer review country report Germany

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Ongoing activities in Germany 1/2

- **However, certain points for improvement and further consideration have been identified and are under discussion or in realization in Germany:**
  - **<u>Systematic</u> approach to evaluate robustness in beyond design events like:**
    - Flooding (e.g. localization of mobile fire fighting pump in the flood-safe emergency feed building)
    - SBO (Postulation of Failure of <u>all 8</u> EDG)
    - Loss of ultimate heat sink (RSK recommendation published)
    - Possible cliff edge effect in case of failure of preventive measures (e.g. load drop, annulus flooding)
    - APC (e.g. commercial Aircrafts)
    - Beyond design Earthquake

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Ongoing activities in Germany 1/2

- **Main requirements of the RSK concerning Loss of Ultimate Heat Sink (protocol of 446. Meeting):**
  - More and more detailed analysis of beyond design events that may cause a failure of all water intake structure (e.g. by blocking with trash, oil…)
  - Define measures to protect the water intake in that situation
  - Even if the water intake is extreme robust, postulate complete loss of ultimate heat sink:
    - Divers water source for more than 72 h (nearly 24 h already available in feed water building)
    - After 72 h external delivery of water and other materials can be take into account
- **Requirements in discussion (examples)**
  - **APC of big commercial airplanes (Analyses)**
  - **Extend battery capacity to 10 h (or additional battery charging generator)**
  - **Simplified emergency cooling chain for primary circuit and fuel pool (using divers water source and existing tube of fire fighting system)**

Summary

- RSK- and EU-tests confirmed: the design of the German NPPs is extreme robust especially against external events, which make it more difficult, to justify further improvements
- "Prevention is better than mitigation": therefore it is necessary not only to assess SAMGs for beyond design events but with first priority plants designed capacity and robustness to PREVENT severe accidents (proper implementation of the Defence-in-Depth concept)
  - *A VW Gol will not be safer than a Volvo VC90 with ABS, ESP, various Air Bags and so on, just because the Gol may have a bigger fire extinguisher*
- However, there are ongoing activities in Germany to further improve robustness also in beyond design scenarios

Concerning external hazards, the design of German NPPs is extreme robust and would have reliable prevented a Fukushima-like accident. However, further improvements of the nuclear safety to mitigate the remaining risk are under way.

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End of presentation

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