Critical Review of the

Updated National Action Plans (NAcP)

of the EU Stress Tests

on Nuclear Power Plants

Study commissioned by Greenpeace Germany

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1 Introduction

The March 2011 accident at the Fukushima Dai-ichi nuclear power plant proved that it was not justified to exclude highly unlikely accidents from happening. In a prompt reaction to this catastrophic accident, the European Council concluded in March 2011 that the safety of all EU nuclear plants should be reviewed on the basis of a comprehensive and transparent risk and safety assessment ("stress tests"). The EU Nuclear Safety Regulators Group (ENSREG) took over this task. [WENISCH 2012]

However, two month later the scope of the EU stress tests was reduced: The EU stress tests were defined as a targeted reassessment of the safety margins of nuclear power plants developed by ENSREG, with contributions from the European Commission. The EU stress tests comprise three topics:

1. The response of a nuclear power plant when facing different extreme situations (earthquakes, floods and extreme weather events, and the combination of events),
2. Capabilities to cope with consequences of loss of power (Station Black-out – SBO) and loss of heat removal via Ultimate Heat Sink (UHS),
3. Capabilities to prevent major radioactive emissions in case of a severe accident: the Severe Accident Management (SAM).

All EU Member States operating nuclear power plants – plus Lithuania – and the neighbouring countries Switzerland, Turkey and Ukraine, took part in the stress tests process.

Stress tests procedure

To understand the larger framework of the (updated) National Action Plans (NAcPs), firstly a short overview over the set-up of the EU stress tests is presented in the following:

The *first phase* of the EU stress tests started in June 2011 – the *operators* of the NPPs prepared a *self-evaluation* of their plants. Licensees had to provide a final report by 31 October, 2011.

In the *second phase,* the national regulator *reviewed* final reports submitted by the operators. All final national stress tests reports were handed over to the EU Commission by 31 December 31, 2011.

Then the *third phase* started: the peer review, which was conducted by experts nominated by the national states to review the national reports. The peer review teams reviewed the national reports in a desktop research. Each country was visited by one expert team. The peer review was completed with a main report that includes final conclusions and recommendations at European level regarding the three topical parts and 17 country reports including country-specific conclusions and recommendations. The report was endorsed and published by ENSREG on April 26, 2012.

The European Commission presented the ENSREG report in June 2012 to the European Council. The EU Commission did not see the Council mandate for stress tests fulfilled and demanded further testing; six additional so-called fact-finding visits were undertaken, those follow-up reports were published in late October 2012.

To implement the stress tests findings, an *ENSREG action plan* (published 1 August 2012) has been developed to track implementation of the recommendations. In line with this document, each national regulator had generated a National Action Plan *(NAcP)*. In October 2012 ENSREG published a compilation of recommendations to assist the preparation as well as the review of national action plans (NAcP) [ENSREG 2012].

By the end of 2012, the national regulators had provided National Action Plans (NAcPs) to remedy the identified shortcomings during the EU stress tests process.[1]

1 In addition to the EU stress tests, the participating countries took into consideration the 2nd Extraordinary

The contents and status of implementation of the NAcPs were presented and peer reviewed via a common discussion in the ENSREG National Action Plans workshop held in Brussels on 22-26 April 2013. Participants were ENSREG member states and also other European countries that participated in the peer review of the EU stress tests.

The presentations also took into account questions or comments already raised before the workshop. The presentations and discussions of NAcPs were followed by rapporteurs[2], who collated the outputs and drafted country specific reports. But, only a very short version of the reports has been published.

The workshop concluded that a follow-up peer review with appropriate mandate and Terms of Reference (ToR) would be valuable by providing an opportunity for exchange of information among participants. It would also contribute to transparency, in particular if conducted regarding the implementation of identified modifications to the European NPPs.

By 31 December 2014, each country was obliged to update its original NAcP to reflect developments since its issue and the current status of the measures and their implementation. The updated NAcPs have been published on the ENSREG website. Stakeholders had the opportunity to put questions regarding the Peer Review of National Action Plans from 8 January to 28 February 2015 via the ENSREG website.

The 2nd ENSREG Post-Fukushima National Action Plans Workshop took place on 20-24 April 2015.

ENSREG´s Terms of Reference

According to ENSREG´s Terms of Reference (ToR) the detailed structure of the NAcPs varied between countries and therefore it is not appropriate to propose a new detailed format, but to only identify the principles for the revisions [ENSREG 2014]. It is expected by ENSREG that the revised 2014 NAcPs will be an update of the existing reports, rather than a new document. The updated NAcPs will incorporate the following issues as either changes to the existing text or additional section(s) as appropriate:

- Response/clarification on any issues identified in the Rapporteur's Report from the 2013 workshop.
- Progress on implementation and update of the NAcP.
- Main changes in the NAcP since the 2013 workshop with justification, (including additional measures, measures removed or modified and changes in the schedule)
- Technical basis leading to the main changes identified in the NAcPs.
- Relevant outcomes of studies and analyses identified in the NAcPs, and completed since the 2013 workshop.
- Nationally identified good practices and challenges during implementation so far.

Scope of the stress tests

It is important to understand that the EU stress tests could not take into account all key safety issues

Meeting of the Contracting Parties to the Convention of Nuclear Safety, which was held in August 2012 and discussed the lessons learned from the Fukushima Dai-ichi NPP accident in six topical areas. These issues are not considered in this report.

2 The rapporteurs were provided from both the nuclear and nonnuclear countries participating in the workshop. No rapporteur was assigned to monitor his/her own country; 2 rapporteurs jointly covered 3 NAcPs.

such as the capability to prevent accidents – the scope of these tests was not designed to deliver a comprehensive risk assessment. Too many factors were not taken into account – most importantly ageing, obsolescence of the design, safety culture and vulnerability against terror attacks. Thus it is important to underline that the EU stress tests cannot be understood as a comprehensive safety check of the NPP in Europe. [WENISCH 2012]

Nevertheless the stress tests revealed a number of shortcomings regarding the plants´ capability to withstand several external hazards and the lack of possibilities to cope with the consequences. However, the outcomes of the stress tests consist only of recommendations for "further improvements". Thus, the public and independent experts were pointing out that the stress tests were mainly set up to improve the confidence in the safety of European NPPs.

The Report: Critical Review of updated NAcPs on the EU stress tests reports

This report presents a critical review of 10 of the updated NAcPs. It is the update of the study "Critical Review of the National Action Plans (NAcP)", which was performed by Oda Becker and Patricia Lorenz in April 2013 and commissioned by Greenpeace [BECKER 2013]. Both studies evaluated the result of the stress test exercise and filters out the real action under all the safety talk and kilometres of reports produced since May 2011. It was not the aim to make a systematic review of all points which need to be addressed; the report rather investigated whether the actions/activities set out in the individual country NAcP are the foundation to remedy the main weaknesses the stress tests revealed. To show a more complete picture of the safety respectively risk of the NPPs, some important safety issues not included in the stress tests are explained. These evaluations did not claim to be exhaustive, but the findings contribute to a more comprehensive understanding of the risk of nuclear power plants in Europe.

This 2015 report at hand evaluates and presents in a concise manner whether an accident comparable to the Fukushima accident could happen in Europe even after the stress tests. By assessing 13 different nuclear power plants in 10 different countries we want to answer the question of lessons learnt from Fukushima. This report looked for each plant into the recommendations made by the ENSREG team and how they have been implemented until now, whether they will be realized or delayed or simply ignored. It also sheds light on the issue of safety culture and the determination of the responsible nuclear authorities to enforce it**.** At the same time "good practices" are not discussed, because the ENSREG reports described them in detail. This report presents the weaknesses and omissions as these are almost completely lacking in the ENSREG report and focuses on the hard facts of the nuclear safety level achieved after completion of the stress tests.

2 Almaraz NPP, Spain

Almaraz NPP comprises two Westinghouse three-loop pressurised water reactors (PWR). Almaraz 1, with a net capacity of 1011 MWe, started commercial operation in 1983, Almaraz 2 (1006 MWe) followed in 1984. In 2010, a ten-year extension of the operation time for both units was granted (to June 2020).

2.1 Spanish National Action Plan (NAcP)

The Spanish NAcP contains a comprehensive compilation of the actions currently on-going in Spain that are related to the post-Fukushima programs, which have been initiated both at national and international level. With the objective of incorporating all the conclusions of the Stress Test process in the Spanish plants, the Spanish Nuclear Safety Council, Consejo de Seguridad Nuclear (CSN) issued a binding complementary technical instruction (ITC-STs) for each of the licensees. [CSN 2012]

The ITC-STs sets an implementation schedule which is divided into three periods: short, medium and long-term, i.e. periods end in the years 2012, 2014 and 2016 respectively. The dates are practically the same for all the plants, with minor differences regarding plant-specific modifications. The Spanish NAcP contains 39 actions: five “generic requirements”, 25 “improvement implementations” and nine cases where “additional analysis” is needed.

The ENSREG peer review team considered the implementation schedule for the planned improvements as being appropriate, but highly demanding in terms of completing the necessary upgrades. They recommended reinforcing the CSN’s technical assessment human resources. The Council announced its plan to ask the Spanish Government for increased funding to properly manage human resources, increase the numbers of technical staff needed to tackle the new tasks derived from Fukushima and other licensing issues in 2013.

<u>The updated NAcP</u>

The updated NAcP includes an additional chapter titled relevant aspects of the revised NAcP. [CSN 2014] This chapter follows ENSREG´s Terms of Reference (ToR). Within this chapter, some information to all relevant aspects is provided. However, the informative value is very limited.

The updated NAcP responds to the following statement of Rapporteurs’ report concerning: *The timeframe to implement all the improvement measures by the end of 2016 is ambitious and commendable. Nevertheless, some measures scheduled for the long term are crucial, such as filtered venting and the installation of PARs*. [ENSREG RR-ES 2014] CSN explained that they are closely monitoring the implementation of the measures and at present only occasional, and in all cases duly justified, deviations from the end date established are expected. However, CSN does not answer the critic concerning the long lasting implementation time for important back-fitting measures.

It stated that the NAcP has been remained without any major modifications, i.e. no relevant additional measures have been included, and the measures foreseen have not been eliminated or significantly modified. [CSN 2014] However, the mentioned main changes are very important issues: Evaluating the earthquake and flooding hazards, and the implementation of the containment filter venting system are delayed. The updating of seismic hazards for example, planned for issuing in 2013, will be issued during the first half of 2015.

2.2 Efforts to Remedy the Weaknesses the Spanish Stress Tests Described

The CSN has planned to require re-analysing the <u>seismic hazard</u> at each NPP site in 2013. As suggested by the ENSREG peer review team the analysis needs to consider geological and paleoseismological data characterizing relevant active faults of the Iberian Peninsula (S1)[3]. *According to the updated NAcP, the issuing of a new ITC (foreseen in 2013) by the CSN is postponed to the first quarter of 2015. Submittal to the CSN of the new assessments by the licensees will be required for 2016.*

The necessary new seismic hazard assessment will take more than 5 years – and it will take several years to backfit the plants after the evaluation is finished. Nearly every new seismic hazard assessment at sites around the world calls for improving the protection against earthquakes.

Implementation of the necessary improvements to reach a seismic margin of 0.3 g regarding the current design basis earthquake (DBE) was envisaged by 31/12/2014 (I1).

According to the updated NAcP, the implementation is completed. It comprised containment integrity, mitigation of SBO situations, the two safe shutdown paths, severe accident management, SFP integrity, and cooling.

Because the seismic hazard assessment is pending, the sufficiency of the seismic margins is not assured. It is even not guaranteed that the plant is able to withstand an earthquake with a return frequency of 10^{-4} per year as recommended by ENSREG.

The Spanish licensees have analysed possible secondary effects of earthquakes during the stress tests (31/12/2012). Significant improvements have been identified and scheduled for implementation by 31/12/2014 (A1and A2).

According to the updated NAcP, the implementation of improvements (regarding internal flooding due to the circumferential rupturing of non-Seismic Class piping, and water containers rupturing with major fluid releases) is completed.

However, the analysis is limited. As mentioned above, the severity of possible earthquakes is not assessed yet, thus it is not possible to evaluate secondary effects adequately. It is also not mentioned that common cause failures have been evaluated.

The site is located on the left bank of the Arrocampo brook reservoir; the Valdecañas dam is situated upstream (storage capacity 1146 hm^3). The dam break analysis was re-assessed to check against the dam emergency plans and to resolve the identified inconsistencies. The analysis was completed by 31/12/2012 (A3).

According to the updated NAcP, this activity is completed – despite the fact that "certain specific cases are pending." It is mentioned that the revision and acceptance by the CSN of the analyses of dam rupture scenarios have undergone something of a delay due to the existing uncertainties having emerged during the review performed by the CSN.

Because of the existing uncertainties, it is not excluded that a dam break could threaten the NPP.

The necessary improvement of external flood protection of buildings containing safety related systems, structures and components (SSCs) was implemented in 2012 (I2).

According to the updated NAcP, this measure is completed.

However, it is not mentioned whether that external flooding includes protection against a dam break scenario.

Studies of the site accessibility in the event of extreme natural events (including possible proposals for improvement) were to be performed (31/12/12, A6).

According to the updated NAcP, the analyses have been completed and have meant the incorporation of improvements at several plants.

Because the hazard assessment is not sufficient, these measures are probably also not sufficient. Thus, the accessibility in case of an extreme natural event is not assured.

The analysis of extreme temperatures at the site, with identification of existing margins and

3 Sx stands for "suggestion", Ix for "Improvement Implementation", and **Ax** means "Additional Analysis needed" according to the updated NAcP.

possibilities for improvement were to be performed (Deadline 31/12/14, A5).
According to the updated NAcP, these analyses have been completed without significant aspects for the implementation of improvements.

Adopting a consistent approach for the return periods associated to heavy rain scenarios at the individual sites is planned as suggested by the ENSREG Peer Review team (S2). In this context, the implementation of the new WENRA Reference Levels for external events_in the Spanish regulation should be finished in 2014.
According to the updated NAcP, the implementation of the WENRA RL is pending.
The threat of natural hazard events is highlighted in the framework of the European Stress Tests. However, the necessary evaluation of the hazards is not yet done, in particular because the specific regulations are lacking. It has to be expected that all in all it will take years to implement the necessary backfitting measures.

The impact of potential combinations of natural external events conceivable at the site was to be identified by 31/12/12 (A4).
According to the updated NAcP, the analyses of potential combinations of natural external events have been completed without significant aspects for the implementation of improvements having been identified.
However, without adequate assessment of the natural hazards, this statement is not credible.

Some limited activities to prevent or to cope with SBO sequences are also completed:

- Demonstration of the capacity to fully close the containment in the event of SBO if its integrity was not established at the start of the event, is completed (31/12/13, I6).
- Furthermore, the implementation of protocols to guarantee the rapid recovery of off-site electrical feed from nearby hydroelectric stations is completed (31/12/14, I3).

New equipment (fixed or portable) to cope with prolonged station black-out (SBO)
-to replace primary circuit inventory,
-to provide electrical supply for equipment and instrumentation and
-to ensure the availability of communications and lighting systems
was to be implemented by 31/12/2014 (I4).
According to the updated NAcP, the implementation is completed.
However, it is not mentioned which kind of new equipment (fixed or mobile) has been installed. Probably only mobile equipment was implemented, because it is much cheaper, but it needs more actions by the staff.

The feasibility of the manual actions required in a situation of total loss of electric supply (including batteries) was to be demonstrated. (31/12/2012, I5)
According to the updated NAcP, this measure is "completed" despite the fact that "certain specific cases are pending".
However, as long as some cases are pending, the feasibility is not demonstrated. Furthermore, the backfitting of automatic systems could be the better choice to prevent a core melt accident.

Analyses of the suitability of the human resources currently assigned to the Emergency Response Organisation (ORE) are to be done. Implementation of improvements derived from the analyses were to be performed by 31/12/13 (I7).
According to updated NAcP, CSN assessment is on-going. CSN is performing a detailed review of the analyses submitted by the licensees in relation to their Emergency Response Organisations, in which they were required to explain the time available for each manual action, including the margin with respect to the appearance of cliff-edge situations. The ENSREG peer review team had some doubts and recommended to verify the assumptions on which these margins are based on.
Up to now it is not verified that the necessary manual actions in accident sequences to prevent a

core melt accident and the release of radioactive substances are possible.

Possible improvements to reinforce the existing capacities of depressurizing the primary system and avoid possible high pressure core damage sequences were to be analysed (30/06/2013, I16).
According to the updated NAcP, the measure is completed. But it is also mentioned that the evaluation by CSN is ongoing.
High pressure core damage sequences are very dangerous, because very large radioactive releases are possible. Thus, possible improvements to reduce the risk are to be implemented. Obviously, CSN does not agree to the assessment of the operator, probably there is a remaining risk.

Analysis of critical instrumentation required for accident management, and guarantee of its operability under SBO and severe accident conditions was to be performed by 31/12/12 (I17).
According to the updated NAcP, CSN´s evaluation is ongoing. It is mentioned that a number of difficulties have been encountered due to the scarcity of international experience.
However, this statement is not credible, because in other countries the same analyses have been conducted. Without adequate instrumentation it is nearly impossible to cope with a severe accident situation, and to prevent the release of radioactive substances.

Containment integrity during severe accident is not assured yet:

A filtered containment venting system to prevent containment overpressure is to be implemented by 31/12/2016 (I14).
According to the updated NAcP, implementation will be carried out during the 2016 and 2017 refuelling outages.
The lack of a filtered containment venting system is a dangerous weak point. Without filtered venting system, a large release of radioactive substance will threaten to occur in case of a core melt accident. Regarding the potential risks, it is not justified to operate the plant without filtered venting system.

No adequate measures to manage the large amount of hydrogen expected to accumulate in the case of a severe accident in the containment are installed yet; they are needed to prevent explosions. The installation of passive autocatalytic recombiners (PARs) should be finished by 31/12/2016. (I15).
According to the updated NAcP, the work is on-going.
The Fukushima accident highlighted the danger of a hydrogen explosion, which is today possible in case of a severe accident at Almaraz. Regarding the potential risks, it is not justified to operate the plant without PARs.

Potential hydrogen hazard in other buildings surrounding the containment should be analyzed by 31/12/2013 (A7).
According to the updated NAcP, the activity is completed. The licensees have carried out the studies requested. These analyses are currently in the phase of evaluation by the CSN.
However, it is not mentioned when this evaluation will be completed nor whether backfitting will be necessary. Thus this measure is not ready at all. It has to be supposed that there is still the possibility for hydrogen explosions in buildings surrounding the containment.

The possible consequences of containment flooding strategies for equipment (instrumentation) located inside the containment were to be analyzed by 31/12/2012 (A8).
According to the updated NAcP, the analyses have been completed and have meant the incorporation of improvements at some plants. The evaluation by CSN is ongoing
However, the measure is not completed as long as CSN´s review is not finished.

If the ultimate heat sink fails, the only possibility to cool the core is via steam generators (SGs). This measure cannot be used in shut-down operation modes. However, there are no plans to implement an alternate ultimate heat sink.

Analyses of possible improvements to be implemented in relation to severe accidents that might develop from an initial shut-down situation were to be performed by 31/12/14 (A9). *According to the updated NAcP, the analysis is on-going. It is stated that a number of difficulties have been encountered due to the scarcity of international experience*.
The reason for the delay is not credible. This kind of analysis is state of the art. This issue is of big importance, because accidents starting in shut-down situations have a considerable contribution to the core damage frequency (CDF).

A Level 2 PSA including shut-down condition should be performed by 31/12/2014 (I25).
According to the updated NAcP, the analysis is on-going.

Implementations of measures to address accidents in the spent fuel pools (SFP) were necessary. An alternative make-up and spraying of fuel stored in the pools was to be implemented by *31/12/2014 (I18)*.
According to the updated NAcP, the measure is completed.

Analysis of additional SFP instrumentation measures, taking into account also the prolonged SBO situation was to be performed by 31/12/12 *(I19*).
According to the updated NAcP, the measure is completed.
However, no further details are provided. It is not explained whether the implementation of the SFP instrumentation is also completed.

The peer review team recommended to complete the development of a full set of requirements for accident management integrated in the Spanish legal framework. The integration was scheduled for December 2013.
According to the updated NAcP, publication is now planned during the first half of 2015.
The precondition for a sufficient accident management is the establishment of a comprehensive set of requirements for accident management, which is still lacking.

Furthermore, the peer review team recommended to develop severe accident management guidelines (SAMG) for accidents initiated during shut-down conditions and speed up plans for the inclusion of SAMG addressing mitigation issues relating to spent fuel pools. The final implementation of new SAMGs at Spanish plants is planned for 2016.

Possible improvements of electrical feeds to control room habitability systems for situations of prolonged SBO were to be analysed by 31/06/12. (I20).
According to the updated NAcP, the analyses have been completed and have meant the incorporation of improvements at all the plants.
However it is not mentioned whether the required improvements have already been implemented. It is important to know that the Spanish NPPs are not equipped with an emergency control room (ECR), thus the habitability of the MCR is of utmost importance to cope with a severe accident, i.e. to prevent the release of radioactive substances.

The construction of a new on-site AEMC (Alternative Emergency Management Centre) which is protected against earthquakes, flooding and radiation should be operating by 31/12/2015.
According to the updated NAcP, the work is on-going.

2.3 Weaknesses the Spanish NAcP Ignored

- **Ageing** will become an increasingly relevant issue during the fourth decade of operation. In spite of this effect, thermal power of both units was increased, further accelerating ageing processes.

- Spain is notable for power plant uprates. Some 519 MWe of the overall increase is already in place. For instance, the Almaraz nuclear plant is being boosted by more than 5% at a cost of US$ 50 million. In January 2011 the government approved 70 MWe uprates for both reactors, with 68 MWe for unit 1 being imminent, the engineering work already having been done. [WNA 2015a]
Power uprates – the increase of the NPP electricity output – can cause unexpected failures in safety systems that could aggravate accident situations. Power uprates also accelerate the development of accidents, thereby decreasing intervention time needed to take action to minimize the accident. Furthermore, in case of a severe accident, the potential radioactive release is considerably higher.

- The **reactor building and the spent fuel pool** are relatively vulnerable against other external events like an airplane crash. In addition to the stress tests, and in a separate process, the CSN has initiated a program aimed at protecting the plants against serious external events that might be produced by mankind and seriously impacting safety. But the actions being requested by CSN focus on the "mitigation" of the consequences of these extreme situations and not on the prevention.
A **crash of a large or midsize airliner** has a high probability to cause major reactor building damage. Such a crash – being an accident or deliberate action – can result in a severe accident.
The **spent fuel pools (SFP)** are located in buildings adjoining the reactor buildings. These buildings are ordinary unprotected industrial buildings. If the walls of the spent fuel pool are damaged and the cooling water is lost, large amounts of radioactive material will be released.[4]

- In 2010, a ten-year extension of the operation time for both units were granted (to June 2020) **without using the state of the art safety requirements**. It is recommended to use the WENRA Safety Objectives for new nuclear power plants to identify possible and necessary backfitting measures. [WENRA 2010]

2.4 Conclusions

The issue of seismic risk is not taken seriously: Instead of conducting the necessary seismic analysis according to the state of the art, which probably will show that seismic hazard resilience is insufficient, has been postponed to 2016. Only after the evaluation will have been completed, necessary backfitting of the plants will start and take several years. Nearly every new seismic hazard assessment conducted around the world calls for upgrading the earthquake protection.

Because the seismic hazard assessment is pending, the sufficiency of the seismic margins is not assured. It is even not guaranteed that the plant is able to withstand an earthquake with a return frequency of 10-4 per year as recommended by ENSREG. However, Almaraz NPP is not only threatened by an earthquake directly but also by external flooding in case the nearby Valdecañas dam would break.

The threat of natural hazards is highlighted in the framework of the European Stress Tests. However the necessary evaluation of the natural hazards has not been done so far – in particular because the specific regulations on how to perform the evaluations are lacking. It has to be expected that it will take years to implement the necessary back-fitting measures.

Some important analyses concerning appropriate instrumentations and shut-down conditions are facing delays. Without adequate instrumentation it is nearly impossible to cope with a severe accident situation and to prevent the release of radioactive substances. Accidents starting in shut-down

4 These buildings, however, are lower than other buildings at the site and therefore not necessarily hit by crashing aircraft.

situations contribute considerably to the core damage frequency (CDF). Not only the delays themselves, but also the reasons given for the delays are alarming. Despite the fact that analysis and back-fitting measures concerning those two issues are considered state-of-the-art in other countries, the argumentation here claims that this lack of knowledge is true for the whole world.

Up to now, none of the two units of the Almaraz NPP has implemented effective accident management measures to assure containment integrity during a severe accident. Implementation of filtered venting systems as well as measures to prevent hydrogen explosion are to be installed by the end of 2016. This approach cannot be called "urgent implementation". The ENSREG peer review team asked the national regulators to consider urgent implementation of the recognized measures to protect containment integrity. However, obviously CNS does not intend to comply with this recommendation. Regarding the potential risks, it is not justified to operate the plant without filtered containment venting system and measures to prevent hydrogen explosions.

The precondition for a sufficient accident management is the establishment of a comprehensive set of requirements for accident management, which is still lacking.

Especially worrisome is the fact that mobile equipment is presented as the solution to compensate deficiencies of the reactors and the spent fuel pools. The EC/ENSREG highlighted as good practice the use of an additional layer of safety systems fully independent from the normal safety systems, located in areas well protected against external events, e.g. bunkered systems or hardened core of safety systems. Nevertheless the Almaraz NPP relies heavily on mobile equipment and manual action of the staff. However, up to now no proof has been delivered to show that necessary manual actions to prevent core melt accident and the release of radioactive substances are possible in accident sequences.

Completing the necessary back-fitting program will last at least until 2016. Taking into consideration the staffing problems CSN is currently facing, it is very likely to take longer.

Furthermore, the modification will not remedy all known shortcomings. Absolutely inacceptable is the fact, that the implementation of an alternate ultimate heat sink is not even planned. In addition, the design weaknesses will remain: The reactor building and the spent fuel pool building are relatively vulnerable against external events. A crash of a large or midsize airliner has a high probability to cause major reactor building damage. Such a crash – whether it isan accident or a deliberate action – can result in a severe accident. Furthermore ageing will become an increasingly relevant issue during the fourth decade of operation. Ignoring the fact that this accelerates ageing processes, thermal power of both units has been increased further.

In the current condition, the units are not safe and should not be allowed to operate.

3 Doel and Tihange NPPs, Belgium

In Belgium, the subsidiary of the GDF-SUEZ Electrabel is operating two nuclear power plants (NPPs). The Doel NPP comprises four pressurised water reactors (PWR): The twin units Doel 1/2 commissioned in 1975, Doel 3 (1982) and Doel 4 (1985). The units Doel 1/2 are Westinghouse 2-Loop reactors with a net capacity of 433 MWe each. Doel 3 and 4 are Westinghouse 3-Loop reactors with a net capacity of 1006 MWe and 1039 MWe, respectively. The site is located on the left bank of the Scheldt River 15 km northwest of Antwerp with 490,000 inhabitants and only 3 km from the border between Belgium and the Netherlands.

The Tihange NPP comprises three pressurized water reactors (PWR): Tihange 1, commissioned in 1975, Tihange 2 (1983) and Tihange 3 (1985). Tihange 1 is a Framatome 3-Loop reactor with a net capacity of 962 MWe; Tihange 2 (1008 MWe) and Tihange 3 (1054 MWe) are Westinghouse 3-Loop reactors. The site is located on the Meuse River, 25 km southwest of Liege with 200,000 inhabitants and at about 80 km southeast of Brussels; the Brussels Region is densely populated with one million inhabitants.

In July 2012, the Belgian government announced the schedule for the forced closure of the NPPs [WNA 2012a]. All the Belgian units were scheduled for shut-down between 2015 and 2025, roughly in line with their 40th anniversaries.[5] However, exactly the very old unit Tihange 1 is permitted to operate 50 years.

In December 2014, the Belgian government has said that Doel units 1 and 2 can operate for another ten years, reversing the earlier decision that the units must shut down in 2015. In February 2015, Electrabel stopped operation of Doel 1. In parallel and in accordance with the decision of the Federal Government of December 18th 2014, the Minister of Energy and Electrabel Group GDF SUEZ continues the discussions on the operation time extension of Doel 1/2. Electrabel required to define a clear legal and economic framework to consider investing locally 600 to 700 million Euro. [ELECTRABLE 2015; WNN 2015a]

3.1 Belgian National Action Plan (NAcP)

The NAcP contains about 600 site and reactor-specific actions. The number of the related European recommendations or national requirements is mentioned for each action. Until full implementation, this action plan will be updated regularly. The majority of planned actions are to be implemented by the end of 2013, only 3 of them are planned to 2017 and the deadline of a handful of actions is not fixed yet. [FANC 2012]

With the exception of the possible implementation of the filtered venting system, the last deadline of the listed actions is 31/12/2014. However, several of these actions are analyses that will probably result in necessary back-fittings. The intended target date for implementing all actions is not mentioned.

The nuclear authority, the Federal Agency for Nuclear Control (FANC), underlines that some of these actions may be amended or cancelled if their relevance for the remaining operating lifetime of the units would seem unnecessary. This was seen as especially valid in the case of the actions intended for the Doel 1 and 2 units which should stop operation in 2015. Most actions that had to be implemented at Doel 1/ 2 in the context of the stress test action plans were originally scheduled to be integrated into their Long Term Operation (LTO). Following the governmental decision to shut down these two reactors, Electrabel was granted permission to refrain from implementing these actions. However, on December 18th 2014, the Belgian government decided to no longer oppose a 10-year life extension for

5 Shut-down dates (according to the decision in 2012): Doel 1/2: 2015; Doel 3: 2022; Doel 4: 2025; Tihange 1: 2025; Tihange 2: 2023; Tihange 3: 2025

these two reactors. Since the licensee Electrabel had still not officially requested this Long Term Operation (LTO) by the end of 2014, the official reference scenario for these two reactors remains a permanent shut-down by 2015, and the Stress Test action plan has not yet been modified. However, if Electrabel decides to apply for a LTO of these two reactors, the FANC will need to reconsider its former decision in the upcoming months.

According to the Rapporteurs' Report of ENSREG, the NAcP doesn't follow the ENSREG national action plan guidance closely; however the required contents are covered in the report [ENSREG RR-BE 2014]

The updated NAcP [FANC 2014]

Despite the fact the envisaged deadline was the 31/12/2014, by the end of 2014, however, 113 out of 366 actions are still not completed. 253 out of 366 actions have been completed by Electrabel, but are at various levels of review by FANC.

The number of actions is different, but also the structure of report of the updated NAcP is totally different compared to the original NAcP. It is explained: For the purpose of readability, the report does not list the status of all actions, only the major actions are highlighted. However, the comparison of the NAcP with the updated NAcP is nearly impossible and thus the progress of the action is nearly impossible. Transparency is not guaranteed at all.

3.2 Efforts to Remedy the Weaknesses the Belgian Stress Tests Described

In April 2011, following the Fukushima accident, Electrabel commissioned a probabilistic seismic hazard analysis (PSHA) using a state-of-the-art methodology. This PSHA resulted in a considerable increase of intensity of the design basis earthquake (DBE): For the Tihange site the value of the peak ground acceleration (PGA) increased from 0.17 g to 0.23 g (increase of 35%), for the Doel site from 0.056 g to 0.081 g (45%). A more elaborate PSHA study, e.g. with due consideration of results arising from the EC-project SHARE (seismic hazard harmonization in Europe) was required.
Detailed studies for both sites will be conducted by the Royal Observation of Belgium (ROB); target date was 31/12/2014. (No. 1 and No. 429)[6].
The updated NACP does not present the results of the studies. Concerning the adequacy of the design basis earthquake (DBE) at the Doel NPP it is explained for the Doel 3&4 that the obtained results still conformed to the values used in the design basis. ***Because of their imminent shut-down, Doel 1 & 2 were not assessed for this aspect.*** *Concerning the adequacy of the design basis earthquake (DBE) for Tihange NPP the re-evaluation of the seismic hazard is currently still in progress. Electrabel plans to have the final report ready by early 2015.*

The seismic margin review[7] in the framework of the stress tests has highlighted that 28 Structure, Systems and Components (SSC) of Doel and Tihange have a low probability of resisting an earthquake exceeding the "Review Level Earthquake" (RLE). The necessary back-fitting was to be finished by 2013.
According to the updated NAcP, the back-fitting is not finished. Electrabel completed most modifications in 2013; the final modifications were completed in 2014. In 2013, the FANC has begun their review process. This review is nearly finished now, but the review brings up questions.

Concerning the necessary reinforcement of the electrical auxiliary building (BAE) at Tihange 1 a feasibility study was to be performed by 2012.

6 Number according to the updated NAcP

7 The method chosen to estimate safety margins and cliff edge effects during the stress tests looks at the probability of the systems, structures and components (SSCs) to withstand a certain Review Level Earthquake (RLE) (Tihange RLE = 0.3g, Doel: RLE = 0.17g).

According to the updated NAcP, this feasibility study showed that the actions necessary for reinforcement are technically difficult or impossible. In spite of this, some specific and feasible improvements could be considered. The improvement of the BAE has been incorporated in the action plan for the Long Term Operation (LTO) of this reactor.[8]

The reinforcement of the re-fuelling water storage tank at Doel 1&2 was to be completed by 15/12/2014.
According to the updated NAcP, when the Belgian government decided in 2013 to permanently shut down these two nuclear reactors in 2015, the FANC deemed it unreasonable to still demand the implementation of this action. At the end of 2014, debates on the permanent shut-down of Doel 1/2 were re-opened again, so it is possible that FANC will demand implementation of this action after all, as part of the LTO requirements.

Concerning the extension of the operation time of Doel 1&2 a lot of questions remain: Does FANC consider requesting all identified stress test actions as necessary to be implemented before the approval of the operation time extension? Which actions originally requested to implement in context to the stress test action plans, but cancelled because of taking into account the limited operation time, will not be required again and what is the reason for this decision?

Improvement of the seismic monitoring (instrumentation) is to be done by 31/12/2013. *The updated NAcP does not mention this issue.*

To mitigate the risk of internal flooding induced by an earthquake, only the seismic management procedures were modified: After an earthquake, a person (agent) is to be sent out as quickly as possible to check if the cooling tower is overflowing. If so, pumps will be shut down rapidly. This action is required for Doel 3 and 4, as well as for Tihange 2 and 3.

The EC staff working document underlines the importance to improve the seismic resistance of the Belgian NPPs. It also underlines the importance to improve the flood protection, particular at the Tihange NPP site.

Flooding hazard for the Tihange NPP site:

During the latest flooding reassessment new design basis flood (DBF) parameters have been derived. Corresponding water heights of the DBF would largely exceed the site platform elevation (up to 1.70 m), causing flooding of all three units and loss of safety related equipment, including all on site AC power sources and both primary and alternate ultimate heat sink.

Already at a flow rate with a return period of about 400 years, Tihange 1 would be completely surrounded by water and all buildings except the reactor building would be flooded. Significant damage to equipment would be caused by floods with return periods of 600 to 1,000 years, aggravating the consequences with increasing return periods (i.e. higher river flow rates).

A peripheral protection of the site (first level of flood protection) which shall consist of a wall including coffer dams to close the opening necessary for normal operation of the NPP is to be implemented by the end of 2014.
According to the updated NAcP, the construction began in October 2013. By the end of 2014, the peripheral protection (wall, pumping chambers, isolation of the release structures, etc.) was almost completed. According to the licensee's schedule, the peripheral protection will be ready for

8 The improvement works are being carried out within the framework of the extension of the Emergency System Building ("Système d'Ultime Repli Eténdu"), aiming at extending the plant capability to go to safe shut-down in case of common-cause-failure scenarios affecting either instrumentation and control, or electrical sources (such common-cause failures can result from a fire in the BAE building, possibly induced by an earthquake).

commissioning by September 2015.

The plan is in a delay of nearly one year. Furthermore, Electrabel planned to construct a wall not higher than the water level of the DBF. The peer review team recommended including a safety margin to adequately cover uncertainties associated with a calculated DBF. As requested by FANC, a safety margin for the wall height to adequately cover uncertainties associated with the new design basis flood was considered. However, the updated NAcP does not explain which safety margin is added. Thus, it cannot be excluded that the protection is not sufficient in the year of completion.

The NAcP required, in addition to the wall, a second level of flood protection (local volumetric protections).

According to the updated NAcP, the second level of protection is cancelled. It is explained that further analyses had shown that the implementation of the second level of flood protection would not provide an infallible protection and would decrease the reliability of the protection strategy against flooding. Electrabel and FANC have therefore decided to abandon this second level.

Regarding the existing flooding threat, it is not justified to cancel the second level of flood protection.

The last additional provision should protect the site either in case of a flood beyond-design, or when the peripheral protection would fail in protecting the site. When conventional equipment is rendered unavailable through flooding, the **non-conventional means (NCM)** equipment preinstalled during the alert phase should be used.

According to the updated NAcP, Electrabel has decided to reinforce the third level of protection, the non-conventional means, to compensate for the delay in the construction of the site's peripheral protection. All the corresponding actions to these non-conventional means were finalized by Electrabel in 2013. At the end of 2014, the FANC carried out the assessment of the modifications and officially closed the actions linked to this level of protection. This level of protection is now considered fully operational.

However, this statement is not credible as the updated NAcP also mention the implementions of measures (e.g. emergency electrical grid) belonging to the NCM postponed to 2016.

The emergency intervention strategy and the crisis management, including corresponding procedures should have been improved by 2012 (Status 2013: in progress).

According to the updated NAcP, the emergency plan now includes means of onsite transport – boats – of personnel and equipment within the units, to and from units. Boats are available since June 2012. In 2013, Electrabel finalised the implementation of the associated procedures and the organization of the training of the personnel.

In addition, the early warning system was to be improved by 31/12/2012 (Status 2013: in progress).

According to the updated NAcP, the flooding alert system is based on a direct communication with the SETHY (the regional authority in charge of the protection against flooding).

At Tihange, the internal hazards potentially induced by extreme flooding (or fire or explosions) when the automatic fire extinction system is lost during flooding was reviewed and additional measures were to be taken (target date 31/12/2013).

According to the updated NAcP, Electrabel proposed protective actions, which were judged acceptable by the FANC and were then completed.

All in all only twelve of the 38 necessary actions against flooding have been completed, the majority still being analyzed by the FANC (16), the review of three actions have been finished but additional questions have been arisen, Electrabel is currently implementing seven actions.

However, all in all the protection against flooding is not sufficient now and it will probably not be sufficient after the completion of the protection wall.

Flooding hazard for the Doel site:

The flood level of the design basic flood (DBF: high tide + storm surge) remains below the height of the embankment. But flooding of the site can occur in case of a combination of very high Scheldt river level with an embankment breach. The initiation of an embankment failure can occur for a severe storm with a return period of 1,700 years. In case of an embankment failure, several tens cm of water will flood the site and intrude into several buildings.

A (volumetric) protection of the concerned safety related buildings was installed (target dates Doel 1/2: 01/04/2013; Doel 3: 01/08/2013 and Doel 4: 15/12/2013).
According to the NAcP, as a preventive measure, sandbags were available to protect the critical entrances. In the framework of the stress tests, these sandbags were planned to be replaced by permanent volumetric protections. These barriers (coffer dams, etc.) against the flooding were installed at Doel in 2013. In 2014, the FANC finalized the assessment and officially closed these actions.

Furthermore, a reinforcement of the embankment were performed and annual inspections and maintenance of the embankment as well as more frequent height measures were arranged in 2012.
According to the updated NAcP, to prevent any possible weakening, Electrabel reinforced the embankment with concrete tiles in 2013. Electrabel also modified the internal procedures to perform embankment inspections more regularly. In 2014, the FANC finalized the assessment and officially closed these actions.

According to the updated NAcP, two actions planned against flooding are closed, three actions are under analysis by the FANC, and the review of one actions raised additional questions.
However for Doel 1 & 2, it is not explained whether evaluations and back-fitting measures have been ceased because of their imminent shut-down.

Extreme weather

The stress tests revealed that the design parameters for extreme weather conditions for the Belgian NPPs are mainly based on historic data and therefore on a return period in the order of 100 years. ENSREG recommends the derivation of design basis parameters with 10,000 years return periods

Regarding heavy rainfalls, a reassessment of the capacity of the sewer system for return periods up to 100 years was required (target date Tihange: 31/12/2013; Doel: 01/11/2012).
According to the updated NAcP, at Doel, Electrabel finalized its revaluation of the impact of heavy rains in 2014. The FANC is currently assessing these studies. At Tihange, important improvements of the sewer systems have to be realized during 2015.
However, ENSREG recommendation (derivation of design basis parameters with 10,000 years return periods) is not applied.

The robustness of safety systems of Doel 1&2 and Tihange 1 in case of a beyond design tornado was to be evaluated (deadline 31/12/2013).
According to the updated NAcP, Electrabel finalized this action in 2014. The FANC is currently making an assessment of these actions.

In summary, at the end of 2014, Electrabel faced a delay compared to the stress test planning for the finalization of the actions to protect the sites against extreme weather conditions: *At Tihange, only one of five actions is closed by FANC, one action is under review by FANC, one action led to additional questions from FANC, one action is currently being implemented by Electrabel. At Doel, only one of six measures is closed by the FANC, the review of three actions resulted in additional questions from the FANC, one action is under review by FANC, and one action is currently being implemented by Electrabel.*

Loss of power and water supplies

According to the updated NAcP, more than one hundred actions have been planned in the NacP for the

enhancement of the power and the water supply in the Belgian NPPs. Electrabel has currently finalized a little more than 50% of these actions.
It is not mentioned when all actions regarding the enhancement of the power and water supply will be completed.

In case of a total loss of power supply (station black out-SBO) and/or loss of ultimate heat sink, Electrabel plans to use new non-conventional means (NCM):

- to refill the steam generators and the spent-fuel pools,
- to ensure make-up for the primary circuit in open configuration,
- to avoid the overpressure in the reactor building,
- to restore the electrical power supply to instrumentation and control panels, and
- to make the emergency compressed air circuit operable.

However, the NAcP pointed out that the operability and practicability of all the listed non-conventional means (NCM) especially under severe accident conditions are not assured. Furthermore, the planned actions are not completed at all.

Tihange: Concerning the actions against the loss of water and power supplies, FANC closed only a few actions (ten of 65), the review of twelve action results in additional questions by FANC, twelve actions are under review by FANC, and 31 actions are ongoing by Electrabel.

Electrabel had to delay several actions related to the CSBO[9] project in order to primarily focus on the flooding project at Tihange in 2012-2013. Only some priority actions have already been executed during plant outages. By the end of 2014, most actions related to the CSBO topic in Tihange are therefore planned for 2016.

It is not understandable why FANC has not considered requiring prolonged plant outages, because of the delay of all projects at Tihange.

To strengthen the power grid of Tihange, Electrabel had to study the feasibility of a better geographical separation of the high-voltage lines (150 kV and 380 kV), in collaboration with ELIA (the Belgian high-voltage network manager). In this framework, a request was sent to ELIA in 2013 to add new high-voltage lines from the other side of the Meuse, passing over the river. This solution was not judged realistic by ELIA.
However, it is not mentioned which solution will be found to this issue and when.

Among others, an alternative power supply for non-conventional means or safety equipment was to be implemented on both sites by 31/12/2013.
According to the updated NAcP, at Tihange, the finalisation of the installation of this emergency electrical grid is postponed to 2016.

CSBO actions specific to Tihange 1 have been included in the action plan of the Long Term Operation (LTO) of this reactor and are no longer considered in the stress test action plan. These actions are ongoing and have to be finalized before the second outage of the reactor following its lifetime extension (2016). This is specifically the case for the actions that will enhance the autonomy of the EAS auxiliary feed water reservoir and will add an auxiliary feed water pump to Tihange 1.
It is not understandable why FANC does not require all actions of the LTO action plan to be finalized before the approval of life time extension.

9 Complete Station Black-Out (CSBO) consists in a loss of off-site power supply and of the first-level and second-level internal power supplies. Compared to the design basis scenario of Station Black-out, this scenario adds the loss of the second-level internal power supplies. As this scenario is a beyond design basis scenario for all Belgian units, Electrabel has proposed a set of additional measures to avoid the cliff-edge effects.

FANC has requested for Tihange 2 and 3 to carry out alignment and operating tests of the emergency deep water intakes from the Meuse River and to justify the availability of the emergency intakes.
According to the updated NAcP, the related actions have been finalized in 2013 by Electrabel and analyzed by FANC in 2014. FANC still does not consider the proposed actions fully satisfying, they were discussed at the end of 2014.
However it is not explained why FANC is not fully satisfied with the proposed actions. The current status of this project is also not mentioned.

At Doel, regarding the actions against the loss of water and power supplies, only ten of 43 are closed by the FANC, the review of four action results in additional questions by FANC, ten actions are under review by FANC, and 18 actions are ongoing by Electrabel.

At Doel 3&4, in the framework of the CSBO, the installation of nozzles on the intake and discharge of the spray pumps, and of connections to the emergency cooling and to the emergency feed water systems, was planned by the end of 2014.
According to the updated NAcP, these actions have been delayed to the end of 2015 due to delays in the equipment delivery. These actions include the purchase of mobile pumps in order to achieve alternative water make-ups. Installation of connections, which is possible only during the plant outages, is already executed, with the use of temporary taps. A new fire truck, which is multifunctional and can also play the role of a mobile pump and a fuel tanker transport of diesel fuel, was also purchased. The delivery will be finished in 2015.

Buildings that are able to withstand external hazards for the permanent storage of the mobile non-conventional means are to be built by 31/12/2013.
According to the updated NAcP, at Doel, the construction of the new storage building for non-conventional means has been completed in 2014. The commissioning of this building is pending.

Alternative make-up possibilities for safety-related water reservoirs, if necessary with additional connection points, were to be implemented at Doel by 2013.
At Doel, the study of alternative water supply for the spent fuel pools using supplementary nozzles has been achieved in 2013. The standpipes for water supply to the spent fuel pools are under construction at the end of 2014.

Procedures describing the actions to take in case of a total loss of heat sinks and in case of SBO were to be implemented by 31/12/2013.
According to the updated NAcP, many of these procedures have been finalized at Doel in 2014, except for the spent fuel pools. Tihange: As these actions are directly linked to the CSBO project, their finalization is not planned before 2016.

Severe accident management

Several actions of the NAcP are not mentioned again in the updated NAcP, thus it is not possible to see whether these actions are done, postponed or even cancelled, among others:

Additional means to assure primary water supply[10] during increased reactor coolant pressure is to be implemented at Doel 1&2 by 30/11/2014.
The updated NAcP does not mention this issue.

To ensure containment integrity during total SBO, checks need to find out whether all penetrations through the containment building can be closed in due time and whether the building isolating systems remain functional, in particular during reactor shut-down states (target date 31/12/2013).
The updated NAcP does not mention the outcome of these checks.

A study of the potential design problems with the siphon breakers in the spent fuel pools were to be

10 Backfitting with shut-off valves on the spray system lines to be able to continue injection with the spray system pumps to the shut-down coolant system circuit

performed by 31/12/2013.
The updated NAcP does not mention this issue.
However, in case of pipe rupture, an insufficient capacity of the siphon breakers may result in the rapid loss of the water covering the fuel.

Multi-unit events: It was necessary to evaluate whether the water capacity is sufficient when all units are affected by the loss of the main ultimate heat sink to ensure cooling of the core and the spent fuel. If necessary, a strategy for the optimization of water consumption were to be developed (target date Tihange: 31/12/2013; Doel: 01/07/2013).
According to the updated NAcP, Electrabel has shown that the water capacity is sufficient in this case for both sites in 2013. FANC has analyzed and confirmed this evaluation in 2014.

Furthermore, the organisation of the emergency plan and adapted logistics of multi-unit events are to be implemented by 31/12/2013.
According to the updated NAcP, Electrabel has implemented the modifications and thus strongly adapted the emergency management organization as requested by FANC. Concerning the estimation of the radiological release in case of a multiple event, the upgrade of the emergency plan model is still ongoing.

The implementation of the revised Westinghouse SAMGs was to be completed by 31/12/2014. *The updated NAcP does not mention this issue.*

None of the Belgian NPPs is equipped with a filtered venting system. ENSREG emphasizes its importance to protect containment integrity and recommended its urgent implementation. Nevertheless only a study of a filtered venting system was to be performed by 31/12/2012.
According to the updated NAcP, filtered venting systems will be installed on every NPP. The realization phase has finally begun in 2014. However, the planning does not yet include the installation of filtered venting systems at Doel 1 &2.
It is not mentioned whether FANC will request the installation of a filtered venting system at Doel 1&2 and if, in which time schedule. Regarding the risk, the installation has to be done before the extension of operation time will be approved. Furthermore the implementation process for the filtered venting systems should be accelerated at all NPPs.

The evaluation of the hydrogen risk of the spent fuel pools during a severe accident needs to be completed by 31/12/2012 (Status 2013: in progress).
According to the updated NAcP, the study performed by Electrabel shows that there is no explosion risk due to the accumulation of hydrogen in the SPF buildings. FANC is still assessing this study.
The conclusion of this issue by FANC is not mentioned. In particular, it is not mentioned whether FANC follow the recommendation by the peer review team and request the installation of PARs. The peer review team recommended in 2012, regardless of the outcome of this study, to consider the installation of passive autocatalytic hydrogen re-combiners (PARs). Because of the high risk it would be justified to request the installation of PARs which is state of the art in other European NPPs.

Measures to guarantee operability and habitability condition during SBO for main and emergency control room or a schedule for their implementation are not listed. It is claimed that these measures are part of the not included action plan for man-made events.
The updated NAcP does not mention this issue.

At Tihange, the site operation centre "COS" was planned to be moved to an underground room in the access control building by 2013.
According to the updated NAcP, this building has appeared to not be conveniently located to resist to a beyond-design flood and to not be ideally protected against earthquakes. Consequently, the COS will be moved in term to a new building to be constructed and put into service in 2017.

Treatment of potentially large volumes of contaminated water after an accident was to be developed by 31/12/2013.
The updated NAcP does not mention the results.

3.3 Weaknesses the Belgian NAcP Ignored

Doel-3 and Tihange-2 stopped operating in June and September 2012, respectively, after the discovery of **thousands of flaws in their reactor pressure vessels** (RPV). A new ultrasound measuring technique – specifically designed to detect underclad cracks – was used for the first time in June 2012 over the whole surface of the Doel 3 RPV, rather than just around the weld zones. Tihange 2 was stopped in August for a maintenance outage after examinations had found similar flaws as Doel 3 [WNN 2013a].

These flaws (Doel 3: about 8000, Tihange 2: about 2000) are thought to having originated from the casting and forging process when the vessels were manufactured. Both RPVs were produced by the same manufacturer (Rotterdam Drydock Company) in the late 1970s.

After having analyzed this issue, a nuclear material expert questions the assumption that the flaws originate from manufacture since no defects were found during the final tests after manufacturing while the flaws found 30 years later have extensions up to 24 mm wide and up to 100 mm deep and exist in remarkable density. The real nature of the flaws is still unknown and can hardly be determined since sampling cannot be performed without destruction of the RPV. The assumed hydrogen flaking process has a considerable incubation time and is continued during operation. The influence of radiation effects and low-cycle fatigue on possibly manufacture-induced defects have not been considered by Electrabel although it is known the radiation embrittlement of the base metal is underestimated by the predictive curves. The eventual influence of MOX fuelling on radiation effects in the RPV wall has not been considered [TWEER 2013].

A possible failure of the reactor pressure vessels due to sudden crack growth in case of local thermal stresses cannot be excluded. The potential for RPV failure could lead to an uncontrollable loss of reactor coolant and possible melting of fuel rods [NW 17/01/2013]

In February 2013, FANC asked Electrabel for more information on the plants before it deemed the reactors safe to restart. FANC requested pressure tests in the primary circuit of the reactors and mechanical tests of reactor material. [NW 08/11/2012].

FANC allowed the reactors to restart, based on 16 conditions, 11 to be undertaken before restart and five to be conducted after the restart. With all the pre-restart checks validated, Electrabel resumed operation at both reactors in June 2013. However, in March 2014, Electrabel announced that the testing done to assess the mechanical properties of the vessels revealed unexpected results.

Initial test results suggested that under certain emergency conditions, namely a quick change in water temperature in the event of the need to cool the reactor core, there was a possibility that the structural integrity of the vessel would not be maintained. The reactors were then shut down on March 25, 2014 in order to conduct further testing.

Before being allowed to restart the Doel-3 and Tihange-2 reactors, operator Electrabel needs to submit a safety case in which it "convincingly demonstrates" that the presence of hydrogen flakes in the walls of the reactor pressure vessels (RPVs) do not compromise structural integrity. FANC and its technical subsidiary Bel V will review the safety case using the expertise of inspection organisation AIB Vincotte, an international review board (IRB), and an external research team. The safety case needs to look at ultrasonic inspection techniques used on the RPVs, material properties and structural integrity.

Two materials scientists disclosed on February 13th 2015 that the problem with the Belgian reactor vessels could be the migration of hydrogen atoms into the steel pressure vessel. As Professor MacDonald explained, the phenomenon is the entry of hydrogen from water which is on the inside of the pressure vessel, the water is in contact with stainless steel sheet, but hydrogen can go through the stainless steel sheet.

It is still unclear if the defects formed over time or if they originated in the manufacturing process, although the latter theory is favoured by FANC. Electrabel said May 13 it was changing the timeline for the restart of both reactors to November 1 from July 1. The reactors are an important component of Belgian power supply. [GREENPEACE 2015; NUCNET 2015; NW 14/0515]

All Belgian reactors have been operating for about 30 years, **ageing of materials** being a major safety issue for the plants. This applies in particular to Tihange 1 and Doel 1/2 that were in operation for nearly 40 years. Frequency of ageing related incidents will increase. Incidents could also indirectly be caused by ageing: If degraded components are replaced, defective mounting or other errors cannot be excluded.

Regarding separation and independence of safety systems, the NAcP called this a general design criterion. This is indeed not the case for the old units Doel 1/2 and Tihange 1. These old units have several significant **design deficits,** thus the prevention of accidents is not sufficient.

The reactor buildings of the oldest units (Doel 1/2, Tihange 1) are extremely vulnerable against an **aircraft crash** (accidental or intentional) that can seriously damage the external concrete structure, with the possibility of projectiles penetrating into the containment. The highly probable failure of the cooling system would result in a severe accident of the most hazardous category: core melt with an open containment. The radioactive releases would be very high and occur particularly early.

Sabotage at Doel 4: On 5 August 2014 it was revealed that sabotage had caused a significant damage at Doel 4. Lubricant had been discharged from the high-pressure turbine through a valve which had probably been opened deliberately by a worker. [WISE 2015a]

Belgium's Parliament is debating legislation put forward by the energy minister who proposes **extending the operation time of the Doel 1 &2** for 10 more years. According to the phase-out policy agreed upon by earlier governments, the Doel 1 was shut down in February 2015, but may be restarted. Doel 2 was supposed to close on the 1 December 2015.

The Council of State, an advisory body to the government, warned the minister a decision to extend reactor lifetimes would require a new licensing procedure including an Environmental Impact Assessment (EIA) and a national and trans-boundary public consultation process, as prescribed by the European Directive 2011/92/EU and the Aarhus and Espoo conventions.

So far the advice was ignored. Even the independent Federal Agency for Nuclear Control (FANC) has published a paper stating that a full EIA would be too complicated and time-consuming given the urgency for Belgium to safeguard energy supply. This position has provoked critical responses from a number of organisations including Greenpeace Belgium and the European watchdog organisation Nuclear Transparency Watch (NTW).

Greenpeace Belgium is trying to prohibit lifetime extensions for the two reactors. In June 2013, the Belgian state was taken to court because of the lack of an adequate nuclear emergency preparedness and response plan. On 19 February 2015, the hearings took place before the tribunal in Brussels and on 1 April the final verdict was published. In a disappointing ruling the judge declared himself incompetent to bring in a verdict. He stated that a ruling would go against the constitutional rule of separation of powers. [WISE 2015b]

3.4 Conclusions

The structure of the updated NAcP is completely different compared to the original NAcP. Thus, the comparison of the NAcP with the updated NAcP is nearly impossible. Several actions of the NAcP are not mentioned again in the updated NAcP, thus it is not possible to see whether these actions have been completed, were postponed or even cancelled. Transparency is not guaranteed at all.

Back-fitting measures to reinforce the plants against earthquake will be finished in several years. However the seismic hazards assessment for the Tihange NPP is ongoing and the earthquake resilience will probably turn out as being insufficient even after all measures will have been implemented. The necessary reinforcement of the electrical auxiliary building (BAE) at Tihange 1 is cancelled for no comprehensible reason.

Because of their expected imminent shutdown, the adequacy of the earthquake protection of Doel 1 & 2 was not assessed and the necessary reinforcement of the re-fuelling water storage tank at Doel 1&2 was cancelled.

Today, in case of an extreme flooding the water level on the Tihange NPP site will reach nearly two meters, all safety systems of the three units would be flooded and out of function. The staff moving around on boats between the buildings would have to prevent severe accidents using mobile equipment.

The implementation of the necessary protection wall is in a delay of nearly one year. Even after the implementation of the flood protections, actions by the staff (close openings, use mobile equipment and so on) are necessary to cope with such an external event. Although the flood hazard will obviously increase in the next decade, sufficient safety margins are probably not used for the protection wall. The previously envisaged second level of flood protection (protection of the buildings) is cancelled. Thus, flooding will remain a dangerous hazard for the Tihange NPP.

Implementation of measures (e.g. emergency electrical grid) belonging to the non-conventional means (NCM) are postponed to 2016. Thus, the third level of flood protections, actions of the staff with mobile equipment is not ready today.

The evaluation of the hydrogen risk due to the accumulation of hydrogen in the spent fuel pool buildings during a severe accident by Electrabel found no explosion risk. The peer review team recommended in 2012, regardless of the outcome of this study, the installation of passive autocatalytic hydrogen re-combiners (PARs) to prevent possible hydrogen explosion. However, the nuclear regulator FANC is still assessing this study.

The solution to strengthen the power grid of Tihange turns out as being unrealistic, however a new solution is not presented. It has to assume that this issue will remain unsolved.

Obviously Electrabel has no intention of performing comprehensive technical back-fitting measures. Some of the planned actions are limited to paperwork. Several actions only consist of feasibility studies or modifications of procedures. Thus, the prevention of accidents depends strongly on actions performed by the staff while a severe accident is developing.

The old units Doel 1&2 show several design weaknesses regarding the prevention of severe accident. Nevertheless, FANC announced, that it will not require necessary back-fitting measures to protect the units against natural hazards and to improve the severe accidents management, because of its short operation time (2015); an utterly irresponsible approach. However, the current situation is even more irresponsible: Because of the problems with other Belgian NPPs and because of the fact that the Belgian power supply depends strongly on their NPPs, the government decided a prolongation of operation time of Doel 1&2 to 2025.

The consequences are very unclear. Because of the extension of operation time all necessary back-fitting measures have to be implemented. However to complete the appropriate assessment of natural hazards protection will take years. Thus it has to be expected that FANC will again take the remaining operation time into account and will only require a limited back-fitting program.

Specific back-fitting measures of Tihange 1 have been included in the action plan of the Long Term Operation (LTO) and are no longer considered in the stress test action plan. These actions have to be finalized after lifetime extension (2016). It is not understandable, why FANC does not require all actions of the LTO action plan being finalized before the approval of life time extension. Instead FANC should have required prolonged plant outages because of the delay of all projects at the Tihange NPP.

A major deficiency of all Belgian NPPs is the lack of a filtered venting system. Despite ENSREG having emphasized its importance, all Belgian NPP will operate for a couple of more years without such systems. Electrabel plans the installation during the NPP outages until to the end of 2017. However, the planning does not yet include the installation of filtered venting systems at Doel 1 &2. It is not mentioned whether FANC will request the installation of such a system at Doel 1&2 and if so, which deadline would be decided.

Because of the lack of filtered venting, the probability of high radioactive release in case of a severe accident is very high. It should be kept in mind that Belgium is one of the most densely populated regions in the world. Tihange NPP is situated close to the centre of Liege; Doel NPP is situated close to the centre of Antwerp. In case of a severe accident, the evacuation of all the people on time (before the radioactive release) is impossible.

A major weakness of Tihange 1 and Doel 1&2 are the vulnerability against aircraft crashes which can cause the most dangerous severe accident, a core melt accident with an open containment leading to early and large releases.

The flaws in the reactor pressure vessel at Tihange 2 and Doel 3, which can trigger or aggravate an accident combined with all other shortcomings, particular at Tihange 2, can only result in one decision, never re-starting these units again.

Considering all facts, we recommend to shut down Tihange 1 and Doel 1/2 immediately. Tihange 3 and Doel 4 need to be taken out of operation at least until all necessary measures are completed.

4 Fessenheim, Gravelines and Cattenom NPPs, France

All 58 French nuclear power plants (NPPs) are owned and operated by Electricité de France (EDF) and equipped with two, four or even six pressurised water reactors (PWR). The 34 oldest reactors belong to the 900 MW class divided in the CP0, CP1 and CP2 series; 20 plants with 1300 MW reactors consist of P4 and P´4 series. The 1450 MW reactors, or N4 series, comprise four reactors.

Fessenheim NPP belongs to the 900 MW class, model CP0 and is the oldest operating reactor in France. It started commercial operation in 1978. The NPP is situated near the German border; 30 km from the German city Freiburg.

Gravelines NPP is the biggest nuclear power plant in France and comprises six reactors. All units belong to the 900 MW class, model CP1. Units 1 – 4 started commercial operation in 1980/81, units 5 and 6 followed in 1985. The NPP is situated on the French coast of the British channel between Calais and Dunkirk.

Cattenom NPP comprises four reactors that belong to the 1300 MW class, model P4´. Commercial operation of the four units started successively in 1987, 1988, 1991 and 1992. The NPP is situated at the Mosel River and about 50 km south of the city of Luxemburg.

In July 2009, the French Nuclear Safety Authority, the Autorité de Sûreté Nucléaire (ASN) approved EdF's safety case for 40-year operation of the 900 MWe units, based on generic assessment of the 34 reactors. Each individual unit will now be subject to inspection during their 30-year outage. ASN ruled in July 2011 that Fessenheim 1 can be operated for ten more years if it complies with nuclear safety requirements.[11] In 2012, the government announced that both Fessenheim reactors would close by 2017, for political reasons and regardless of safety evaluations, effectively over-ruling the prior decision by the ASN. In September 2014 a parliamentary report was presented to the National Assembly confirming that there were no technical reasons for closing the plant, and closing it in 2016 would cost the state some €5 billion, including some €4 billion in compensation to EdF.

In February 2014, EdF gave parliament a breakdown of its €55 billion reactor life extension program, mostly to be completed by 2025. This includes spending €15 billion replacing heavy components within its fleet, €10 billion on post-Fukushima modifications and €10 billion to boost safety against external events. ASN said it would evaluate life extensions on the basis of Gen III criteria regardless of when particular reactors were built.

In March 2015, the ASN said that there were no generic elements to prevent the twenty 1300 MWe units operating safely to 40 years. However, it said these assessments do not take into account any evaluations of the fitness of the units' reactor pressure vessels for operation beyond 30 years, nor the results of tests carried out during the reactors' third ten-yearly inspections, from April 2015 to 2024. [WNA 2015b]

France’s government has pledged to reduce nuclear power from 75% of generation to 50% by 2025 and is currently navigating through parliament “energy transition” laws on the subject. The energy transition bill was approved by France’s lower house, the National Assembly, but the Senate March 3 approved an amended bill, removing the 2025 target and replacing this with the less specific language of “over time.” [NW 09/04/2015]

11 Amongst these is a requirement to strengthen the concrete basemat, a task which must be completed before 30 June 2013. The basemats are only 1.5 meters thick, which does not guarantee corium retention for 24 hours. EDF plans to thicken the basemat by 50cm, as well as to increase its surface area by allowing corium to flow from the reactor pit through a purpose-built channel into an adjacent room, the floor of which will also be thickened.

4.1 French National Action Plans (NAcP)

In France, the stress test process fitted into a dual framework: firstly a European framework with the organisation of the stress tests, and secondly in a national framework with the performance of a safety audit of the French civilian nuclear facilities in the light of the Fukushima Daiichi accident, as demanded by the Prime Minister on 23rd March 2011. [ASN 2012]

In addition to the stress tests, ASN conducted a campaign of inspections targeting topics related to the Fukushima Daiichi accident, during the summer of 2011. The results of these inspections were taken into account in the development of the NAcP.

Representatives of the French High Committee for Transparency and Information on Nuclear Security (HCTISN), the local information committees (CLI) and several safety regulatory bodies from abroad were invited to attend the technical meetings as observers and to take part in the targeted inspections carried out by ASN. Some observers provided input to the analysis of the reports submitted by EDF.

In comparison to the NAcPs of other countries, it is relatively easy to comprehend the French NAcP.

The Rapporteurs'Report underlined the ambitious nature of the implementation times for the measures to improve safety in the nuclear power plants, taking into account that the concept of the hardened safety core will lead to substantial plant modifications and extensions. The schedule of actions to be performed by the licensee covers the years 2012 to 2018. It also pointed out, that some of the tasks however, that are planned for the next Periodic Safety Review, will not be completed within this timeframe. [ENSREG RR-FR 2014]

According to the updated NacP, ASN has supplemented the prescription it issued in 2012 by a set of resolutions dated 21 January 2014 aiming to clarify certain design provisions of the "hardened safety core". These clarifications will lead to the organisation of several meetings of ASN's Advisory Committees of Experts as of 2015 in order to examine in detail the various studies carried out by EDF.

The implementation is planned in three phase [ASN 2014]:

- Phase 1 (2012-2015): implementation of temporary or mobile measures to enhance protection against the main situations of total loss of the heat sink or electrical power supplies.
- Phase 2 (2015-2020): implementation of definitive design and organisational means that are robust to extreme hazards, such as the fundamental elements of the hardened safety core designed to respond to the main situations of total loss of the heat sink or electrical power supplies beyond the baseline safety requirements in force.
- Phase 3 (as from 2019): this phase supplements phase 2, in particular to improve the level of coverage of the potential accident scenarios considered. EDF indicates that these means have also been defined with a view to continuing operation of the reactors beyond forty years.

According to the updated NacP, the discussions on the implementation of the phase 2 provisions are not yet finalised. The baseline requirements produced by EDF will be examined during meetings GP1 (Extreme natural hazards) and GP2 (Control of accidents) of the Advisory Committee of Experts for Reactors (GPR). Projected date of meeting is the mid-2015.

The discussions on the implementation of the phase 3 provisions are also not yet finalised and will form the subject of several meetings in 2015. The baseline requirements produced by EDF will be examined at the meetings GP3 (Control of severe accidents, projected date of meeting: early 2016) and GP4 (Ability to manage complex accident situations, projected date of meeting: 2017)

Furthermore, it would in principle seem necessary to have one or more meetings of the GPR, in the same way as for a periodic safety review, to assess the actions resulting from the stress tests. (GP5: assessment of the stress tests, projected date of meeting: 2018).

4.2 Efforts to Remedy the Weaknesses the French Stress Tests Described

ASN asked EDF to propose a hardened safety core ("noyau dur" (ND)) of robust material and organisational measures designed in response to the extreme situations studied in the stress tests, by 30/06/2012. The hardened safety core includes systems that are independent and diversified with respect to the existing systems in order to limit common mode risks. The systems, structures and components (SSCs) shall be protected against on-site and external hazards. (ECS-1)[12].

According to the updated NAcP, a specific meeting of the Advisory Committee of Experts for nuclear reactors (GPR) was scheduled for 13 December 2012 to decide on the objectives associated with the ND. The GPR concluded on the need to supplement the functional perimeter of the ND and to detail the design hypotheses, particularly with regard to earthquakes. On this basis ASN has issued complementary prescriptions through a set of resolutions dated 21 January 2014. On 30 June 2014, EDF submitted the list of new and existing equipment items intended to form part of the ND, the general hypotheses for the design, construction, verification, qualification and testing of these new or existing equipment items, the seismic levels for each site in response to ASN's demand of 21 January 2014. These files will be examined by the GRP in the first half of 2015.

However, the time schedule for the definition of the ND was postponed. Thus, the year of implementation of the ND will be not early as 2020. Further delays cannot be excluded.

The stress tests revealed that France has not evaluated the design basis earthquake (DBE) using state of the art methods, but relied on a deterministic approach only. ENSREG recommended to perform a probabilistic seismic hazard assessment (PSHA).

According to the updated NAcP, ASN has introduced a probabilistic component with a return period of 20,000 years into the definition of the hazard. The methodological developments must be continued so that such a study can be implemented in the framework of forthcoming periodic safety reviews. **However, this will take several years.**

ASN requested EDF to conduct a more in-depth seismic margin assessment (SMA), which was performed during the stress tests in a simplified way. The review of the equipment likely to suffer cliff-edge effects, and the initiating of the necessary corrective measures was to be done until mid-2014. (FLE-3)

According to the updated NAcP, this activity is delayed. Remaining elements will be submitted by mid of 2015. The methods of verifying the seismic margins transmitted as part of the response will be applied to verify the SSCs of the hardened safety core. They are currently being examined by ASN.

However, the seismic margin assessment and in particular the necessary backfitting is not finished at all. A schedule for completion was not set. Thus, it cannot be seen, when the resistance against earthquake will be sufficient.

A study to compare the seismic instrumentation currently used in France with that used internationally to determine the need of its replacement is to be performed by 31/12/2013 (ECS-8).

According to the updated NAcP, this measure is completed. ASN considers that the technology used enables these equipment items to fulfil their assigned safety function satisfactorily.

A study evaluating the seismic resistance to an earthquake of the fire-fighting systems (fire detection and fixed extinguishing systems) and a program of necessary modification was to be done by 30/12/2012 (ECS-12).

According to the updated NAcP, this measure is completed. The necessary modifications will be carried out during the periodic safety reviews of the reactors concerned.

However, until the backfitting has not been completed, the firefighting system would fail in case of an earthquake.

Study of the implementation of automatic shut-down in the event of an earthquake (ECS-13).

According to the updated NAcP, this measure is completed. EDF has examined the advantages and

12 Number according to the updated NAcP

drawbacks of implementing a system for automatically shutting down its reactors in the event of an earthquake, and has decided to implement such a system. The modification has been agreed by ASN (CODEP-DCN-2014-047520 of 17 October 2014).
However, the schedule of the implementation is not mentioned.

A schedule of the necessary backfitting measures of the hydrogen systems, of the equipment that could damage lines carrying hydrogen as well as of hydrogen detectors and their shut-off valves (located outside the reactor building) to withstand a design basis earthquake (DBE) were to be provided by 31/12/2012. **(Fleet-04)**
According to the updated NAcP, the work is finished at Fessenheim and will be completed at Graveline in 2017 and at Cattenom in 2018.
However, it will take a quite long time to implement the necessary backfitting to guarantee seismic resistance of hydrogen systems and lines carrying hydrogen.

Earthquake induced flooding for the Gravelines site: The retaining walls along the sides of the intake channel need to remain stable in order to guarantee the heat sink flow. ASN asks to perform additional studies to examine the behaviour of this channel beyond the SSE, for the fixed-level earthquakes used in the design sizing of the hardened safety core. (GRA-07)
According to the updated NAcP, the studies have demonstrated the stability of the intake channel to the SSE.
However, the ability of these walls to withstand an earthquake larger than the SSE is not mentioned thus the stability is probably not assured.

Earthquake induced flooding represents a hazard for *Fessenheim*: The seismic robustness of the Grand Canal d'Alsace embankments and other structures designed to protect the NPP against flooding and the possible consequences of a failure of these structures were to be analysed by 31/12/2013. (ECS-11)
According to the updated NAcP, EDF submitted the synthesis of its studies at the end of 2013. The studies necessitated additional analyses. ASN has asked its technical support organization, IRSN, to evaluate the robustness of the embankments and other protective structures against earthquakes including more specifically surveys of the in situ structures. The conclusions should be available at the end of the first quarter of 2015.
However, the threat of flooding remains.

For Fessenheim, where the heat sink lies at a higher elevation than the site platform, there is also a risk of a major leak in the event of rupture of the cooling systems and thus a water channel emptying onto the site. A study on preventing this hazard (improvement of the robustness of the shut-off valves up to a beyond-baseline level) was to be performed by 31/12/2013.
According to the updated NAcP, in the first half of 2015, as part of the examination of the hardened safety core (ND), ASN will adopt a position on the studies submitted by EDF.
However, it will take years to implement the necessary back-fitting measures.

It was not possible to compare the levels of design basis flood (DBF) defined according to the French requirements with the methodologies used in other European countries. ASN has published a new guide regarding the external flood risk which includes a probabilistic exceedance target of 10^{-4} per year (as recommended by ENSREG) in 2013.

Gravelines: Not all modifications and tasks resulting from the experience feedback approach after the flooding of the Blayais NPP in 1999 were implemented in 2011. These modifications (e.g. elevating and strengthening the wave protection, electrical back-up for the plant sewer system pumps) are to be carried out by 31/12/2014.
According to the updated NAcP, this work is done.
However, these modifications were completed not early as 15 years after the dangerous flooding event.

In addition to the requirement on the hardened safety core, ASN required EDF to present the modification it intends to make, before 31 December 2017, to reinforce the protection against the risk of flooding for the beyond-design-basis scenarios, such as maximum rainfall or flooding resulting from failure of on-site equipment under the effects of an earthquake by 31 December 2013. (ECS-6)
According to the updated NAcP, the reinforcement of the protection against flooding will be completed for Cattenom by 31/12/2015; for Fessenheim by 31/12/2016; for Gravelines by 31/12/2017.
However, this is a very long implantation in regard to the flooding risk.

The peer review team emphasised the need for a systematic design basis and safety margin assessment with respect to extreme weather conditions. Analyses were performed on the possible impact of strong wind events and the resistance of the equipment against extreme hail loading and extreme lightning. The results were integrated in the required definition of the "hardened safety core".
According to the updated NAcP, EDF has submitted the design baseline requirement for the hardened safety core against extreme external hazards other than earthquakes and flooding. This subject will be examined by the GPR in June 2015.

None of the French reactors is equipped with an alternative ultimate heat sink, but recent events highlighted the vulnerability of the ultimate heat sinks (UHS). An overall review of the design of the heat sink was to be submitted before the 30 June 2012.
According to the updated NAcP, this point has been examined by the Advisory Committee of Experts for Reactors (GPR) and ASN has adopted a position with respect to it (CODEP-DCN-2014-040468 of 23 October 2014). EDF has proposed several changes which bring an improvement in the monitoring of heat sinks and their protection against external hazards. ASN nevertheless considers that further improvements are required, particularly in the identification of hazards and their combinations, in the requirements applicable to equipment for dealing with a massive influx of clogging debris, in the operational control documents and maintenance programmes, and in the monitoring of functions important for safety in the pumping station.
(In addition, in the long term, as part of the implementation of a hardened safety core, EDF will build an alternate heat sink, based on either artesian wells or existing tanks, whose seismic behaviour will be verified for earthquakes beyond the initial design-basis of the facilities (hardened safety core level earthquake).
A situation with loss of UHS can be induced by a DBE or by flooding slightly beyond the DBF and will affect all units at a site. In those cases, the core could become uncovered in just a few hours.

EDF presented the planned modifications for installing technical backup devices for long-term heat removal from the reactor and the spent fuel pool in the event of loss of UHS (emergency water supply resources). These devices must meet the requirements on the hardened safety core.[13] (ECS-16)
According to the updated NAcP, a report of the modifications has been submitted for all the sites and is currently being examined by ASN.
However, no schedule for implementation was set. It was not mentioned, when the modifications have to be installed.

A proposal for an emergency water make-up for the injection of borated water into the reactor core when it is open during SBO situations is to be submitted by 30/06/2013. (ECS-16.II)
According to the updated NAcP, ASN has given its agreement for the installation, on all 900 MWe reactors, of a fixed mean including an electrical motor-pump connected to the containment spray system and the safety injection system. The implementation of these modifications is achieved. On other reactors, EDF justified that the existing equipment items allow the injection of borated water in

13 This backup ultimate heat sink would be achieved by installing hardened motor-driven pumps to pump water from a dedicated well, except for a few sites where this is not possible and a special reservoir would be created instead [NW 13/12/2012].

the primary circuit in these situations.

One additional electrical power supply[14] for each reactor on the site capable of supplying the systems and components of the hardened safety core during SBO situations is to be installed by 31/12/2018. In the meantime, a temporary system at each reactor for supplying the I&C (Instrumentation and Control) system and the control room lighting was installed (30/06/2013).

The battery discharge time, which is in the range of 1 hour, has been identified as the cliff edge effect for all reactors (loss of information in the control room and of the I&C). However, increasing battery autonomy is not an immediate task, only to be completed by 2014. (ECS-18-1)
According to the updated NAcP, the power autonomy of the batteries has been increased from 1 hour to 2 hours (completion of works at end of 2014), and at the end of June 2013 the licensee installed temporary ultimate backup diesel generator sets pending the installation by the end of 2018 of ultimate backup diesel generator sets capable of withstanding the design-basis conditions of the hardened safety core.

The fuel building is not designed to contain steam generated by the boiling of the water of the spent fuel pools (SFP) during events with a pressure increase. It consists of a metal cladding roof and a thin concrete wall (about 30 cm). The thermohydraulic development of a pool accident, i.e. a study of behaviour of the fuel and the water in the SFP under loss of cooling and loss of water situations (in particular the radiological ambient atmosphere, along with the hydrogen concentrations) including measures to be taken was to be performed by 31/12/2012. (ECS-24).
According to the updated NAcP, the proposed mitigation measures consist in restoring the water inventory in the pools through water makeup which forms part of the hardened safety core. These measures shall be examined at the GPR meeting planned for June 2015.
No schedule was set for the implementation of these measures.

ASN asks EDF to submit the safety demonstration for avoidance of the onset of a severe accident following deterioration of the reactor coolant pumps (RCP) seals, in a situation involving loss of off-site electrical power supplies and all on-site electrical sources on a site by 2013. (All – 23)
According to the updated NAcP, EDF has finalised the installation of high-temperature seals capable of withstanding loss of cooling for an extended period. EDF has also studied the installation of a passive device for protecting seal No.1 of the RCP in the event of loss of the electrical power supplies. This device is undergoing qualification before being installed on all the coolant pumps of the reactor fleet on the basis of a schedule that is currently being defined.

The reinforcement of measures to prevent complete and rapid siphon emptying of the spent fuel pools in the event of a break of a connected pipe was to be performed by March 2014. (ECS-22)
According to the updated NAcP, the measures have been implemented.
However, a more successful approach to prevent an accident – the automation of cooling system intake line isolation – is to be implemented by the end 2016.

Devices to measure the temperature and water level of the spent fuel pool as well as the radiation level in the fuel building during SBO are to be implemented by 31/12/2013. (ECS-20)
According to the updated NAcP, this measure is completed.

EDF has to reinforce its material and organisational measures to take account of accident situations simultaneously affecting all or some of the facilities on the site by 31 December 2012.
According to the updated NAcP, the *revised on-site emergency plan baseline is applied on all NPP sites. It takes into account the setting up of the FARN with the necessary human and material resources to intervene on a site with 4 plant units and the local emergency resources in accordance with the respective regulatory deadlines.*

The integration of the new provisions for handling the extreme situations (affecting several reactors on

14 These systems must meet the requirements concerning the hardened safety core per requirement.

the same site, and for all operating states) into the accident operations procedures and the severe accident management guidelines (SAMGs) is to be completed by 2015.
According to the updated NAcP, EDF has partially responded to the demand and will submit the remainder of the response before 31 December 2015.

A Nuclear Rapid Response Force (FARN), i.e. specialised teams capable of relieving the shift teams and deploying emergency response resources in less than 24 hours, with operations starting on the site within 12 hours following their mobilisation, was to be deployable to intervene on one reactor of a site by 31/12/2012; for intervening simultaneously on all the reactors of a given sites by 31/12/2014, only for Gravelines by 31/12/2015. (ECS-36)
According to the updated NAcP, the FARN and personnel recruitment are running in accordance with the regulatory schedule.

The mobile equipment necessary for emergency management was not managed satisfactorily in 2011; the storage conditions did not guarantee permanent availability, particularly in the event of external hazards. The adequate storage of these mobile devices was to be completed by 30/06/2013. (ECS-30)
According to the updated NAcP, this measure, implemented by EDF, is checked as part of the ASN inspections.
The results of these inspections by ASN are not presented.

Habitability and accessibility of the main and emergency control room in the case of filtered venting is not guaranteed. Therefore EDF is planning to reinforce the electrical back-up of main control room ventilation and filtration by an ultimate backup diesel generator.
According to the NAcP, the definitive ultimate backup diesel generator sets shall be built as part of the hardened safety core by the end of 2018. Before this modification is implemented, the Nuclear Rapid Response Force (FARN) is intended to deploy means to ensure the electrical back-up of these equipment items for the damaged reactor.

The installed filtered venting systems are not resistant against earthquakes; also, the filters are not designed to retain iodine which is mainly responsible for exposure of people living in the NPP vicinity. A detailed study of the possible improvements to the venting-filtration system, taking into account the existing deficiencies[15] was to be performed by 31 December 2013. (ECS-29)
According to the updated NAcP, the studies were submitted. ASN will give a ruling after analysing the studies.
However, no schedule was set up for the necessary back-fitting measures.

Redundant means to detect vessel melt-through and hydrogen in the containment are to be installed for Fessenheim, Gravelines by 31/12/2016 and for Cattenom by 31/12/2017. (ECS-19)
According to the updated NAcP, the implementation is finished in Fessenheim and will be completed in Graveline and Cattenom in 2017 and 2018 respectively.

A feasibility study for the installation or renovation of a geotechnical containment or equivalent technical measures to prevent the transfer of radioactive contamination to groundwater in the event of a severe accident leading to corium melt-through of the vessel was to be performed by 31/12/ 2012. (ECS-27-1)
According to the updated NAcP, EDF concluded that a geotechnical containment at an economically acceptable cost is not feasible. This file is currently being examined by ASN.
The management of large volumes of contaminated water is to be considered in 2013.
According to the updated NAcP, EDF has carried out detailed studies on this subject. ASN will adopt a position on these studies in the first half of 2015.

15 (resistance to hazards, limitation of hydrogen combustion risks, efficiency of filtration in the case of simultaneous use on two reactors, improved filtration of fission products, in particular iodines, radiological consequences of opening the device for the site and the control room

4.3 Weaknesses the French NAcP Ignored

- In December 2011, Greenpeace activists trespassed on two EDF nuclear reactor sites to highlight the **security issue**. Design weaknesses of the old reactors increase the "success" of a terror attack. To implement more stringent measures of passive protection (alarm systems, fences, and video surveillance) at nuclear sites cannot compensate these facts.

- *Fessenheim and Gravelines*: High vulnerability against external events because the reactors are protected only with a single-walled containment structure.

- The double-walled containment of the Cattenom NPP was designed to provide better resistance to external initiating events. But the absence of an inner metallic liner has made the reactor more vulnerable to disruption from internal threats such as hydrogen explosions [MAKHIJANI 2012].

- **Ageing** is a major safety issue of the old French NPPs (900 MW class including Fessenheim and Gravelines). Faults caused by ageing of material have the potential to aggravate or even trigger an accident. An example for a safety relevant ageing fault is the occurrence of micro cracks in a bottom-mounted instrumentation penetration nozzle at the botton of the reactor pressure vessel of Gravelines-1. The cracks were detected with non-destructive examinations conducted during the reactor's 30th-year outage in summer 2011. In France's 900-MWe class pressurized water reactors, some 50 small tubes around 38 mm in diameter penetrate the bottoms of the reactor pressure vessels. They allow for instruments to be inserted through the vessel and into the reactor core, but their construction is important to nuclear safety because it represents part of the boundary of the pressurized cooling system. [WNN 2011]

- All six units of Gravelines are authorized to use **MOX fuel**. The consequences of a severe accident are more serious than those involving only uranium dioxide fuel.

- On 18 January 2012, EDF notified ASN that the absence of a siphon breaker on the fuel storage pools of Cattenom 2 and 3 had been detected during an inspection carried out as part of the complementary safety assessments (CSA). In the event of an incident, the injection pipe could extract the water from the pool through a siphon effect instead of injecting it, which would lead to a drop in the water level. A significant drop would lead to the damage of the fuel assemblies. Owing to its potential consequences, this event was rated level 2 on the INES scale. The absence of a siphon breaker is on no account the first non-conformance the inspections in the frame of the CSA revealed. During the conformance checks conducted in August 2011, ASN observed 35 non-conformances during spot test. This high figure and their safety relevance indicate the operator´s insufficient **safety culture**.

- On 28th May 2015, reactor 1 in the Cattenom NPP the reactor protection system triggered a series of automatic measures which automatically shut down the reactor as a result of a system valve being blocked completely open. Deterioration of the reactor's thermohydraulic parameters led the licensee to trigger the on-site emergency plan. The event caused a sudden drop in pressure and level in one steam generator (SG) and may have damaged the internal structures of this SG. Measurements revealed no damage to a tube of the steam generator affected. However, in the event of rupture of one or more tubes on the SG affected, the radioactive contamination of the reactor coolant system can then be released into the environment. The significant safety event of 28th May 2015 was rated by ASN level 1 on the INES scale. [ASN 2015]

- According to a study published in 2013 by the Institute for Radiation Protection and Nuclear Safety (IRSN), for France alone the costs of a major accident with an uncontrolled release of radiation could exceed 430 billion Euro ($548 billion), requiring long-term evacuation of more than 100,000 people [NW 14/02/2013].

- The French power company and NPP operator, Electricité de France (EdF), announced late in October 2014 that **drones** had been observed over several nuclear power plants since 5 October. On 19 October, for example they had flown over four NPPs located far from each other, indicating that this was a well-coordinated action. According to the media, the drones were sometimes two meters wide and therefore could potentially carry smaller quantities of explosives.

A report of Greenpeace concerning this issue did not go into the many speculative ideas regarding the background of current events [GREENPEACE 2014b]. The subject of the report was the question of what dangers are associated with such drone overflights – were they to be carried out by a terrorist group. The danger from terrorist attacks on nuclear power plants is mostly played down. It is argued that nuclear power plants are sufficiently secured but for confidentiality reasons no details can be released. These arguments are dramatically contradicted by the drone overflights: For one thing it appears that operators and officials are powerless to halt the overflights and for another, it must now be assumed – after potentially successful reconnaissance flights – that existing security measures are now known.

Proceeding from the hypothesis that a terrorist or criminally motivated group is responsible for these drone overflights, this report has reviewed the resulting danger. The report concluded there is a danger from drone flights over French nuclear power plants. Not only the drone overflights themselves but also the inability of security officials to explain and prevent such activity caused concern.

In their military applications, drones – including smaller portable ones – have assumed increased importance as an instrument for reconnoitring and monitoring potential opponents. In that role, drone technology has made rapid progress in recent decades. To date, there has been no military application of smaller, easily transportable drones with "standard" armament or that are equipped with e.g. explosive munitions. However, civilian drones capable of payloads of 1 kg are available that, e.g., could be armed with explosives.

Due to their design flaws and special susceptibility to disruption, it cannot be ruled out that an attack, particularly on the 34 oldest French nuclear power plants (900 MW class), using explosives-carrying drones against some critical points of the facilities would result in an event that could not be managed by the safety systems and the emergency measures of the staff so that radioactive materials would be released.

The goal of the report, however, was to examine whether terrorist attack scenarios using drones is conceivable and whether as a consequence a core meltdown would be practically inevitable; in other words, an attack that would cause damages for which intervention measures to hinder the release of a radioactivity would be impossible.

In light of the current situation on the availability and employability of drones and considering the vulnerability of French nuclear power plants at Fessenheim, Gravelines and Cattenom, three different variants appear to be conceivable:

Variant 1: drones support an explosives strike by insiders. Estimates indicate that an informed insider would need less than 10 kg of explosives to trigger a core meltdown. This quantity could be delivered by a very small number of drones without any difficulty because their payload is sufficient and it is obvious that they can fly over a NPP.

Variant 2: a multiple strike on the containment using an antitank guided weapon. If thermobaric warheads were also used an AT-14 from several hundred meters distance could cause a core meltdown accident with considerable radioactive releases. The drone overflights might have had as their goal to get details of the sites and their security.

Variant 3: preparation for a potential aerial attack, e.g. using a helicopter. With the added assistance of drone overflights the strategies, resources and effectiveness of countermeasures of the operator and officials could be tested. The drones could function to a certain extent as "trial balloons". The drone overflights demonstrate that the existing security measures are not effective. This applies apparently not only to surprise actions but also for actions that can be expected.

All of these three variants have a high probability that the result of an attack on the reactor buildings would be a core meltdown with an open containment. The expected release of radioactivity in such cases is particularly high and would begin a few hours after the attack. Thus, there would be only very little, probably too little, time for the required evacuation of the populace.

The building used for storing fuel elements would also sustain great damage under the attack scenarios examined. The result would be a serious accident with releases of high amounts of radioactivity.

The radiological consequences of a severe accident triggered by the terror attacks discussed above on a NPP reactor at Cattenom, Fessenheim or Gravelines demonstrates that depending on the weather conditions many countries (in particular Belgium, Germany, Luxembourg, Switzerland and France) would experience wide areas of contamination.

4.4 Conclusions

The French NPP belonging to the 900 MW and 1300 MW class show considerable deficiencies. The stress tests revealed for example that in France the design basis earthquake (DBE) was not evaluated using state of the art methods. The seismic margin assessment and in particular the necessary back-fitting is not finished at all. A schedule for completion was not set. Thus, it is not possible to foresee when the resistance against earthquake will achieve a sufficient level

Safety important equipment, in particular the filtered venting system, but also the fire-fighting system lack seismic qualification. The necessary modifications will be carried out during the next Periodic Safety Reviews of the reactors, which take place only every ten years. No schedule was set up for the necessary back-fitting measures of the filtered venting systems.

None of the French reactors is equipped with an alternative ultimate heat sink, but recent events highlighted the vulnerability of the ultimate heat sinks (UHS). In case of the loss of the UHS, respectively its unavailability, the core could be uncovered in just a few hours. EDF has proposed several changes that are not seen as sufficient by ASN. However the danger will persist until an alternate heat sink will be built as part of the implementation of a hardened safety core,

EDF and the nuclear authority ASN try to direct attention to the future protection level which will be reached by the “hardened safety core” (“noyau dur” (ND)). The ND includes systems, structures and components (SSCs) which will be safe from any on-site and external hazards. However, the time schedule for the definition of the ND was postponed, because the Advisory Committee of Experts (GPR) concluded that the EDFproposal for the ND was insufficient. ASN has supplemented their requirements. The updated list of new and existing equipment items intended to form part of the ND is still under consideration. Further delays cannot be excluded.

The implementation of the necessary back-fitting measures is planned in three phases. Until now only the implementation of temporary or mobile measures is ongoing (phase 1). From 2015 to 2020 (phase 2), the implementation of definitive design and organisational means, such as the fundamental elements of the hardened safety core is planned. The end of phase 3, which will start in 2019 is not determined yet.

The full implementation is probably not ready before approximately 2025. However, to assess the hazard, the current situation needs to be considered: regardless of its low probability, an earthquake, flooding or another hazard can occur any day from now on over the period of the next ten years.

The spent fuel building, consists of a metal cladding roof and a thin concrete wall (about 30 cm), is not designed to contain radioactive substances during severe accident events. However, no decision is made about the time schedule for implementation of necessary measures.

But there is another point to consider even if the hardened safety core will be implemented: Some of the back-fitting measures required as a result of the stress tests, EDF was already planning in the framework of the life time extension program. An operation time of 60 years for the old dangerous plants means ageing becomes an increasing safety issue for the very old plants, faults caused by ageing could trigger accidents which are not incorporated in the scope of the hardened safety core. Furthermore there are design weaknesses that cannot be remedied, e.g. the insufficient protection against terror attacks.

In autumn 2014, drones had been observed over several nuclear power plants. On 19 October, for example, they had flown over four NPPs located far from each other, indicating that this was a well-coordinated action. The drones were sometimes two meters wide and therefore could potentially carry smaller quantities of explosives. Not only the drone overflights themselves but also the inability of security officials to explain and prevent such activity caused concern.

The old Fessenheim NPP is the most vulnerable plant, and at the same time threatened by earthquake as well by flooding induced by an earthquake. The seismic robustness of the Grand Canal d'Alsace embankments and the possible consequences of an earthquake induced damage of the dam were analysed. But further studies are necessary to draw final conclusions. However, the threat of flooding remains. In regard of those facts we recommend to shut-down Fessenheim immediately.

The Gravelines NPP comprises six units, which are located at a coastal site, but lacking sufficient flood protection and suffering from ageing related problems; plus using MOX fuel which increases the consequences during severe accidents. The only justified response: ASN issues the order for shut -down.

The inspections as well as several relevant incidents at the Cattenom NPP revealed shortcomings in the safety culture. Thus, Cattenom NPP has to stop operation, at least until all envisaged back-fittings are completed and in addition the whole plant has been properly checked.

5 Gundremmingen NPP, Germany

Gundremmingen NPP consists of two boiling water reactors (BWR) of the German construction line ´72 with relatively high power output: net capacity per unit 1284 MWe, 1288 MWe respectively. Commercial operation started in 1984/1985. The site is located at the Danube River about 90 km northwest of Munich; distance to Austria is around 100 km.

Right after the Fukushima accident, German NPPs were subjected to a two-month safety review by the Reactor Safety Commission (RSK).[16] Furthermore an Ethics Commission "Secure Energy Supply" re-assessed the risks associated with the use of nuclear energy. These projects resulted in a phase our decision which is formulated in an amendment of the Atomic Energy Act (August 6, 2011): The operational licenses for the seven oldest NPP (commissioning before 1980) and the incident-prone Krümmel NPP were declared expired. The licenses for the operating NPPs will expire on a step-by-step basis between 2015 and 2022. Gundremmingen B has to stop power operation in 2017, Gundremmingen C in 2021. (Note: Gundremmingen A was shut down after the largest accident in Germany in 1977.)

5.1 German National Action Plan (NAcP)

The above-mentioned RSK safety review in 2011 included, in particular, natural hazards and postulated unavailability of safety and emergency systems.[17] To assess the robustness of the plants, three respective topic-specifically defined degrees of protection were introduced.

In its statement of 16 May 2011, the RSK made first recommendations on the robustness of the German nuclear power plants. On the basis of further consultations, the RSK supplemented its recommendation on 26 and 27 September 2012. RSK also took into account the peer review process recommendations of the ENSREG stress tests for preparing their own recommendations. In parallel, the technical support organization (GRS) to the Federal Ministry (BMU) also produced an Information Notice (Weiterleitungsnachrichten – WLN) on the conclusions drawn from the Fukushima Daiichi accident for German NPPs to improve control of beyond-design-basis events. On this basis, the Federal Environment Ministry, together with the competent nuclear regulatory authority of the Länder, drew up the National Action Plan [BMU 2012].

The NAcP comprises 23 actions, which are explained in some detail and refer to all related ENSREG recommendations. Germany modified the structure proposed by the ENSREG guidance. A comparison between the NAcP and the ENSREG recommendations is quite complicated.

The German NAcP also included a plant-specific list of measures. The specific action plan for the Gundremmingen NPP only announced 13 very general measures without descriptions of any details.

The nuclear regulatory body in Germany is composed of authorities of the Federal Government and authorities of the Länder governments. Licensing and supervision, inspection and enforcement as well as plant-specific safety assessments and reviews of nuclear power plants are executed by the Länder. The national regulator sets up the NAcP, but the Länder define the plant-specific actions. This double layered system takes time and results in insecurities concerning competencies.

According to the updated NAcP, "*whether or not the competent nuclear supervisory authorities of the Länder still see a need for review regarding the measures is listed*". [BMU 2014] It can be seen that there are differences of the scope of the provided information depending of the competent nuclear authorities, the measure listed for the NPP of Baden-Württemberg are more details than Gundremmingen (Bavarian).

16 During the safety review, the operators had to shut down the operating NPPs commissioned prior to 1980.

17 Man-made hazards were also examined, such as aircraft crash and blast waves, but the discussions are not finished yet.

The updated NAcP represents the second update following the publication of the German Action Plan of 2012, describing the current status towards the end of 2014. It contains one additional action, in context to the resilience against extreme weather conditions, which is based on a RSK recommendation published in November 2013.

Schedule of the implementation of the NAcP: Many of the activities were completed in 2012 and 2013, and a small number of items and studies will be completed at identified NPPs in 2014. However, some activities are studies which may result in further improvements. These will be implemented within the normal regulatory oversight processes. [ENSREG RR-GE 2013] According the updated NAcP, the actions are completed according to schedule. But as stated above, this completion does not mean the assessment or necessary back-fitting measures are completed. Authority and operator make decisions about necessary improvements "taking in account the remaining operation time" behind closed doors with in a not at all transparent process. According to Rapporteur' Report of ENSREG, there may be a need for further clarity on how the plans will be fully developed and reported when the relevant studies and consultations are complete. [ENSREG RR-GE 2013] However, the updated NAcP, does not mention this issue.

According to the updated NAcP, the BMUB asked its expert committee, the RSK, for a generic review of the implementation of the RSK Recommendations concerning the German NAcP. [BMUB 2014] However the results are not mentioned.

After having visited the Gundremmingen NPP, the ENSREG fact-finding team voiced concerns about the scope of back-fitting measures: A challenge may exist in implementing improvement measures for plants with (legally) limited operational time. For complex measures requiring long lead times for analysis and implementation, a plant might be closing on its scheduled shut-down at the time an improvement measure would finally be in place. Regardless of this circumstance, nuclear safety is an overriding priority and has to be maintained at a high level until the end of the operation time [ENSREG GE 2012]. However, the specific reason/issues for this statement of the fact finding team are not explained. It is also not known how the nuclear authority respond to this concern, however it does not seen that the scope of back-fitting measures has been extended. It is also not mentioned whether there are differences between the requirements for Gundremmingen B or C taking the different operation time into account.

All in all, the information provided by the updated NAcP is very limited. But it has to be supposed that the scope of backfitting measures at the Gundremmingen B/C are also very limited.

5.2 Efforts to Remedy the Weaknesses the German Stress Tests Described

The last re-evaluation of the seismic hazard at the Gundremmingen NPP site took place twenty years ago (in 1993) and is completely outdated. The margins as well as the cliff edge effects for seismic events have not been determined. Nevertheless, the site-specific NAcP does not require any analysis concerning earthquake resistance of Gundremmingen B/C.
Thus, the existing seismic hazard for the Gundremmingen NPP is not known. This is important because not all systems are qualified against earthquakes (see below).

According to the evaluation during the stress tests, the water level of the calculated design basis flood (DBF) is 33 centimetres higher than the grade elevation of the Gundremmingen NPP site. Thus, some parts of the plant would already be flooded in this case. The NAcP requires that the flood protection of German NPPs need to fulfil at least Level 1 of the criteria specified in the RSK safety review[18].

18 The safety can be demonstrated only by applying probabilistic considerations:" Alternatively, it may be demonstrated on the basis of site-specific conditions that a postulated discharge quantity, which is determined by extrapolation of existing probabilistic curves to an occurrence frequency of 10^{-5}/a, will not result in the

However, according to RSK, this is not the case for Gundremmingen B/C. The site-specific NAcP for Gundremmingen asked for the review and improvement of flood protection by 2012 (No 9; N-15)[19].
According to the updated NAcP, this action was completed. Recent studies have shown that the site will not be flooded in case of design basis flood (DBF). The safety margins until the design flooding levels are reached are greater than originally assumed. Notwithstanding, provisions have been made for the temporary installation of mobile sheet pile walls to improve the accessibility of those access doors for which structural flooding protection (staircases) has been built within the buildings.
However, the differences between the assumption for the new and the previous evaluation of the water level of the design basis flood are not provided. It is also not mentioned who has performed this new evaluation. It is also not explained that authority has reviewed the new flooding study. Protection of safety relevant safety systems is only assured by protection of the buildings (e.g. cable penetrations are sealed). Experiences with flooding events in other NPPs showed that these protections measures can fail. Furthermore the area surrounding the site will be flooded in case of a flooding event. This leads to the assumption that Gundremmingen NPP flood protection was a paper exercise conducted to demonstrate the low probability of flood events.

Regarding flooding margins, the NAcP requires a systematic analysis to prove that the safety is ensured in case of beyond design flooding. However, the site-specific NAcP for the Gundremmingen NPP requires only to obtain boats to improve accessibility of the plant grounds in a flood. (No 8; N-13, N-15).
According to the updated NAcP this action is done: Three boats for conveyance of passengers have been obtained.
However, this is not sufficient at all to response against extreme flooding events.

The peer review team recommended considering the assessment of margins with respect to extreme weather conditions. Because RSK has not completed its studies and discussions on this topic, Germany has not included specific requirements regarding extreme weather conditions in the original NAcP. However the updated NAcP includes the following new requirement:
Assessment of the coverage of extreme weather conditions by the existing design with regard to whether it is possible that additional measures can make a contribution to further risk prevention that is not merely slight. (No. 14, N-24).
According to the updated NAcP, this action has been completed.
However, no information beyond mentioning the review was carried out was provided.But extreme weather situations and conditions could aggravate flooding events for Gundremmingen.

In case of a total station black-out (SBO) and loss of ultimate heat sink (UHS), accident management (AM) measures have to ensure decay heat removal from the spent fuel pool. The evaporation losses of water can be made up by mobile pump(s) only. Because the spent fuel pools are located outside the containment in the upper part of the reactor building, comparable with the pools at the reactor of Fukushima NPP, the injection of water is quite difficult. Therefore, the following measure is required:
a permanently installed injection path into the spent fuel pool from outside the reactor building was to be installed in 2013. (No 6; *N-8, N-22)*
According to the NAcP, the measure is still in progress (New deadline: April 2015). The report mentioned that an injection path is permanently installed so that there is no need to enter any rooms that are at risk .
Without water injection in the spent fuel pools, the water level drops, and after a while fuel damaged with a major release will occur.

Because no severe accident management (SAM) measures for the mitigation of radioactive releases or

loss of vital safety function. In this respect, the uplift resistance of canals and buildings is to be considered."

19 Number according to the updated NAcP

preventing hydrogen explosions after severe damage of spent fuel in the pools were available, the NAcP calls for the backfitting of hydrogen recombiners (deadline 2014) (No. 4, N-7).
According to the updated NAcP, this measure is completed: Passive autocatalytic recombiners (PARs) are installed in the area of the spent fuel pool in both units.

The demonstration of integrity for spent fuel pools when the temperature rises to 100 °C was to be finalised by 2013 (No. 12, N-22).
According to the updated NAcP, this activity is done: Compliance with the protection goals "Spent fuel pool cooling through evaporation and make-up feeding of water in beyond-design-basis events" has been demonstrated.
However, it is not mentioned whether this demonstration is already reviewed by competent authority or the BMUB and RSK respectively.

Obtaining and providing a mobile emergency power generator and connections points protected against external hazards for the supply of the accident overview measuring systems and for the reactor pressure vessel (RPV) feeding was to be done by 2013 (No. 1; N-1, N-2, N-19).
According to the updated NAcP, the activity is done. Mobile diesel generators have been obtained. These are dimensioned such that they can provide the necessary power for the supply of consumers of the battery system, ventilation and lighting distribution of a safety subsystem. Preparation of the corresponding chapters of the emergency manual and the determination of the scope of in-service inspection has been concluded.

Based on the results of the plant-specific safety review of German NPPs in the light of the events in Fukushima, revealed in 2011 that the successful use of accident management/emergency measures under long-term SBO conditions and severe accidents condition is not assured. Also the ENSREG peer review team pointed out in most cases detailed qualitative descriptions of the measures that would be undertaken in case of various severe accident scenarios are presented without comments regarding their adequacy also under extreme conditions.

In general, the feasibility and operability of accident management measures (e. g. injection possibilities for the cooling of fuel assemblies) under adverse conditions even after a design basis earthquake or another design base natural hazard is not proven. This is very important, because it has to be expected that after a natural hazard accident management measure are necessary to prevent the release of radioactive substances.
Thus, the introduction of new/improved emergency measures (early opening of motorised pressure relief valves, increase of the possible pressure of reactor pressure vessel (RPV) injection via mobile pumps, additional option of using fire engines as mobile pumps for RPV injection, early switch-off of individual diesel generators to conserve fuel supplies, quicker execution of the emergency measure for injecting into the spent fuel pool) was required by 2013 (No 5; N-8, N-18, N-19).
According to NAcP, this action is done.
However no further information is provided. It has to be supposed that only or mainly paperwork was done and in a severe accident the prevention of radioactive release or the mitigation of the consequences is not guaranteed.

A systematic review of the robustness of emergency measures with consideration of external hazards was scheduled for completion by the end of 2013 (No. 2; N-5, N-6, N-9, N-16).
According to the updated NAcP, the activity is done – a corresponding report has been prepared. **However, measures resulting from the review are not mentioned. The implementation of further improvements is expected to be necessary; i.e. the current measures are not sufficient to prevent core melt accidents with large radioactive releases after an earthquake or flooding event.**

Severe Accident Management Guides (SAMGs) to cover beyond design basis accident scenarios were to be developped and its introduction and instruction at the plant was to be finalised by 2013 (No 13; N-23).

According to the updated NAcP, this action is completed: The SAMGs were prepared in the form of a manual for mitigating accident management measures and adopted into the operating rules of Gundremmingen B/C. They were successfully validated in an emergency exercise in June 2014.

Review of the availability of the emergency control room (remote shutdown and control station) during and after an external hazard, and if necessary its re-location was required by 2014 (No 10; N-18).
According to the updated NAcP, this activity is done: A review of the availability of the remote shutdown and control station was carried out. Afterwards, a new remote shut-down station was set up, which represents an improvement as regards availability. Its equipment was completed.

The German NAcP also required reviewing the performance of the filtered venting system under severe accident conditions (e.g. long lasting SBO).
According to the updated NAcP, this review is not required for Gundremmingen B/C without any explanation given.

Storage of equipment for pumping over or transporting secured fuel from depots was to be performed by 2013 (No 11; N-19).
According to the updated NAcP, this measure is done.
However, it is also mentioned that the "Conclusion of the review by the supervisory authority is expected shortly." Thus this action is not really closed.

The use of the GRS-developed QPRO code as a diagnostic and prediction aid for source term calculation is required by 2013 (No. 3; N-6, N-18, N-23). .
According to the updated NAcP, the action is done: The code is being adapted on the basis of results of the plant specific Level 2 PSA. A scenario for the validation of QPRO was developed and the code was fully introduced in an exercise in June 2014.

Further means of communication to increase the robustness of the communication between crisis team, control room, remote shut-down and control station, and the supervisory and disaster control authorities were to be obtained by 2012. (No. 7; N-10).
According to the updated NAcP, the measure is completed. The control room and, amongst others, the emergency organisation, have been equipped with satellite phones. Hence communication in an emergency is ensured.

5.3 Weaknesses the German NAcP Ignored

- The vulnerability against a deliberate aircraft crash is not mentioned: According to a study on behalf of the national regulator (BMU), a crash of a Boeing 737 against the reactor building can cause a severe accident. In case of (1) a major destruction of the reactor building or (2) a damage of the control room by fire and debris combined with leakages in the cooling system, a severe accident could occur.

- The spent fuel pools are located inside the reactor building, but above and outside the containment (like in the Fukushima Daiichi NPP). In case of a severe accident, there is no barrier to the environment. Thus, the vulnerability against a terror attack is relatively high. In case of a damage of its structures and the loss of cooling water, a severe accident with a major radioactive release will occur. The stored MOX fuel increases the potential exposure by inhalation.[20] In total, 3219 spent fuel assemblies could be stored in the spent fuel pool of each unit. This is about four times more than is placed in the reactor cores (784 assemblies).

20 In 2012, the operator announced not to use MOX anymore, but it will be stored are stored in the spent fuel pool for several years [GF BAYERN 2012].

- A study concerning the risks of Gundremmingen B and C pointed to several design deficits [RENNEBERG 2013].
  - the construction of the reactor vessel does not represent the technical state of the art
  - only two of the required three redundancies of the emergency core cooling system are sufficiently qualified as safety systems;
  - some safety-relevant components and subsystems are not qualified to resist the design basis earthquake (DBE);
  - the basic design of the spent fuel pool and its cooling system is outdated.

5.4 Conclusions

The evaluation of the design basis earthquake (DBE) has not been done adequately; existence of a safety margin has not been demonstrated. The NAcP does not include analysis concerning seismic hazards yet. Thus, the existing seismic hazard for the Gundremmingen NPP is not known. Furthermore not all safety systems are qualified against earthquakes.

According to the NAcP, the site will be flooded in case of a design basis flood (DBF). The only response to this issue: the NPP purchased boats. According to updated NAcP, despite the recommendation to improve the flood protection, a new study "shows" the site will probably not be flooded in case of a DBF. However, the updated NAcP does not provide information on who conducted the analysis or its exact results. As assumed earlier, the improved "flood protection" consists only of paperwork. Obviously this is not an acceptable response to the risk of extreme flooding events. No information concerning the review of extreme weather situation was provided. Heavy rains could even aggravate flooding events for the Gundremmingen NPP site.

The Gundremmingen NPP has several design deficits (e.g. concerning the emergency core cooling system) which have not been included in the stress tests.

Besides earthquake and flooding, also terror attacks could cause a severe accident. According to a study conducted on behalf of the national regulator (BMU), a crash of a Boeing 737 against the reactor building can cause a severe accident. A large amount of radioactivity can be released not only from the reactor core but also from the spent fuel pools that are located in the upper part of the reactor building, above and outside the containment (like in the Fukushima Daiichi NPP). In case of a severe accident, there is no barrier to the environment. In case of a damage of its structures and the loss of cooling water, a severe accident with a major radioactive release will occur.

The stress tests revealed that the severe accident prevention at Gundremmingen NPP relies on outdated (severe) accident management measures which are insufficient to respond to external hazard conditions or the need of long-term heat removal. The operability of accident management measures has been reviewed. However, for Gundremmingen the scope and the time schedule for necessary improvements are not known. It is has to be assumed that mainly paperwork was done and thus in a (severe) accident the prevention of radioactive release or the mitigation of the consequences are not guaranteed.

According to the updated NAcP, 13 out of 14 actions are completed. But this does not mean the assessment or necessary back-fitting measures are completed. The Nuclear authority and the operator make decisions about necessary improvements "taking into account the remaining operation time" behind closed doors without any transparency.

In sum, the information provided by the updated NAcP is very limited. It is fair to assume that the scope of back-fitting measures implemented at the Gundremmingen B/C also is very limited.

The German Regulatory body needs to follow the ENSREG advice *that nuclear safety is an overriding priority and has to be maintained at high level up to the end of the operation time* and deliver the list of measures needed or rather the safety goals to be achieved to the operator RWE/EON; the decision whether the investment still makes sense lies fully with the operator, responsibility with safety with the regulator. In the current condition without the serious intent to improve the condition, there is a considerable risk combined with the operation of the units thus and Gundremmingen units B/C have to be shut down immediately.

6 Krško NPP, Slovenia

The Krško NPP, located in a seismically active region, is a 2-loop Westinghouse PWR with a net capacity of 688 MWe operating since 1983. Within the 25 km radius around the NPP, 55,000 people live in Slovenia and 147,700 people in Croatia.

Currently, a lifetime extension process is ongoing. The operator envisages a prolongation of the operation time for additional 20 years. The NPP is designed to operate until 2023.

6.1 Slovenian National Action Plan (NAcP)

The main part of the NAcP represents the planned Safety Upgrade Program (SUP), which was ordered, reviewed and approved by the Slovenian Nuclear Safety Administration (SNSA). This upgrading program was already envisioned in the Slovenian legislation from 2009. It required to upgrade its systems, structures and components (SSCs) to cope with severe accidents in the period after plant lifetime extension will have been completed [SNSA 2012].

In response to the Fukushima accident, the SNSA decided to speed up the implementation of severe accident management (SAM) measures. Thus, in September 2011 the SNSA issued a decision requiring the plant operator to reassess the severe accident management strategy, existing design measures and procedures. This evaluation was finished in January 2012. The action plan was reviewed and approved by the SNSA. According to the schedule, all measures of the Safety Upgrade Program (SUP) should be completed by 2016.

However in September 2013, the Krško NPP applied for the extension of the final SUP deadline. The main reasons for the delay were announced: the size of the project, complexity of design documentation, delivery times of some of the main components, as well as inclusion of the Krško NPP into the Public Procurement in Water Management, Energy, Transport and Postal Services Area Act. The SNSA approved the extension of the deadline until the end of 2018. [SNSA 2014]

But there was another change: In the beginning of 2014, the Krško NPP notified the SNSA that the implementation of the SUP until the end of 2018 is going to be challenged due to financial constraints. Namely, the two owners of the Krško NPP (Slovenia's state owned GEN Energija d.o.o. and Croatia's stated owned HEP d.d.) became unwilling to finance the SUP due to doubts that the plant could, after the implementation of the project, still continue to provide electricity at a competitive price. The owners ordered a financial viability study, after which they will decide about the continuation of the project.

Comment: Meanwhile, the supervisory board of the Krsko nuclear power plant (NPP) has endorsed a study that found it would be feasible to extend its lifespan until 2043. The study, conducted by PricewaterhouseCoopers, has confirmed the option of extending the lifespan of the plant offers better pay-off than investing in replacement capacity. The board has also approved a long-term investment plan that features eight nuclear safety projects worth a combined 218 million euro. The projects are a key precondition set by the Slovenian Nuclear Safety Administration for extending the lifespan of the existing NPP. [PMR 2015]

According to the updated NAcP, the SUP is divided into three phases. Phase 1 includes two modifications that were already implemented in 2013, Phase 3 includes the "BB2 project", while Phase 2 contains other SUP changes not yet implemented.

The structure of the updated NAcP is easy to understand: Most of the changes and important updates of the updated NAcP have been gathered in the new chapter (5 of Part IV) and in the updated Table 4, while most of the chapters of the original report have stayed the same. Changes which are reflected in these original chapters have been marked with blue coloured sentences.

6.2 Efforts to Remedy the Weaknesses the Slovenian Stress Tests Described

The Krško NPP is the only NPP in Europe situated in a seismically active region. The national stress tests report refers to several active faults which were identified in the immediate region of Krško. In line with US NRC nuclear regulation and standards, the peak ground acceleration (PGA) of 0.3 g was used for the safe shutdown earthquake (SSE). Seismic hazard assessments in 1994 and 2004 led to raising the PGA values for the SSE: In 1994 to PGA= 0.42g and in 2004 to a PGA= 0.56g, which is nearly twice the original PGA.

Nevertheless, today the Krško NPP complies only with the current requirements for the original design basis of 0.3g. But the additional systems, structures and components (SSCs) which will be implemented within the SUP (Safety Upgrade Project), will be designed and structured in accordance with the design extension conditions (DEC) requirements specific for the NPP design and site location. DEC systems, structures and components will be located in two new bunkered buildings, one already built and the other one to be built in phase 3 of the SUP.
However, the PGA value of the DEC concerning earthquake is 0.6 g. This value offers almost no seismic safety margin (0.04 g) regarding the current value of the SSE. A new seismic hazard assessment is not mentioned. It is also not mentioned whether SNSA have knowledge of any investigation which indicates that a ground motion acceleration higher than 0.6 g is possible. The mentioned date of the last seismic hazard assessment is 2004. But even more worrisome is that the seismic hazard at the Krško site is significantly higher than the original design base of the plant. The updated and increased hazard levels, however, did not lead to a change of the design base [BMLFUW SL 2014].

Furthermore even the limited value of the DEC systems, structures and components will be implemented only partly in the next several years until 2018. The other part is not scheduled yet, respectively only scheduled to "after 2018".

SNSA claims that in case of an earthquake with a PGA over 0.6 g, core cooling can be assured by alternative means, but pointed out that implementation of alternative means requires that manual actions are performed in relatively short time.
However, it seems to be quite impossible to prevent a core melt accident with alternative means after an extreme earthquake with a PGA over 0.6g taking into account the destruction of the NPP and the infrastructure.

An earthquake with a PGA in the range of 0.8 g or higher would be likely to cause core damage: Mechanical damage could disturb the reactor core geometry and thus the insertion of the control rods. Radioactive releases cannot be excluded. A recurrence period of 50,000 years was estimated for seismic events with a PGA of 0.8 g.
However, there are uncertainties in the calculated recurrence period of 50,000 years for the seismic events with a PGA of 0.8 g. All in all, an extreme earthquake is possible.

A recent study pointed out that the results of the stress test report, e.g. the consequences of *PGA* > 0.8 g, should be weighed in the context of both the presently known relatively high accelerations due to moderate-magnitude earthquakes, and of the seismotectonic setting of the area. It is concluded that based on the revised PSHA and SPSA (seismic probability safety assessment), the statement of the SNSA "a return period for seismic events with PGA higher than 0.8 g is considered to be larger than 50,000 years" is in the opinion of the authors not yet demonstrated.[SIROVICH 2014]

The necessary earthquake resistance remains an issue. First the possible maximal strength of an earthquake is not clear. Second it is not assured so far that it is possible to backfit the NPP against such an extreme earthquake. Third despite the fact that it is known what would happen in case of an extreme earthquake, the envisaged seismic margins are limited. And the last and also the least the envisaged measure are postponed to 2018 or even to "after 2018" without

mentioning the new target date. And despite all the facts, it is planned to extent the operation time for 20 years.

The plant is located in an area prone to flooding. The plant is located at 155.20 m on a plain, which is 0.69 m below the water level of the probable maximum flood (PMF[21]) of 155.89 m. Thus, flood protection has to be assured by dikes (157.10 m). With including extreme wind, it is possible to expect a raising of water surface at the nuclear power plant for 0.46 m, resp. at the elevation 156.35 m. Increasing the dike height upstream from the plant is in progress. The design extension conditions (DEC) are described among others with a new maximum flood level of 157.53 m.

The flood protection of the nuclear island and the bunkered building will be improved by 2015. The newly installed equipment according to the Safety Upgrade Program (SUP) will be protected against the failure of flood protection dikes or extreme water level exceeding flood protection dikes by 0.4 m (deadline 2016).
According to the updated NAcP, this measure is in progress. However, it is also mentioned that the inspection for verifying the external flood protection equipment has not yet been performed. Because the topic of external floods is one of the regular topics and it is being reviewed and inspected regularly every few years. This inspection will be again performed in 2015, when also several SUP modifications for flood protection of the nuclear island and BB1 building will be implemented.
Thus, the status of the existing flood protection is not known.

SNSA plans to include in its legislation requirements regarding both the use of advanced deteriorating weather warning systems and the use of seismic monitoring systems by 2014. (No. 2.1)[22]
According to the updated NAcP, the activity is in progress. The drafts of the amendments have already been prepared, which also consist of the last WENRA Reference Level updates (adopted in September 2014). Final internal revisions are needed before the amended rules can be submitted to public hearing and then to the Government for approval. The new deadline for adopting the revised legislation is the end of 2015.
The time schedule which will be set for the implementation of the necessary back-fitting measures is not mentioned.

To prevent a total station-black out (SBO), a comprehensive safety upgrade of AC power is required by 2015. (SUP, No. 1.1)
According to the updated NAcP, the action is in progress.
However, the finalisation is postponed to 2018.

To prevent the loss of the ultimate heat sink (UHS), an alternate UHS needs be installed by 2015. The alternate UHS is to be seismically qualified and independent from the ultimate heat sink (Sava River). (SUP, No. 1.3).
According to the updated NAcP, these activities are in progress.
However, the finalisation is postponed to "after 2018".

To assure core cooling in case of SBO and/or UHS, the installation of additional high pressure pump for feeding steam generators (SGs) installed in the separated bunkered building with dedicated source of water is scheduled by 2015 (SUP, No. 1.2)
According to the updated NAcP, these activities are in progress.
However, the finalisation is postponed to "after 2018". The design value of the bunkered building is the protection against the DEC, which are also limited.

21 The PMF represents the hypothetical flood that is considered to be the most severe reasonably possible, based on application of probable maximum precipitation and other hydrologic factors favorable for maximum flood runoff such as sequential storms and snowmelt.

22 Number according to the updated NAcP

Additional pumps (low and high pressure, as well as a special pump for seal injection[23]) are to be implemented by 2015. The pumps will be installed in the separated bunkered building with a dedicated source of water for 8 hours and with provisions to refill with the help of mobile equipment from different water sources. (SUP, No. 1.4)
According to the updated NAcP, these activities are in progress.
However, the finalization is postponed to "after 2018".

All in all, it is irresponsible to operate a nuclear power plant in a seismic active area, with all the known shortcomings.

To assure containment integrity during a severe accident, the implementation of containment filtered venting systems and passive auto-catalytic recombiners (PARs) to avoid hydrogen explosion were to be done by 2013. (SUP, No. 1.5)
According to the updated NAcP, this activity is completed.
The EC staff working document recommended completing the severe accident management (SAM) upgrading measures as soon as possible [EC 2012]. This statement means translated into "normal language": the current situation is dangerous. It was reacted with the quick implementation of a passive containment filtered venting system and passive autocatalytic recombiners. **However, the seismic margins of the containment filtered venting systems and the PARs are – as explained above – very limited. Furthermore, the topic "presence of hydrogen in unexpected places" is intended to be covered with the analysis that will represent basis for the installation of PARs within the SUP. But neither the results nor the need for backfitting measure are mentioned. Thus, all in all the actual prevention of a hydrogen explosion in case of a severe accident is not guaranteed.**

Dedicated beyond design basis accident (BDBA) I&C capable of monitoring and controlling from the existing as well as the new emergency control room is to be installed by 2016 (SUP, No. 1).
According to the updated NAcP, it is postponed to 2018.
However, the installation of dedicated I&C for the spent fuel pool is not scheduled yet. It is only mentioned that SNSA need to amend its legislation to include requirements for BDBA I&C for SFP by 2014.

A fixed spray system around the spent fuel pool with provisions for quick connection from different sources of water is to be installed by 2015. (SUP, No. 1.7)
According to the updated NAcP, the activity is in progress.
However, the action is postponed to 2016. It is not mentioned that the implementation of the necessary back-fitting is in accordance to the postponed deadline.

Mobile heat exchanger with provisions to quickly connect to spent fuel pool (SFP), containment sump or reactor coolant system are to be provided by 2015 (SUP, No. 1.8).
According to the updated NAcP, the activity is in progress.
However, the action is postponed to 2018.

The Krško NPP has in place a probabilistic safety analysis (PSA) Level 2, including all external hazards, but only for full power modes. A full scope PSA Level 1 and 2 for low power and shutdown modes events shall be implemented by the end of 2015. (No.10)
According to the updated NAcP, this activity is in progress. The Krško NPP has started preparing the PSA for the spent fuel pool on its own initiative in 2014. It also started a project of developing the PSA for the low power and shutdown modes.

A new emergency control room (including expansion of existing remote shutdown panels) in the separate bunkered building is to be installed by 2016. (SUP, No. 1.6)

23 The Krško NPP has considered installing temperature resistant reactor pump seals, but decided not to install them. Instead, one more of above mentioned charging pumps will be installed within the SUP.

According to the updated NAcP, this activity is in progress.
However, the action is postponed to 2018.

The establishment of new technical support centre (TSC) and upgrade of existing operational support centre (OSC) (emergency operating facilities) is to be finished by 2015 (SUP, No. 1.10)
According to the updated NAcP, this activity is in progress.
However, the action is postponed to 2016 (OSC) and to 2018 (TSC) respectively.

SNSA plans to assign dedicated inspections to verify the external hazard protection equipment and to systematically review and inspect SAM equipment, SAMGs, test and maintenance procedures, as well as full scale training events at the Krško NPP by 2014 (No. 4)
According to the updated NAcP, most of this inspections were performed by the SNSA in the years 2013 – 2014.
However, as mentioned above the inspection for verifying the external flood protection equipment has not been performed yet.

SNSA plans to consider preparing a national strategy (also amending legislation if needed) in regard to the handling of large volumes of contaminated water after and during a severe accident by 2016.
(No. 3)
According to the updated NAcP, this activity is in progress.

6.3 Weaknesses the Slovenian NAcP Ignored

- Seismic reassessment of the Krško site became necessary in the context of the planned new reactor Krško-2. Statements on the website of the Slovenian regulator, the SNSA, raise questions about the potential impact of a fault known as Libna on the seismic hazard at Krško as well as the need to update the seismic hazard assessment of Krško 1. The French national expert organisation the Radioprotection and Nuclear Safety Institute (IRSN), one of the institutes to bring forward this issue, urged in an open letter to the operator GEN Energija d.o.o. and the SNSA to seek further clarification. In opposition to the operator and regulator, the IRSN confirmed the need to reassess the seismic data used in the design of the Krško NPP. The IRSN suggested to the operator that it should assure sufficient local data input of a study concerning Libna fault in order to minimise the identified uncertainties. [GREENPEACE 2014a] In December 2014, Slovenian state-owned power supplier Gen Energija, co-owner of the NPP Krsko, has awarded a contract worth over 2.5 million euro for site investigation services to U.S.-based Company Rizzo Associates. [PMR 2014]

- The Krško NPP also prepared an analysis of the impacts of aircraft crashes on the plant. While this report is confidential and was not part of the peer review process, the national regulator states that the plant is well prepared even for such events. However, there is no proof to underpin this statement. It cannot be assumed that this reactor type would withstand a crash of an airliner.

- The Nuclear Authority SNSA underlined that the implementation of SUP reduces the core damage risk at Krško NPP by half and the risk of radioactive releases in case of a severe accident will be reduced by 70%. However, even after implementation of all upgrading measures, both the calculated core damage frequency (CDF) of $8.46*10^{-5}$/year and the large early release frequency of $2.5*10^{-6}$ /year remain relatively high. [SNSA 2012]

- On 8 October 2013, a fuel damage occurred, when a 50cm length of fuel rod broke off during transfer of a fuel assembly to the spent fuel pool. Subsequent investigations revealed mechanical damage in other peripheral fuel assemblies, all at the same height in the upper part of the reactor core. The operator, NEK, determined that the damage was caused during operation as a result of cross flow of the coolant through the gaps between the vertical baffle plates (baffle jetting). According to NEK, in the short term, the hydraulic situation could not be changed completely.[24] This will be possible during the next outage.

Other possible causes of damage to the fuel are also small foreign objects that could be rubbed against the walls of the fuel rods. With a special robotised device ("submarine") the entire interior of the reactor vessel and primary circuit has been thoroughly screened and small debris that were found have been removed.

The Slovenian Nuclear Safety Administration (SNSA) that closely monitors all analyses and actions undertaken by the NPP Krško and its subcontractors considers that the conditions for refuelling of the reactor core are met and the plant starts operation again. [NEI 2013, SNSA 2013]

But during the next outage (April 2015) again two damaged fuel rods were found. SNSA stated: Obviously, measures to ensure the fuel integrity, implemented during the outage 2013, were quite successful in reducing fuel damage problems which is significantly less than a year and a half ago. During the 2015 outage, modification of coolant up flow conversion through the core bypass was performed, which will eliminate baffle jetting, the cause for the extensive damage of the fuel in the long term. [SNSA 2015]

However, it seems not to be proven that the debris were not an important cause of the damage of the fuel rods. And the question about the origin of the debris remains. Al in all, the safety culture of NEK, and SNSA is questionable.

6.4 Conclusions

The Krško NPP, in operation for 30 years, is situated in an area highly inadequate for an NPP because it is prone to flooding and in particular to earthquakes: It is the only NPP in Europe situated in a seismically active region.

In conjunction with the ongoing lifetime extension process (for additional 20 years), the comprehensive safety upgrading program (SUP) was to be finished by 2016. But now, the finalisation is postponed to 2018. For the most important back-fitting measures, the finalisation is even postponed to "after 2018" without mentioning the new target date.

The necessary earthquake resistance remains an issue. In 2004, a new assessment has shown that the seismic hazard (PGA= 0.56g) is significantly higher than used for original design base of the plant (PGA=0.3g). The increased hazard levels, however, did not lead to a change of the design base. *Only the earthquake resistance of the* additional systems, structures and components (SSCs) which will be implemented within the SUP has to be improved. However, the new value of the earthquake protection (0.6 g) provides almost no seismic safety margin (0.04 g). Furthermore, even the limited resistance of the new systems, structures and components (SSCs) will be implemented only partly in the next years until 2018. The other part is not scheduled yet.

Both operator and regulator SNSA claimed that the plant and staff is able to cope with the consequences of a beyond design accident to a certain degree. After having assessed all facts, this claim cannot be upheld.

It seems to be quite impossible to prevent a core melt accident with alternative means after an extreme earthquake taking into account the destruction of the NPP and the infrastructure. But even more worrisome, a recent study pointed out that an extreme seismic event causing an unavoidable core melt accident could not be excluded. However, the updated NacP does not mention a new seismic hazard

24 In those fuel elements to be placed at the same location in which the damage has occurred on their outer edge steel bars will be installed instead of the fuel rods. This represents a kind of reinforced barrier which will protect the remaining fuel rods from the hydraulic jets

assessment. In case of a core melt accident, the containment filtered venting systems should prevent a major release of radioactive substance, but the earthquake protection of this system is also insufficient.

In addition to the extreme threat of an earthquake, the Krško plant has several more serious safety issues. For example, a dedicated monitoring and control system for the spent fuel pool is lacking and the prevention of a hydrogen explosion in case of a severe accident is not guaranteed.

To assure core cooling in case of total loss of power and/or heat removal, additional high pressure pumps for feeding steam generators (SGs) were to be installed in a separated bunkered building with dedicated source of water (alternate heat sink) by 2015. Even this key back-fitting measure has been postponed to “after 2018”. However, this level of earthquake protection of the bunkered building will not suffice under the conditions at the Krško site.

The key issue will remain: Despite the Nuclear safety authority, SNSA, and the operator being fully aware that Krško NPP is situated in a seismic active region, obviously insufficient measures are taken. Even after implementation of all measures, the resistance against earthquakes will not be sufficient. The plant is operating and operation is intended to continue for two more decades with an almost zero seismic margin.

Summing up, it is irresponsible to operate a nuclear power plant in a seismic active area, with all the deficits known.

Considering the undoubtedly high seismic hazards and the inadequate scope of the safety upgrade program (SUP), we recommend to permanently shut down Krško NPP immediately.

7 Mochovce NPP, Slovak Republic

The construction of the Mochovce NPP started in 1981. In 1996, the "Mochovce NPP Nuclear Safety Improvement Programme" was developed in the frame of unit 1 and 2 completion project. Today, Mochovce NPP comprises two pressurised water reactor (PWR) units VVER 440/V213, operating since 1998 and 2000 respectively, and two units VVER 440/V213 under construction.

Construction of Mochovce 3 and 4 resumed in 2008 after a 16 year hiatus. The two additional units had been expected to start up in 2012-2013.Due to construction delays, start-up of Mochovce 3 and 4 is currently expected in 2016 and 2017 and the estimated cost of completing the project has risen from €2 billion in 2007 to €4.6 billion [WNN 2015b]. The plant is situated 90 km north-east of Bratislava.

7.1 Slovak National Action Plan (NAcP)

The latest Periodic Safety Review (PSR) of Mochovce 1 and 2 (EMO 1/2) was completed in 2011. [UJD 2014] Based on the results, the Nuclear Regulatory Authority (ÚJD SR) issued the operational permit for subsequent 10 years of operation. The permits are associated with approval of safety upgrading program aimed at closer compliance of the safety level with contemporary safety standards. The program includes also implementation of comprehensive severe accident mitigation measures [UJD 2012].

The majority of tasks resulting from the NAcP are covered by ÚJD SR decisions issued in the past and in particular after completion of the PSR. According to these decisions, the operator will report annually to ÚJD SR on the course and the results of the implementation.

Pre-Fukushima and post-Fukushima improvement programs are interlinked – they proceed, to some extent, parallel in time and concern the same topics.

The measures of the NAcP are divided into three groups: short-term (to be finished by 31/12/2013); medium-term (to be finished by 31/12/2015) and additional measures, which may result from analyses, defined by medium-term measures and will be implemented after 2015 [UJD 2012].

The NAcP which followed the structure proposed in the ENSREG Action Plan contains a comprehensible presentation of the envisaged actions in response to the recommendation of ENSREG. [ENSREG RR-SK 2014]

The updated NAcP consist of a short introduction and table containing the status of implementation and some additional information. A considerable part of the measures listed is in an advanced stage of implementation, but also concerns analyses, studies and planning further measures. Depending on the outcome of analyses to be performed by 2015, the implementation of the technical and administrative findings will take place after 2015. [UJD 2014] The scope of required measures and the time schedule for their implementation is obviously not part of the NacP and thus not transparent any more.

7.2 Efforts to Remedy the Weaknesses the Slovakian Stress Tests Described

Resistance against earthquakes: A value of the peak ground acceleration (PGA) of 0.1 g was used during plant construction. After a reassessment in 2003, the value was increased to 0.143 g. The nuclear authority UJD SR (decision No. 100/2011) ordered the implementation of seismic resistance at Mochovce 1/2 to a new value of 0.15 g by December 31, 2018.
The ENSREG peer review team recommended considering prioritization of the seismic upgrading measures. The NAcP includes this recommendation: The seismic reinforcement of structures with the highest priority is to be finished by 31/12/2015. (ID 6)[25]
According to the updated NAcP, priorities of the tasks defined. The Priority 1 (highest) includes

25 Number according to the updated NAcP

buildings where equipment important for long-term residual heat removal after a seismic event is situated: Fire station, access point for external power supply, pipeline of emergency SG feed, emergency response centre, etc. Other systems, structure and components (SSCs) will be seismically reinforced up to 2018.

However, it is not mentioned whether the reinforcement project is implemented according to time schedule. Additionally, and even more important, the reliability of the current seismic hazard assessment is not assured yet.

An analysis of the resilience of this equipment under beyond design earthquake conditions was not available. Therefore cliff edge effects cannot be excluded. The NAcP requires analysing seismic margins of selected SSCs by 31/12/2013. (ID 5)

According to the updaed NAcP, the measure is completed: Seismic margins of civil structures evaluated.

However, neither the results of the seismic margins assessments nor the scope and time schedule for their implementation are presented

The protection against the design basic flood (DBF) of Mochovce 1/2 is adequate mainly due to the relatively high difference in altitude between the site and the closest rivers. However, an assessment of the safety margins against extreme flooding events was required; places where water accumulates were to be identified. Immediate implementation of temporary solutions and the proposal of a final solution were scheduled to be finished by 31/12/2013 (ID 12).

According to the updated NAcP, the measure is completed. New metrological studies for the site were developed. Immediate measures (flood protection bags) were implemented. In December 2013, a draft time schedule of implementation of measures for 2014 - 2018 was prepared .

However, the envisaged measures to enhance the safety margin against flooding are not provided.

Concerning extreme weather events, evaluation was required of the resistance of selected SSCs against extreme weather events (floods caused by heavy rain, high and low external temperatures, direct wind and other relevant events) on the basis of updated new studies on meteorological conditions. Events with intensity corresponding to the probability of occurrence once per 10,000 years were to be considered. The plan for implementing these measures was to be prepared by 31/12/2013 (ID 4).

According to updated NAcP, the measure has been completed. New metrological studies for the site were developed and in December 2013 a draft time schedule of implementation of measures for 2014 - 2018 to enhance the resistance of selected civil structures was prepared.

However, it is not explained which measures are envisaged nor why the deadline for the implementation is not early as 2018.

Furthermore, the implementation of the warning and notification system in case of deteriorating weather and the implementation of the procedures for NPP operating staff response was to be done by 31/12/2013 (ID 9).

According to the updated NAcP, the measure is completed: The predictive regulation[26] was prepared and implemented. Additionally a project for independent data flows from the Hydro-meteorological Institution is under preparation.

Regulations to address qualified plant walk downs with regard to natural risks (to provide a more systematic search for non-conformities and correct them) are to be prepared; and to update them after finalization of an international guide by 31/12/2015 (ID 11).

The updated NAcP reports the current status: Seismic walk downs are performed always after the end of main overhauls or in case of significant changes. For other external extreme events (wind, snow, rain) the documentation is being completed.

To prevent a total station black-out (SBO), it is planned to install a 400 kV circuit breaker in the local

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substation to enable disconnection of units from the power grid in the case of damaged transmission lines. The time schedule for the installation was to be submitted by 31/12/2014 (ID 19) .
According to the updated NAcP, the measure is completed. The project is approved. The procurement process has started.
However, the installation is to be performed not earlier than 2017 – 2018.

Diversifying of emergency power sources by deploying mobile diesel generators (DG) that can also charge the accumulator batteries was to be finished by 31/12/2013. (ID 20)
According to the updated NAcP, the measure is completed. Mobile DG (0.4 kV) with connecting cabling were purchased and mobile rectifiers to charge accumulators from this DG were supplied.
However it is not explained whether the operability is assured in a catastrophical situation.

An independent diversified alternate UHS does not exist nor is it planned to prevent the loss of the ultimate heat sink (UHS). Only the following limited back-fitting measures are envisaged regarding alternative cooling and heat sink by 31/12/2013 (ID 18):

- The emergency feedwater source to steam generators (SG) by assurance of mobile high-pressure sources was to be diversified.
- The physical availability of technology needed for gravity filling of SG from feedwater tanks in case of SBO was to be reviewed.
- Means for cooling water make up from in-site and off-site water sources in the case of lack of cooling water (incl. preparation of respective procedures) are to be analysed and if needed be ensured.

According to the updated NAcP, feed water make-up pumps to steam generators for each reactor unit were purchased in 2012. The pumps are situated on a fire truck chassis. The physical access for gravity filling of SG was tested. Because of the necessity of physical manipulation with selected valves it was decided to procure a 3 kW power supply to ensure a remote operation of these valves. Necessary equipment has been purchased and tested during emergency exercises. The procurement for shelters for placing the 0.4 kV mobile DG and its equipment is in progress The required modifications of existing equipment for connection of diverse mobile feedwater and power sources resistant to external events are to be finished by 31/12/2015.
However, the measure which aims to ensure heat removal via steams generator to the atmosphere using mobile pumps are less reliable compared to the installation of an independent alternate ultimate heat sink (UHS).

The severe accident management (SAM) implementation project, initiated in 2009, was accelerated after the Fukushima accident, with the new deadline being 2015.

One of the most important modifications concerning the prevention of major radioactive releases during accidents is the external cooling of the reactor pressure vessel (RPV). This so-called in-vessel retention (IVR) concept aims to ensure the integrity of the RPV during a severe accident. The implementation of it was already planned before the Fukushima accident, and was performed in 2011/2012. The measure requires a number of technical modifications. Since the cooling of the RPV from the outside is a complex procedure, extensive analyses and experiments have been performed at the CERES test facility to demonstrate the feasibility. Analyses of consequences of RPV failure and the preservation of containment integrity in case of a severe accident are on-going. Until now proof that this concept fulfils all the intended functions was delivered only with limited experimental analyses. Therefore, the ENSREG peer review team recommended considering a failure of the reactor pressure vessel (RPV), despite the fact this is claimed to be very unlikely. However, the evaluation of the consequences of RPV failure is not included in the NAcP.

The need for filtered containment venting and other potential technical measures for long-term heat removal from the containment are to be analysed by 31/12/2015 (ID 2).

According to the updated NAcP, the project is in the phase of elaboration with the contractor VUJE. Finishing of the project is being expected by the defined deadline.
Successful in-vessel retention leads to rather limited pressure increase in the containment, and to limited release of radionuclides into the containment atmosphere. Comparatively low releases into the environment are the result. However, if late containment failure due to over-pressure occurs, the radioactive releases are still significant. Furthermore, it is not explained why UJD did not follow the recommendation of the peer review team to consider a RPV failure. Without cooling and stabilization of the molten core inside the reactor vessel, containment failure and thus a major release of radioactive substance appears likely.

The SAM project being currently implemented is based on originally defined scope with assumptions for occurrence of a severe accident on only one of two units. The analysis and the modification of the SAM project from the viewpoint of severe accident management at both units are necessary. The plan of implementation of additional measures were to be prepared by 31/12/2014 (ID 39; ID 44)
According to the updated NAcP, the measure is completed. An analysis of severe accident management at all units on the site has been prepared. The licensee performed a self-assessment on the implementation of severe accident management. The plan of implementation of measures is dependent on the evaluation of the analyses results.
However, it is neither mentioned when the analyses will be completed nor which time schedule for implementation of measures is envisaged. It is also not mentioned why the measure has been announced to be "completed", despite it is actually not completed. Furthermore, only the self-assessment by the licensee is mentioned but not the assessment by the nuclear authority.

The update of the severe accident management guidelines (SAMGs) with regard to potential damage of infrastructure, including long-term accidents and accidents with an impact on several units and neighbouring industrial facilities is necessary; however only an analysis and plan of implementation of additional measures is scheduled to be conducted by 31/12/2015 (ID 40).
According to the updated NAcP, this measure is in progress. Finishing of the project is expected by the defined deadline. Based on outputs of the analyses, possible additional measures with time schedule of their implementation will be prepared.
However, it will take years to complete the additional measures probably needed. Until this date, the staff will not be able to cope with a severe accident.

The SAM project from the viewpoint of potential migration of hydrogen to other places is to be analysed by 31/12/2015 (ID 46).
According to the updated NAcP, the project is in the phase of elaboration with the contractor UJV Řež. Partial project outputs can be expected at the beginning of 2015.
However, this issue is one of the most important lessons to be learnt from the Fukushima accident, and until now no measures are taken, there is even no decision how to handle this issue, i. e. the prevention of hydrogen explosion.

In the area of severe accident prevention and consequence mitigation, the following measures were announced:

- Instrumentation and monitoring: The availability of important parameters, and if needed, to ensure mobile measuring units which can use stabile sensors also without standard power supply is to be analysed by 31/12/2015. (ID 22)
  According to the updated NAcP, the technical specification and procurement of the mobile measuring unit is in progress.

- The conditions of the environment of rooms with safety relevant equipment during long-term station blackout (SBO), loss of ultimate heat sink (UHS) and severe accidents were to be analyzed. The plan of the required measures was to be prepared by 31/12/2013 (ID 25). *According to the updated NAcP, the measure is completed. A plan on the implementation of*

some additional measures resulting from the analyses was prepared.
However, no further details or time schedule for necessary back-fitting measures are provided.

- The leak-tightness of all penetrations through the containment under severe accident conditions (in particular leak-tightness of seals) are to be analysed by 31/12/2015 (ID 54).
According to the updated NAcP, the project is completed. A study was prepared by UJV Řež to test the sealing under SA conditions. Replacement of seals at the reactor pressure vessel cavity lids and doors is in progress.

- Solutions for treatment of large volumes of contaminated water after an accident at a study level from the conceptual viewpoint are to be prepared by 31/12/2015 (ID 47).
According to the updated NAcP, the *project is in the phase of elaboration with the contractor UJV Rez. Partial project outputs can be expected at the beginning of 2015.*

In addition to the actions recommended by ENSREG, a concept of large area fire control, (including fire control documentation, analysing the equipment and training of the staff) is to be prepared by 31/12/2015 (ID 55).
According to the updated NAcP, analyses of fire distribution after the impact of a cargo Air plane were prepared by the Technical University in Ostrava. Based on the analysis, the fire brigade on the site prepared an operative fire control plan. Plan of procurement of technology, training of the personnel in cooperation with external organisations is in progress.
However, the implementation of fire control measures will not prevent a destruction of the reactor building in case of a crash of an airliner, which will probably cause the loss of reactor cooling and thus a core melt accident with a major release of radioactive substances.

7.3 Weaknesses the Slovakian NAcP Ignored

In late 2008, Mochovce 1/2 have uprated power output. According to an Austrian Expert Statement, the **power uprate** with an increase of the thermal power to 107 % results in a decrease on the safety margins. Particularly because in the framework of the power uprate – contrary to common practice –, no plant modifications are performed. In the framework of a comparable power uprate at the NPP Paks, numerous plant modifications were performed in order to roughly preserve the safety level. Several systems and components will be affected by the power uprate. [UBA 2007] The experts stated:

- It has to be anticipated that due to the power uprate, the embrittlement of the reactor pressure vessel will increase accelerated.
- The power uprate was not accompanied by modifications of the steam generator, which is known to be failure prone.
- The power uprate caused an acceleration of accident sequences. Thus, the effectiveness of the accident management is not assured.
- The electric equipment has turned out to be failure prone so far. A negative effect of the power uprate on generators and the electric equipment, particularly regarding a potential increase of the fire hazard, is to be expected.
- The aging processes of all safety-related systems will be accelerated.
- The power uprate will increase the likelihood of a severe accident and the amount of radioactive emission.

Seismic hazard assessment of the Mochovce site has been extensively discussed in the Slovakian-Austrian Expert Workshop on site seismicity and seismic design in context of the completion of

Mochovce 3 /4.[27] The Austrian Expert Team identified several points that require further clarification [BMLFUW SK 2014]:

- Hazard assessment: Open points concern the earthquake catalogue (in particular, the estimation of the magnitude of historic earthquakes), seismic zoning, and the determination of maximum and minimum (lower-bound) magnitudes.
- Investigation of faults: Open points concern the study of faults in the near-region, and the results of geological investigations there. The re-evaluation of the capability of near-regional faults is particularly suggested by the new seismologic data obtained from the seismic monitoring system. These data were acquired after the completion of seismic hazard assessment and are therefore not included in the assessment.
- Peak ground acceleration (PGA): The open point concerns the discrepancy between the results of seismic analyses for the Mochovce site and the SESAME and GSHAP hazard maps.
- Seismic monitoring system: The open point concerns the use of newly acquired microseismic data for identifying active faults and for defining seismic source zones.
- Seismic design and the lower bound magnitude (LBM) concept: The open point concerns the possible effects of low magnitude/high acceleration earthquakes, focusing on systems and components, but also including civil structures.

The assessment of safety margins performed during the ENSREG Stress Tests indicate that a loss of containment integrity in Mochovce 1/2 is assumed not to occur below PGA=0.2g. This number indicates a rather small safety margin as the DBE for the plant is currently assessed with PGA=0.143. The reliability of the seismic hazard assessment is therefore highly important. However, the reliability of the current seismic hazard is not assured yet. [BMLFUW SK 2014]

The reactor buildings do not provide sufficient protection to the plant against external impacts like **airplane crashes or explosions**. The spent fuel pool (SFP) is located outside the containment barrier in the reactor hall. Taking into account the existing risk of **terrorism**, it is irresponsible to operate a nuclear power plant with such a high vulnerability to external attacks.

7.4 Conclusions

Earthquakes are a major hazard for Mochovce NPP, comprehensive upgrades are envisaged. However, completing the necessary back-fitting program will take several years: Measures of high priority are scheduled for completion by 2015, other measures even later – 2018. Only once the seismic margins will have been assessed it will be possible to set up and start implementing back-fittings measures. It will take several more years to achieve the planned level of earthquake protection. Additionally, and even more important, the reliability of the current seismic hazard assessment is not assured yet.

Information on the envisaged measures to enhance the protection against external flooding and extreme weather events is not provided, but the necessary measures will not be realized before 2018.

To prevent the total loss of power and/or heat removal only limited measures – the use of mobile equipment – are planned. However, there is no proof that mobile equipment does work sufficiently under the condition of a catastrophe and prevent a nuclear accident from happening. . Clearly mobile equipment is less reliable compared to the installation of new bunkered safety systems (e. g. an independent alternate ultimate heat sink (UHS), which will e.g. be implemented at French NPP. Furthermore the prevention of a severe accident depends strongly on the actions taken by the staff. The power uprate performed several years ago resulted in a decrease of the safety margins and thus also in the intervention time available to the staff in accident situations.

27 EMO 3+4 Completion: Expert Workshop on Site Seismicity/Seismic Design, Bratislava, 2010-07-14

Under these circumstances it is hard to recognise nuclear safety as being the guiding principle of the Slovak Authority ÚJD. Those measures which might be the key in case of an earthquake the NPP cannot fully resist – Severe Accident Management measures – will not be implemented before the end of 2015. Some indispensable measures will be performed even later; after that the issue of severe accidents will still be open because there are no guarantees that the most important modification (the in-vessel retention (IVR) concept) can definitely prevent major radioactive releases. A measure commonly installed to prevent major radioactive releases in case of a severe accident – a filtered containment venting system will probably not be implemented. Decisions concerning the prevention of hydrogen explosions are also lacking, despite the fact this issue is one of the most important lesson to be learnt from the Fukushima accident.

Several actions of the NAcP are announced as having already been completed, but only the time schedule for the envisaged implementation has been submitted. Some NAcP measures consist of analyses to be performed until 2015. Depending on their outcome, the implementation of the technical and administrative findings will take place after 2015. The scope of required measures and the time schedule for their implementation is obviously not part of the NacP and thus not transparent at all. In general, the NAcP analyses showed that planned back-fittings are not going to cover the whole extent of what is technically possible.

Obviously the original design of Mochovce NPP has a number of safety deficits; Slovak Nuclear Authority ÚJD and the operator ENEL share the belief that upgrades would compensate for those deficits. However, this goal cannot be achieved. The VVER 440/V213 reactors have safety deficits which cannot be remedied: The reactor buildings do not provide sufficient protection against external impacts like airplane crashes. Taking into account the existing risk of terrorism, it is irresponsible to operate a nuclear power plant with such a high vulnerability to external attacks.

Mochovce 1 and 2 is a nuclear power plant with severe design deficiencies. At the same time, the Nuclear Regulator and the operator do not take nuclear safety culture seriously and do not intend to use all technical means available to increase nuclear safety; therefore the only safe recommendation can be permanent shut-down.

8 Muehleberg NPP, Switzerland

Muehleberg NPP (373 MWe), in operation since 1972, is a General Electric Boiling Water Reactor (BWR/4) with a Mark I containment, which is the same type as unit 2-4 at Fukushima-Daiichi. The plant is located at the Aare River, only 14 km west of the city of Bern with 125,000 inhabitants.

A nuclear phase-out decision was made in Switzerland in September 2011, in the wake of the Fukushima catastrophe. Projected new reactors at Muehleberg, Beznau and Niederamt were cancelled. As a result, lifetime extension of existing reactors became crucial for Swiss nuclear operators. [GREENPEACE 2014a]

In 2009, the Swiss environment ministry issued an unlimited-duration operating licence to the Muehleberg NPP. This decision, however, was overturned in March 2012 by the country's Federal Administrative Court (FAC), which decided the NPP can only operate until 28 June 2013 [WNA 2013a]. Operator BKW has lodged an appeal against the FAC's ruling. On 28 March 2013, the Federal Court overturned the decision by the FAC and thus Muehleberg NPP is holding an open-ended operating licence [SWISS 2013].

Although having earlier received a limitless operating licence for Muehleberg, BKW announced in October 2013 that the plant will be permanently shut down in 2019 instead of the earlier planned 2022 because of "uncertainty surrounding political and regulatory trends."[WNN 2015e] BKW explained it had chosen to close Muehleberg in 2019, to avoid making long-term investments in the plant. [NW 5/12/2013].

BKW explained that a weak power price outlook in the coming years — in particular impacted by continuing expansion in renewable power in neighbouring Germany – did not justify the investments required for longer term operations. BKW said in its revised plan that the maintenance would cost around CHF 15 million ($16.8 million) instead of several million CHF that was estimated before.

The most important measures to remedy the weaknesses were cancelled (protection against earthquake and flooding; alternate ultimate heat sink), or postponed (cooling system for the spent fuel pools) arguing that the closure date leaves only little operation time, but, however, it is not assured that the Muehleberg NPP will actually shut down permanently in 2019. [NZZ 2015]

8.1 Swiss National Action Plan (NAcP)

In the Swiss NAcP prepared by the Swiss Federal Nuclear Safety Inspectorate (ENSI), a clearly arranged table of all required and planned actions is missing. ENSI has set the goal of investigating the identified issues and implement the derived measures by 2017. [ENSI 2012].

ENSI carried out an analysis of the events at Fukushima and published the results in four reports. These reports provide detailed descriptions of the causes, consequences and radiological impacts of the accident at Fukushima. 37 specific checkpoints (PP) were identified from the lessons learned for further investigation. Eight open points (OP) were added to the list on completion of the analyses for the European Stress Tests. Two additional issues (PRT) were identified by the Peer Review Team of the European Stress Tests.

A complete listing of the PPs, OPs and PRTs are provided in the updated NAcP, but these tables do not include the implementation status or the envisaged deadline for the implementation. According to the updated NAcP, the issues related to the PPs, OPs and PRTs are being processed in a Swiss action plan, called “Action Plan Fukushima”, which is updated and published on a yearly basis. It describes ENSI’s oversight activities related to Fukushima. For an overview on the status of all Fukushima issues, it has been referred to the yearly updates of the “Action Plan Fukushima” on ENSI’s website.

It is stated that ENSI has set the goal of investigating the identified issues and implementing the derived measures by 2015. Some additional major backfitting, in some case linked to requirements for LTO, may take two additional years to complete and again refer to the ENSI's website. It is explained that further details on the planned actions will be presented in the ENSI Fukushima Action Plan 2015 to be published in German in February 2015. [ENSI 2014]

However, all in all it is not possible to get an overview of the present or the envisaged safety status of the Muehleberg NPP.

8.2 Efforts to Remedy the Weaknesses the Swiss Stress Tests Described

An earthquake exceeding the design basis can possibly occur at the Muehleberg site. The seismic hazard assessment of the PEGASOS project (2004) indicates that the current design maximum PGA of 0.15g for safety significant buildings and systems could be exceeded at a frequency of approx. 6×10^{-4} per year, which is not extremely rare. The resistance of the Muehleberg NPP against earthquake is not in compliance with the ENSREG recommendation. In order to reduce the uncertainty of the PEGASOS results, the PEGASOS Refinement Project (PRP) was initiated. The re-assessment should define the updated site-specific seismic hazard levels (H3)[28]. The PRP project was expected to be completed in 2013 (PP1)[29].
According to the updated NAcP, this measure is completed. The PRP results were submitted to ENSI for final review. ENSI is reviewing the submitted documents. Depending on the outcome of the review, a renewed seismic safety assessment by the operators may be required.
However, the review and publication of the results of the PRP, announced for 2014 at the latest, have been delayed once again and are now scheduled for release at the end of 2015. A lot of questions remain: What are the outcomes of the PRP? What are the reasons for the new delay? Which site-specific values (PGA) for the seismic hazard (H3) have been evaluated? Will a new seismic safety assessment be requested by ENSI? If yes, in which time schedule the re-assessment and the subsequent backfitting measure are to be performed?

The operators have to submit an updated seismic assessment to prove that the Muehleberg NPP can cope with the seismic load possible at the site, which is not proven yet. Moreover, a sufficient seismic margin assessment is pending. It is notable that ENSI stipulated for the purpose of the EU Stress Tests not to refer to new hazard level (H3), but to compare the seismic robustness of the Swiss plants and the robustness of classified structures, systems and components (SSCs) to the outdated hazard levels (H1 and H2).[30] For some plants and some SSCs, this comparison revealed only small safety margins. (e. g. one safety train for core cooling and strain for spent fuel pool cooling,). It remained open whether the hazard level H3, which is apparently significantly higher than H1/H2, is enveloped by some margin, or not.

The potential failure of the Wohlensee dam located 1 km upstream is a serious seismic hazard for the Muehleberg NPP. The dam is very old and might break in case of a severe earthquake. After the dam break, clogging of the NPP cooling water intakes has to be expected, potentially causing the reactor cooling to fail. (PP1)
According to the updated NAcP, this activity is completed: The Muehleberg NPP started a project for

28 ENSI distinguished three seismic hazard levels referred to as H1 (hazard which the plant was originally designed to withstand by a deterministic approach), H2 (hazard for which the plant was requalified or, for the newer Swiss plants, already used as original design basis; established by a probabilistic approach) and H3 (hazard in accordance with the latest seismic studies in the Pegasos Refinement Project with an exceedence frequency of 10-4 per year, basis for the new deterministic proof by 31 March 2012). [BMLFUW CH 2014]

29 Number according to the updated NAcP

30 This approach to use H1 and H2 as benchmarks for the safety margins was accepted by ENSREG as a stringent definition of term "seismic safety margin" has not been given during the Stress Tests process.

reinforcing the Wohlensee dam against sliding, in order to further decrease the hazard of seismically-induced flooding. The project for the reinforcement was completed in 2014, which significantly increased the seismic capacity of the installation .

However, the results of the PRP, whose review is still ongoing, could show the need for a new assessment. Today it is impossible to exclude flooding of the Muehleberg (KKM) power plant site, with a hazard posed to the safety equipment of all the safety trains by dam wall breaches caused by a severe earthquake.

Regarding seismic robustness of the containment and primary circuit, ENSI will complete the reviews for all the NPPs by issuing evaluation reports in the course of 2013. Possible further actions will be decided upon in 2013 (OP 2-2).

According to the updated NAcP, this activity is still ongoing. With respect to the seismic proof that has still to be supplied, ENSI will require a more detailed examination of the seismic robustness of the isolation of the containment and the primary circuit.

The status of this action is not provided. The question concerning seismic assessment remains. However, it will take years to perform the necessary backfitting. Probably, ENSI will take credit of the limited operation time of the Muehleberg NPP, i.e. measure will not be required by ENSI.

In 2013, ENSI has set up a working group to investigate the necessity to implement automatic scrams triggered by seismic instrumentation. Once the information including international practice is collected and structured, ENSI will issue an evaluation report. Based on these results, a backfitting demand could be sent to the licensees, if considered necessary. (OP 2-1).

According to the updated NAcP, this activity is still ongoing. ENSI is analysing the advantages and disadvantages of an automatic shutdown. Depending on the results of the analysis, upgrades could be initiated.

However, it is not explained when the decision will be made. It is a quite long time for this investigation in particular considering that ENSREG has recommended this measure. In France, for example, the decision has already been made.

ENSI will follow up on the impacts of a total debris blockage of hydraulic engineering installations at the Muehleberg NPP.

According to the updated NAcP, this activity is still ongoing: The Muehleberg NPP started a project for reinforcing flooding protection of an additional water intake on the Aare River by building a new pump station on an elevated location in 2014. The implementation is still ongoing.

However, the timeline of the project is not provided. But before the implementation is not completed, the flooding hazard persists.

In 2012, a project was initiated in Switzerland to develop the scientific data necessary to further redefine the flood hazard assessment. In 2013, ENSI started a project with the aim of increasing the safety margins in case of accidents beyond the design basis (including seismic and external flooding events) (PP1, OP 2-2, PRT-1).

According to the updated NAcP, the operators' reports on increasing the safety margins regarding external flooding were submitted to ENSI and are under review. Depending on the results of the review, ENSI will consider to demand further improvements to enhance safety margins.

The status and the timeline of the project are not explained. Until the review is not finished, the need for improvements is not known. However, it has to be expected that backfitting measures are necessary. Thus, the protection against extreme flooding events is probably not sufficient.

The stress tests revealed that margins for extreme weather events (besides winds and tornadoes) and combinations thereof were not considered adequately. In 2012, ENSI defined specifications for analyses on the protection against extreme weather conditions, including combinations thereof, to be performed by the licensees. The probabilistic hazard analyses, as well as the proof of sufficient protection of the NPPs against these hazards, have to be submitted by the end of 2013, including submission of the existing margins. Subsequently ENSI will evaluate the licensees' reports in 2014 (PP1, OP 4-1).

According to the updated NAcP, the updated hazards for extreme weather conditions were submitted at the beginning of 2014 and safety cases will be submitted to ENSI by the end of 2014.

However, it is not mentioned when ENSI will finalize the review and what time schedule for implementation of backfitting measures will be set? It has to be expected that backfitting measures are necessary. The extreme weather events could trigger or aggravate an accident sequence.

In addition to the ultimate heat sinks, at all Swiss NPP core cooling and residual heat removal can also be achieved by use of well water as an alternate ultimate heat sink, the only exception being Muehleberg NPP. According to present knowledge, a flood-induced blockage of both intake structures cannot be excluded. As a consequence of such an event, the water supply will be lost, causing a threat to the core cooling and the fuel integrity [BMLUFW-CH 2014]. In order to assure core cooling and residual heat removal in case of loss of the ultimate heat sink, ENSI ordered the Muehleberg NPP to implement a diversified heat sink that is independent from the Aare River by the end of 2017 (project DIWANAS).

According to the updated NAcP, in 2013 the Muehleberg NPP decided to permanently shut down the plant in 2019 and informed ENSI about its intention of abandoning the approved concept for the alternate ultimate heat sink. In 2014, the Muehleberg NPP submitted a proposal of alternative measures for a diverse ultimate heat sink taking into account its limited remaining operating lifetime. In its evaluation, ENSI approved the proposed concept for the diverse ultimate heat sink, which has to be implemented by the Muehleberg NPP by 2015.

It is not justified to take credit of the lifetime for the safety. The concept approved by ENSI does not meet the requirements of seismic robustness corresponding to the site-specific seismic hazard levels. Furthermore a lot of questions remain: How does the approval take the limited remaining operation time into account? What is the justification of approving a concept that does not meet the requirements of seismic robustness? Does the approval include, for example, the requirement to install a diverse ultimate heat sink according to previous concept in case operation time will be prolonged after 2019?

In 2012, the ENSREG peer review team criticized the hydrogen management, i.e. the prevention of hydrogen explosion in case of severe accident. It is recommended to require a passive system for hydrogen management for severe accident conditions. It is also recommended to conduct further studies on hydrogen management for the venting systems. Within its action plan for 2013, ENSI requested the NPPs to investigate systematically the issue of migration of hydrogen (PP7, OP6-1; PRT-2).

According to the updated NAcP, the activity is still ongoing. The licensees submitted the requested studies. Some licensees proposed to equip their containment with Passive Autocatalytic Recombiners (PARs). ENSI's review of all these studies is ongoing. Preliminary results seem to confirm the need of backfitting measures in those NPPs without inertization. ENSI will follow up on the extent to which the current deployment strategies for the containment venting systems in severe accidents should be retained.

Meanwhile, ENSI's review of all these studies is completed. However, at the Muehleberg NPP, no hydrogen management system is implemented for the secondary containment. It is not explained why an upgrade of the hydrogen management system is not required by ENSI. Note: The need of an improvement of the prevention of hydrogen explosions was one of the important lessons learned from the Fukushima accident.

The restoration of the containment integrity in case of a total Station Black-Out (SBO) during shutdown, ENSI also identified as an open issue. (OP6-2)

According to the updated NAcP, the specifications for the analyses to be performed by the operators *were issued at the end of 2013. The operators submitted the relevant studies in October 2014. These reports are currently under review.*

At the end of the first EU Stress Tests Follow-Up workshop in April 2013, ENSI was also suggested to put additional emphasis on this issue. [ENSREG RR-CH 2014] **In fact, fairly large containment openings are present for a specified period during shutdowns in connection with the annual refuelling and maintenance outages. Despite the fact that this is an important weakness, it is not mentioned when ENSI will finish the review.**

For Severe Accident Management, the mobile equipment stored on-site plays an important role. In addition to the on-site stored mobile equipment, a flood-proof and earthquake-resistant external storage facility is in place (at Reitnau) since June 2011. It contains various operational resources, in particular mobile motor-driven pumps, mobile emergency power generators, hoses and cables, radiation protection suits, tools, diesel fuel and boration agents. The storage facility is accessible by road or by helicopter.

According to the updated NAcP, this measure is completed. In addition to the operational provisions at the external storage facility Reitnau, additional emergency equipment is now being stored on-site.

ENSI reassessed cooling, integrity, and instrumentation of the spent fuel pool (SFP) against external hazards and required the following back-fitting measures to be implemented:

- Two additional feed lines for SFP cooling without the need for entering the SFP buildings or rooms as an accident management measure (AMM) by 2012
- Accident-proof SFP level and temperature measurement instrumentation by 2014
- Seismically robust SFP cooling systems are to be installed in the older NPPs Muehleberg and Beznau by 2015.

According to the updated NAcP, only the first two measures are completed. The backfitting projects are ongoing at the Muehleberg NPP.

At the Muehleberg NPP, cooling of the SFP is ensured by safety train 1, which is however, not qualified against seismic hazard level H2. In case of loss of safety train 1, vaporisation is compensated by re-injecting water into the SFP. This accident measure (safety train 3) is implemented with the help of mobile operational equipment [BMLFUW CH 2014]. ENSI accepted to postpone the installation of SFP cooling system to 2020 and to install only some cooling devices within the SFP by 2016.

Muehleberg NPP is an old reactor and does not fulfil the Swiss nuclear regulator´s requirement of strict physical separation of redundant safety systems. At the lowest elevation of the reactor building (in the annulus space), several components including pumps and heat exchangers for the emergency core cooling are installed without physical separation. In case of internal flooding, several systems could be affected simultaneously, possibly resulting in a cliff edge effect (PP3) .

According to the updated NAcP, the ENSI required the implementation of measures that reduce the internal flooding hazard.

However, the scope of the backfitting measures (e.g. installation of additional valves in lines) is limited because there is not enough space to construct additional walls to achieve physical separation.

Regarding SAM Training, a revised regulatory guideline (ENSI-B11) will give ENSI the possibility to require staff exercises lasting up to 24 hours.

According to the updated NAcP, this measure is completed. In 2013, equipment, procedures and organization of the Reitnau external storage facility were tested during an alarm exercise and the general emergency drill. During the national emergency drill, accident management equipment was tested (also from the Reitnau external storage facility) as well as procedures and organisational *processes*[31].

However, a consequence of cancelling necessary improvement measures taking into account the probably limited operation time, the staff is very important to assure cooling of the fuel in the core and the spent fuel pool and to prevent a severe accident with a major release of radioactive substances. The necessary competence of the staff is not assured yet [NZZ 2015]

In 2013, ENSI required an investigation of the handling of radioactive water in case of a severe accident.

According to the updated NAcP, this measure is ongoing. In 2013, ENSI issued a report on the situation in Switzerland in case of a discharge of large quantities of radioactivity into the Aare and Rhine rivers. It concluded that the measures to protect the population are in principle adequate. Some improvements e.g. in the alarming process and continuous surveillance of radioactivity have been identified. In 2014, the implementation of the improvements was initiated and should be completed by the end of 2015. To verify the improvements, a table top-exercise and at least one alarm exercise are planned until the end of 2015. The licensees have developed a basic concept for dealing with large quantities of water. By the end of 2015, the licensees will complete the corresponding plant-specific investigations.

8.3 Weaknesses the Swiss NAcP Ignored

Muehleberg NPP has been in operation for 40 years, thus **ageing of components and equipment** is an important issue. Small failures could develop into breaks (pipes and tanks), pumps, valves and other equipment could fail. To limit ageing related failure at least to a certain degree, a comprehensive **ageing management program** (AMP) is necessary. But the AMP shows **shortcomings** because it does not contain all generic IAEA AMP attributes. Furthermore the ageing management review for some systems, structures and components (SSCs) for Long Term Operation (LTO) is incomplete [IAEA 2012]. These are two of several issues the IAEA Operational Safety Review Team (OSART[32]) observed during the Muehleberg NPP mission from 8 to 25 October 2012. Despite the fact this issue was improved, the years of dealing not adequate are supposed to result in a lot of undetected deficits in the plant.

The OSART team pointed out another issue of importance regarding ageing related problems and accident prevention: **Analysis of events is not performed in a timely manner** and applying sufficient level of detail. Root causes, human factor and corrective actions are not always defined in a specific and measurable way. According to the follow-up OSART Mission, these issues are among the remaining open issues. [IAEA 2014]

An important shortcoming regarding the expected backfitting measure the OSART Team observed: The modification programme is not tracked in sufficient detail to ensure that modifications are identified and finished in a timely manner. A **backlog exists on closing modifications** and there is no tracking indicator on implemented modifications remaining open. Forty-four modifications implemented since 2009 have not been finished. These deficits are among the open issues found during the Follow-up OSART Mission in June 2014. [IAEA 2014]

An important safety issue has been left unsolved for years, but tolerated by ENSI: During a routine inspection in 1990, **fissures were detected on the core shroud** (a reactor pressure vessel internal). The core shroud does not function as a barrier to contain radioactivity, however, it is important for the safe reactor shut down. Nevertheless, the operator, BKW, has been refusing to replace the core shroud for several years, due to economic factors. The fissures increased in length in the past years due to

31 The underlying scenario implied damages to two NPPs, namely the Leibstadt NPP and the Beznau NPP with its twin units.

32 The OSART mission is designed to review operating practices.

pressure in the RPV. In 2000, the operator changed the chemistry of the reactor water to inhibit the growth of the fissures, but the growth of the fissures was not stopped only reduced. So-called anchor bolts have been installed on the core shroud as a precautionary measure, but expert assessment (TÜV Nord) commissioned by ENSI came to the conclusion that the implemented measures are not adequate for the long-term operation of Muehleberg. ENSI asked the operator to submit a revised solution proposal for long-term operation, which was submitted by the end of 2010 [ENSI 2013].

There is a critical value of crack length beyond which severe damage of the core shroud must be expected, especially under exceptional loads, for example in the event of an earthquake, a loss of primary circuit coolant or strong transients. The critical crack length, which should be the criterion for obligatory replacement, was recalculated twice after the cracks had exceeded the initially calculated critical value. Thus the original safety margins have been gradually decreased. Despite this problem, the reactor output has been uprated by more than 20 per cent in recent years, increasing the stress on the core shroud weld seams. [GREENPEACE 2014a]. Regarding the limited operation time, ENSI has only requested that BKW perform non-destructive tests on the reactor core shroud during each annual safety review at Muehleberg. [WNN 2015e]

In March 2012, the Federal Administrative Court in Bern decided that Muehleberg could operate only until June 2013 due to significant safety issues, namely the status of the core shroud as well as further defects due to ageing. BKW and the Swiss Federal Department of the Environment, Transport, Energy and Communications (UVEK) challenged the judgement. BKW additionally submitted an application for lifetime extension and presented a new maintenance plan that suggests repairing the cylindrical hull of the core inside the RPV with brackets, so as to avoid an expensive replacement of the core shroud. Former used brackets, consisting of 240 separate pieces, had come loose and fragments had fallen into the core, causing additional safety problems. In March 2013 the Supreme Court reversed the Federal Administrative Court's ruling, and BKW announced that Muehleberg would continue to operate until 2019. [GREENPEACE 2014a]

Operator of Muehleberg, with **vessels made by Rotterdam Dry Dock, or RDM**, in the mid-1970s, around the same time as the Belgian ones, conducted special inspections and did not find any similar flaws. However, it seems not to be assured that there are actually no flaws regarding the fact for example that the second check at Tihange and Doel found additional flaws. It would be more sufficient if there have been an investigation of an external expert group instead of an evaluation by the operator.

The very old Muehleberg NPP has **obvious design weaknesses** which cannot be eliminated: The **generic assessment for BWR-4 / Mark I containments** estimated that the end cap could lift, resulting in containment failure at pressures and temperatures of appr. 0.6 MPa and/or 370ºC – occurring easily during severe accidents. This happened in the case of the Fukushima accident in 2011.

8.4 Conclusions

Although the probability of an earthquake exceeding the plant's design limit is low, the possibility of a severe earthquake persists, which could trigger a severe accident. The key issue – the possible earthquake intensity – remains open. A new assessment revealed that the current earthquake protection is utterly insufficient. However, the review and publication of the results of the new seismic assessment (PEGASOS Refinement Project - PRP), announced for 2014 at the latest, have been delayed once again and are now scheduled for release at the end of 2015.

The hazard of flooding endangering the NPP cannot be excluded in case of an earthquake induced break of the Wohlensee dam.

The most important measures to remedy the weaknesses were cancelled (protection against earthquake and flooding; alternate ultimate heat sink), or postponed (cooling system for the spent fuel pools), arguing that the closure date leaves only little remaining operation time. Concerning the risk of the Muehleberg NPP, it is not justified to take credit of the lifetime for the safety. Furthermore, it is not assured that the Muehleberg NPP will actually shut down permanently in 2019.

Mobile equipment will be used to ensure the cooling of the spent fuel pool in case of an earthquake. As a consequence of having cancelled necessary improvement measures taking into account the (probably) limited operation time, plant personnel is very important to assure cooling of the fuel in the core and the spent fuel pool and to prevent a severe accident with a major release of radioactive substances.

The restoration of the containment integrity in case of a total Station Black-Out (SBO) during shutdown was also identified as an open issue during the stress tests, but is not resolved yet. Decisions about the use of an automatic scram triggered by seismic instrumentation are not done yet, despite the fact that ENSREG has recommended to implement this measure. Hydrogen management system will be not implemented for the secondary containment, despite the fact that the need for improving the prevention of hydrogen explosions was one of the important lessons learned from the Fukushima accident.

A lot of back-fitting measures are scheduled for implementation in the upcoming years. Regarding the observed backlog of modifications, completing all back-fitting measures is likely to take even longer or will be cancelled arguing the short remaining operation time.

Muehleberg NPP, one of the oldest operating NPP in Europe, has design weaknesses that cannot be eliminated (e.g. containment) or the scope of the back-fitting measures (installation of additional valves in lines) is limited, because there is not enough space to construct additional walls to achieve physical separation of emergency cooling systems.

This NPP has been in operation for 40 years, thus ageing of components and equipment is an increasing issue. An important safety issue has been left unsolved for years, but tolerated by ENSI: During a routine inspection in 1990, fissures were detected on the core shroud.Regarding the limited operation time, ENSI has only requested that the operator BKW performs non-destructive tests on the reactor core shroud during each annual safety review.

Muehleberg NPP combines a high number of serious safety issues: seismic hazard both for the plant and the close-by dam is high, fissures on the core shroud, severe design shortcomings of an old reactor plus operational weaknesses allow for only one recommendation: immediate shut-down.

9 Ringhals NPP, Sweden

The Ringhals NPP is situated on the west coast of Sweden about 60 km south of Gothenburg. With a total net capacity of 3747 MWe, it is the largest nuclear power plant in Sweden. The plant comprises four reactors: Ringhals 1 is a boiling water reactor (BWR), in operation since 1976. Ringhals units 2, 3 and 4 are pressurized water reactors (PWR), in operation since 1975, 1981 and 1983 respectively.

Ringhals is owned by Ringhals AB, which in turn is owned by Vattenfall (70.4%) and Eon (29.6%).

In April 2015, Vattenfall announced that declining profitability and increased costs have forced to close units 1 and 2 of the Ringhals NPP earlier than previously planned. The decision would see the units shut between 2018 and 2020, rather than around 2025. Vattenfall explained that the final decision to decommission the reactors early has yet to be made by the board of directors of the Ringhals plant and requires the agreement of Eon. Vattenfall's head of business area generation explained: "Unfortunately, we see market conditions with continued low electricity prices in the coming years. At the same time, we are facing increasing production costs." According to the media release, Vattenfall´s plans remain to operate Ringhals 3 and 4 and its three other reactors (Forsmark 1, 2 and 3) for at least 60 years, until the beginning of the 2040s. [WNN 2015d]

9.1 Swedish National Action Plan (NAcP)

The Swedish NAcP listed the measures in three different categories – 2013, 2014 and 2015 – according to the year when the measures have to be completed [SSM 2012]. However, according to the Swedish Radiation Safety Authority (SSM), the measures are considered completed when the investigation is submitted. All necessary actions resulting from the investigations are to be fully implemented before the end of 2020.

After having visited Ringhals NPP in September 2012, the ENSREG fact-finding team concluded: The plant is advised to update the action plan taking into account the full set of ENSREG recommendations. The plant and SSM should establish the processes to ensure that the plan is implemented in accordance with the established schedule, and in particular that the important safety modifications will be implemented in the near future [ENSREG SE 2012].

The NAcP does not present a systematic comparison of the ENSREG recommendation and the actions to be taken, which makes the understanding of the Post-Fukushima plant´s safety very difficult. Also, the lack of direct referencing renders it difficult to get an overview for the review of the implementation of these recommendations. According to the Rapporteurs' Report, these references were addressed and clarified during the Post-Fukushima National Action Plans Workshop 2013. [ENSREG RR-SE 2014] However, these references are not presented in the updated NAcP. Furthermore, plant specific actions are not mentioned at all. Thus, it is neither possible to assess the current nor the envisaged safety status of Ringhals NPP.

The updated NAcP is a long report (70 pages) including mainly the same general information provided by the original NAcP. Part V provides short information according to the ENSREG Terms of Reference. [SSM 2014]

It is explained that no measures have been removed or modified, but one new milestone has been added in the schedule SSM issued a decision on the 15 December 2014 requiring an independent Core Cooling function to be in place by 31 December 2017 for all reactors. It is also pointed out that the question regarding a new function for independent core cooling is the issue that has strongly dominated the work with implementation of the NAcP.

9.2 Efforts to Remedy the Weaknesses the Swedish Stress Tests Described

The original design of the Ringhals units did not take into consideration the protection against earthquakes. Ringhals became subject to general requirements imposed on resilience against earthquakes when the new Swedish regulations entered into force in 2005. The deadline for taking measures was determined to be 2013. The reason for the long time was to allow licensees sufficient time to fulfil the requirements. Identified deficiencies were for example the spent fuel cooling systems, the roof of the reactor building at Ringhals-1; control room ceiling at Ringhals-3 and -4. The original NAcP mentioned that work is on-going at all units in order to fulfil the regulation regarding design basis earthquake (DBE).
The updated NAcP has not mentioned whether all back-fitting measures designed to meet the current Swedish regulation (2005) have been completed. However, the duration of the implementation time has to be chosen in regard of the protection of the people and not in regard of the protection of the operator.

Seismic plant analyses are to be performed by 2013. A return frequency of 10-5/year (with a minimum peak ground acceleration of 0.1g) shall be used as a basis for plant reviews/back-fitting (T1.LA.1)[33].
According to the updated NAcP, the action is completed. It is stated that further studies regarding the structural integrity of the reactor containments, scrubber buildings and fuel storage pools have been performed. The analyses showed that those structures can withstand an earthquake significantly stronger than the Swedish 1E-5-earthquake.
However, the Stress test revealed that the methodology used for seismic hazard assessment (SHA) is not fully compliant with current international standards and research results.

The analysis of the maximum earthquake severity which the plant still can withstand without loss of fundamental safety functions or severe damage to the fuel becoming unavoidable was not performed. Thus, the NAcP asked for an investigation of seismic margins; an evaluation of structures, systems and components (SSCs) against ground motions exceeding DBE is to be performed by 2015 (T1.LA.9).
According to the updated NAcP, the margin analyses are ongoing.

In April 2012, the ENSREG peer review team recommended to the Swedish Nuclear Authority (SSM) to consider a more timely manner for the implementation of protection against earthquake-induced flooding of for example damaged water storage tanks. The NAcP demands investigations regarding these secondary effects of earthquakes by 2014 (T1.LA.2).
According to the updated NAcP, this action is completed. It is stated that also seismic induced fires have been analyzed. Minor weaknesses have been addressed. No further details are provided.
However, leakage from broken water storage tanks and cracks in the cooling water channels can aggravate an accident caused by an earthquake. It is not explained which backfitting measures were performed and which additional measures are envisaged.

The utilities were also obliged to review the seismic monitoring systems including procedures and training program, followed by implementing them by 2014 (T1.LA.3).
According to the updated NAcP, this measure is completed.

The ENSREG peer review revealed that the methodology used for seismic hazard assessment (SHA) is not fully compliant with current international standards and research results. Thus, SSM will start a research project concerning the influence of paleoseismological data on the existing model regarding frequency and strength of the ground response spectra in 2013 (T1.RA.1).
According to the updated NAcP, this measure is completed: A literature search has been initiated.
However, it is not mentioned in which time frame the research project will be completed. Thus, the protection against earthquake is probably not sufficient.

The Ringhals units are located near the sea and thus they can be significantly affected by flood events.

33 Number according to the updated NAcP

Full compliance for protection against external flooding in accordance with the current Swedish requirements (2005) was expected to be reached in 2013.
The updated NAcP does not mention whether all back-fitting measures designed to meet the current Swedish external flooding protection regulation (2005) have been completed. Nevertheless the long implementation time is not justified regarding the possible hazard.

The site ground elevation is only 35 cm above the seawater level of the calculated design basis flood (DBF), but this water level does not include possible waves. Once the seawater level (including waves) rises higher than 65 cm, large amounts of water will enter the units through various openings; fuel damage is possible. After having visited the plant, the ENSREG fact-finding team concluded: The definition of high sea level for assessment of the margin against flooding remains an issue to be further considered since the site platform is at about 3 m level in comparison with the high sea level 2.65 m, which could be a concern regarding adequacy of the margin. In connection with this issue the team underlined the importance of re-assessing the vulnerability of the on-site emergency control centre (ECC) [ENSREG SE 2012].
The updated NAcP does not mention how SSM deal with this conclusion of the ENSREG fact-finding team. It is neither explained how SSM assess the flooding risk of the Emergency Control Centre (ECC) nor whether immediate installation of flood protection was required by SSM.

The NAcP requires a flooding margin assessment in line with the initial ENSREG specification for the stress tests of 2014 (T1.LA.6).
According to the updated NAcP, weaknesses have been addressed and physical measures will be taken at some plants.
However, it is not mentioned which weaknesses have been identified or which time schedule for the back-fitting measures are set.

The investigation of extreme sea water levels is necessary. SSM underlined the fact that historically extreme sea water levels in Scandinavia have always been accompanied by very high wind speeds. An analysis of the combined effects of waves and high water including potential dynamic effects is scheduled for completion by 2015 *(*T1.LA.5) .
According to the updated NAcP, the work is ongoing.
However, the new values for the extreme sea water levels are not presented. It is not mentioned whether new values are still available. In regard of the flooding risk, the long time to perform all measures is not justified.

ENSREG recommended to conduct a new evaluation of the flooding protection (volumetric approach)[34] which was scheduled for completion by 2014 (T1.LA.7).
According to the updated NAcP, this measure has been completed.
However, the result of this evaluation is not presented. It is only stated that "[b]ased on performed stress tests, measures will be performed at some plants." Neither measures nor time schedule of the implementation are provided.

A formal assessment of margins for all external hazards (including seismic, flooding and severe weather) plus identification of potential improvements is to be performed by 2015 (T1.LA.9). *According to the updated NAcP, the work is ongoing.*
It is not mentioned which improvements are already identified and which time schedule for their implementation is set.

The current Swedish regulation addresses extreme weather without quantification of the loads. An investigation of plant characteristics in extreme weather conditions is required to be performed by 2015. This investigation will assess plant robustness against extreme weather combined with events

34 This study serves to identify critical areas and spaces regarding flooding of the sites and considers the need of further protection of the buildings containing safety related equipment located in rooms at or below ground level.

such as ice storms and heavy snow load on structures. (T1.LA.4)
According to the updated NAcP, the work is ongoing.
Some shortcomings were already identified (e.g. vulnerability of the reactor building of unit 1 against tornado and heavy snow load) but it is likely that further analyses will identify additional deficiencies. A deadline for implementing the necessary backfitting measures is not mentioned.

SSM was obliged to initiate a study with the target of a more precise assessment of extreme weather conditions in 2013. (T1.RA.1)
According to the updated NAcP, the action is completed. This study has been performed by the Swedish Meteorological and Hydrogical Institute (SMHI).
However, it is not explained whether the results of this study of the SMHI call for additional protection of the NPPs against extreme weather events.

All in all, the protection against extreme weather conditions seems not to be sufficient. Furthermore, it is not clear how long this problematical situation will last.

The improvement of an early warning notification was to be investigated by 2013 (T1.LA.8)
According to the updated NAcP, the action is completed. The licensees have introduced instructions that the control room staff shall check the weather forecast once per shift with the Swedish Metrological Institute (SMHI). Discussions are ongoing with SMHI to create a routine where SMHI provides the licensees information directly on weather situations that may pose a threat to a plant.
However, it is "surprising" that such routine is not established yet. This indicates shortcomings in the safety culture.

To prevent SBO situations, the re-assessment of the AC and DC power supplies and distribution systems is required by 2014 (T2.LA.3; T2.LA.4).
According to the updated NAcP, this measure is completed. Concerning AC power: All licensees have drafted plans to strengthen the power supply. Concerning DC power: Measures are envisaged to expand the battery capacity of existing battery systems or to apply load shedding or a combination thereof.
However, it is not mentioned when the envisaged improvements to strengthen the AC and DC power supplies and distributions are to be completed.

The integrity of the primary system especially of the primary pumps seal for the PWRs was to be reassessed (T2.LA.5).
According to the updated NAcP, this measure is completed. For PWR, the integrity of the primary system has been further evaluated and reassessed for prolonged extreme situations. This included reassessment of the primary pumps seals which will be replaced.
However, the time schedule for this backfitting measure is not mentioned.

The primary ultimate heat sink for all units at Ringhals is sea water.[35] Ringhals-2, -3 and -4 (PWR) have another option to release residual heat to the atmosphere via the steam generators. However, this procedure is dependent on the water sources available for the auxiliary feed water system, and is thus limited. Ringhals-1 (BWR) has no alternate ultimate heat sink at all.
It is not explained why the licensees or SSM did not consider implementing an alternate ultimate heat sink. It is now part of the new independent core cooling system which has to be installed not earlier than 2020. Furthermore, it has not to be installed in the oldest and vulnerable plants Ringhals 1 and 2.

If **loss of off-site power** occurs, power is to be supplied by emergency diesel generators (EDG). Most of the emergency diesel generators (EDG) depend on seawater cooling, and will fail if the ultimate

35 The Ultimate Heat Sink (UHS) removes heat from the primary cooling circuit and other essential systems necessary to avoid a severe accident.

heat sink fails. To cope with the situation in which all EDGs fail, gas turbines (GTs) are installed as alternate AC power sources. But the GTs are in most cases not fully protected against external hazards (e.g. earthquake) and thus could fail in case of an external event.

All in all, there are several weaknesses that could result in the total loss of power supply (station black-out SBO) and loss of heat removal, but the time to prevent fuel damage in such situation is very short:

- In case of loss of off-site power, manual action for Ringhals-1 is necessary to connect to the GTs. In case of loss of off-site and emergency power (Station Black-out (SBO)), various mobile units can be used. If these devices are unavailable, fuel damage becomes unavoidable after approximately 16 hours for Ringhals-1 and after approximately 9 hours for Ringhals-2, -3 and -4.[36]
- In case of loss of UHS, fuel damage becomes unavoidable at Ringhals-2 after 11 hours, and Ringhals-3,-4 after 8 hours. But if manual actions are delayed, damage to fuel will be unavoidable within 2 hours.

Fundamental design principles of an independent core cooling system for water injection to the reactor pressure vessel to cope with SBO situation were to be defined by 2014 (T3.LA.2).
According to the updated NAcP, the activity is completed. In a joint project, the licensees have developed a "Position Paper" defining the requirements to be adopted.

SSM requires the implementation of **Independent Core Cooling system** by 2020**.** SSM wants the plants to have a "robust permanent installation that includes power supply and systems for pumping of water and an external water source independent of those used in existing emergency cooling systems." The licensees must submit a plan by the end of 2015 for implementing the permanent measures.

The Independent core cooling system is the most important safety measure in the Swedish National Action Plan. An independent core cooling system reduces the risk of meltdown in an accident and that of a major radioactive release to occur. The need to increase the reliability of core cooling in a nuclear power reactor by introducing an independent function was brought up already when drafting the Swedish Nuclear Power Inspectorate's (SKI) in the early 2000s. The need for Independent Core Cooling received further attention after the Forsmark 1 event on 25 July 2006, as well as after the serious accident at the Fukushima Daiichi nuclear power plant.

It is explained in the *world nuclear news* that the public announcement follows many years of dialogue between SSM and the operators concerning diversification and improvement to core cooling in emergencies. [WNN 2014a]

The licensees must also submit an implementation plan by the end of June 2015 for the temporary measures. SSM requires an **independent Core Cooling function** to be in place by 31 December 2017**.** These transitional/temporary measures do not have to fully meet the design basis for the independent Core Cooling system. The measures consist mainly of enforcing the emergency power by upgrading the existing gas turbines (GT) and purchasing new mobile equipment, with new connection points and new power feed trains.
According to the updated NAcP, the licensee may choose to apply this transitional solution in part or in its entirety as a component of the final design. The transitional solution may be applied during the remaining period of operation to reactors that the licensees only intend to operate for a limited period of time after 2020. In those cases, the licensees have the opportunity to apply for exemptions.
Ringhals 1 and 2, intended to close between 2022 and 2026, now will probably stop operation

36 All units are equipped with steam driven systems to provide core cooling capabilities, either directly to the reactor pressure vessel (BWR) or via the steam generators (PWR) as long as the batteries allow, or for as long as the water from available water sources lasts. Therefore the time span before damage to the fuel is unavoidable is short, but prolonged in comparison to Forsmark and Oskarshamn units.

between 2018 and 2020. Thus, the licensee will probably apply for an exemption. However, it is not justified that for the oldest and vulnerable plants SSM considers the very limited transitional solution for the independent core cooling function sufficient.

Alternative means of cooling and residual heat removal for the reactor cores and the spent fuel pools as well as alternative means of cooling the safety systems needs further evaluation and reassessment by 2015 (T2.LA.2).
According to the updated NAcP, the work is ongoing.
The long time for necessary improvements is not justified.

In case of a total loss of power (SBO) or loss of Ultimate Heat Sink (UHS), currently no system is available for cooling the spent fuel pools (SFP). The only usable source for the preparation of make-up water necessary for the pools is firefighting water. Manual actions must be performed before the onset of harsh conditions (humidity, temperature, radiation) in the spent fuel area.

The integrity and robustness of the spent fuel pools during prolonged extreme situations were to be evaluated and reassessed by 2013. (T2.LA8).
According to the updated NAcP, the re-assessments have defined technical and administrative measures to be addressed. For example measures have been identified and addressed regarding strengthening of the water supply to the fuel pools.
However, the time schedule for the backfitting measures is not mentioned. Thus, the threat of a severe accident in prolonged extreme situation persists.

Improving the capability of SFP cooling (e. g. installation of permanent pipes for make-up water from a protected location) and their instrumentation was to be considered by 2014 (T3.LA.1; T3.LA.3). *According to the updated NAcP, this measure is completed. The concept of the preliminary studies and analyses is based on the feed-and-bleed cooling concept of the fuel pools. The necessary instrumentation to monitor temperature and water level in the fuel pools will be installed in connection with the implementation of alternative measures for cooling the fuel in the pools.*
However, it is not mentioned when the implementation will be finished. Until this date, as mentioned above, the prevention of a severe accident in the spent fuel pools is very difficult. Thus, the prevention of a major release of radioactive substances is not assured.

The containment filtered venting system is not designed to cope with accident scenarios with the duration and aggravated conditions which have occurred during the Fukushima accident. Therefore, the use of the containment filtered venting system during prolonged severe accident conditions of more than 24 hours is also scheduled for review until 2014 (T3.LA.16).
According to the updated NAcP, this measure is completed. Investigations and assessments of the ability to manage a severe accident have been performed by the licensees. Different solutions to the case have been suggested.
However, it is not mentioned how SSM assess the different suggested solutions regarding the filtered venting system. It is also not mentioned when the implementation of the necessary back-fitting measures will be finished.

New analyses are necessary to answer questions relating to the long-term management of hydrogen in the containment. Also the possibilities and consequences of hydrogen accumulating in the reactor building were to be investigated by 2014 and suggestions made on necessary instrumentation and management (T3.LA.17).
According to the updated NAcP, this measure is completed. The study performed by the licensees concluded that none of the examined phenomena are expected to cause substantial degradation of the containment and increase the emissions. Uncertainties remain for some plants regarding the risks of corrosion and degradation of polymeric materials; research in these areas should be followed.
It is not mentioned that SSM requires additional measures in regard of the remaining uncertainties. It is important to remember that the hydrogen issue is one of the important

lessons learned from the Fukushima accident.

Capabilities to handle more than one affected unit were to be assured by 2014 (T3.LA.5) *According to the updated NAcP, this measure is completed. The licensees have developed training scenarios and emergency exercises in which more than one reactor is involved.*

The operability and habitability of the Main and Emergency Control Rooms (MCR and ECR) as well as the Emergency Control Centre (ECC) were to be re-assessed by 2013. (T2.LA.6)
According to the updated NAcP, this measure is completed. Some weak points have been identified and will be addressed. For example, the inner roofs in control rooms have been strengthened to withstand strong earthquakes.
However, it is not mentioned which additional measures have to be implemented and which time schedule has been set.

The risk of criticality and/or re-criticality was to be reassessed and measures to manage recriticality are to be improved by 2014 (T2.LA.19; T3.LA.6).
According to the updated NAcP, these measures are completed. For Ringhals PWRs, re-criticality must be considered in the long term. Measures have been identified and addressed. The overall probability for re-criticality that endangers the containment integrity is judged to be very small for the BWRs. The review of existing Emergency Operating Procedures (EOP) with bearing on re-criticality has resulted in an updating of the instructions in the EOP instructions.
However, the measures to avoid re-criticality at the Ringhals PWRs are not explained.

The following measures have been done, but they consist only of paperwork:

- Strategies for managing loss of containment integrity were to be developed by 2014 (T3.LA.7).
  According to the NAcP, this measure is completed. The licensees have investigated possible strategies on loss of containment function and approaches to assess the containment damage extent. The outcome of the investigations will be incorporated in the Emergency Operating Instructions (EOP).
- The accident management programs for all plant states including spent fuel pools and multi-units events are to be enhanced by 2014 (T3.LA.8).
  According to the updated NAcP, this measure is completed. A review of the instructions has been carried out. Some changes have been implemented based on the findings. As the emergency preparedness organization develops, further mobile equipment is introduced and analyses carried out, the emergency procedures will be developed.
- An extended scope of training and drills (regarding multi-unit accidents under conditions of infrastructure degradation) were to be considered by 2014 (T3.LA.9).
  According to the NAcP, this measure is completed. The licensees have developed training scenarios and emergency exercises in which more than one plant is involved.

Concerning several issues necessary t**o prevent a severe accident and with a deadline in 2015**, the updated NAcP only states the action is “according to plan”:

- Reassessment of the instrumentation and monitoring (T2.LA.7)
- Evaluation of the need for mobile equipment (T2.LA.9)
- Evaluation of the need for resources (T2.LA.13)
- Evaluation of the accessibility of important plant areas (T2.LA.14)
- Investigation of the effects of simultaneous events affecting all reactors at the site (T2.LA.15)
- Reassessment of the use of severe accident mitigation systems (T2.LA.16)

- Reassessment of procedures and operational training (T2.LA.17)
- Evaluation of the need for external support (T2.LA.18)

However, the time schedules for the evaluations and investigations are quite long – despite the fact that all of these measures belong to important tools in case of prevention of a severe accident.

The need for means to manage large volumes of contaminated water is to be evaluated by 2015. (T3.LA.12)
According to the updated NAcP, the work is ongoing.

The Swedish strategy for dealing with a BWRs (for example Ringhals 1) core melt is letting the core debris fall into a large volume of water in the lower regions of the containment. This is a relatively unusual approach and only a few reactors in the world apply this strategy. The Swedish strategy could most likely avoid a major initiating interaction between concrete and core melt. An extensive national research programme was set up in the 1980s to highlight all important aspects needing to be addressed and this programme is still progressing.
According to the updated NAcP, however, the severe accident research is directed towards providing proof that the uncertainties of the chosen solution are acceptable. Some open issues are related to steam explosions which could occur when the core melt interacts with the water and the ability to cool the core debris in the containment.
However, it is the current status of the open issues not mentioned. Thus, there is no proof today that a steam explosion will be prevented. In case of a steam explosion during a severe accident, a major release of radioactive substance will be the result.

9.3 Weaknesses the Swedish NAcP Ignored

- In July 2009, the Ringhals NPP has been placed under special investigative measures by the Swedish Radiation Safety Authority (SSM) to address shortcomings in safety culture after a series of failures jeopardising reactor safety since 2005. Ringhals management had ignored repeated warnings from SSM about the problems and the need to correct them. Under special oversight, a nuclear plant's management is required to file special reports with SSM twice a year and meet with regulators. Ringhals management was also required to give SSM reports prior to the restart of any reactor after annual maintenance or repairs. On 22 November 2012, SSM announced to continue its special oversight [NW 29/11/2012]. On June 11, 2013 Swedish regulators, SSM, lifted special oversight of the Ringhals nuclear plant, almost four years after it began.

- In May 2011, the management decided to start a containment pressure test three days earlier than scheduled, but forgot to inform the personnel. A short circuit in a vacuum cleaner forgotten in the containment caused a fire. The fire generated a substantial amount of ash that is difficult to remove from the containment. During cleaning measures, old scrap from welding work was found in important safety systems (containment sprinkler systems) at Ringhals-2 and later in Ringhals-4. Considerable modernisation was conducted at those units in the 1980s and 1990s and it is possible the scrap had been there since then. That the scrap was not detected earlier is alarming and shows that the safety systems were not tested properly over many years.

- Ageing of materials is a major safety issue at all units, especially at Ringhals-1,-2. The ENSREG stress tests do not investigate the quality of the plants' safety-related systems and components, such as the material of pipes, reactor vessel, valves and pumps, control and instrumentation equipment. The stress tests take no account of degradation effects, even though these could significantly aggravate the development of an accident caused by an external event.

- In 2015, a power uprate has been approved for Ringhals 4. The operator, Ringhals AB applied to the regulator in 2007 for permission to increase thermal output of Ringhals 4 by 18% from 2783 MWth to 3300 MWth. A prerequisite for the uprate was the replacement of the unit's three steam generators. These were replaced during the summer of 2011 as part of an uprating and life extension project. [WNN 2015c] Power uprates – the increase of the NPP electricity output – can cause unexpected failures in safety systems that could aggravate accident situations. Power uprates also accelerate the development of accidents thereby decreasing intervention time needed to take action to minimize the accident. Furthermore, in case of a severe accident, the potential radioactive release is considerably higher.

9.4 Conclusions

The evaluation of the Ringhals NPP in the light of the Fukushima accident and according to the ENSREG stress tests specification has revealed a number of shortcomings. In spite of this, almost all "actions" planned for the Swedish NAcP are more the less only investigations that are scheduled to be finished by 2015. The deadline for the implementation of resulting back-fitting measures is 2020.

The earthquake protection level at Ringhals will not be adequate even relevant back-fitting measures decided in 2005 will have been implemented, the, because the methodology used for seismic hazard assessment is not fully compliant with international standards. The research project to implement the international State-of-the-Art is not finished yet. Thus, the protection against earthquake is not sufficient yet.

Obviously neither the operator nor the regulator take the flooding hazard seriously enough to take action. The design basic flood (DBF) has been not calculated according to the State-of-the-Art. The updated NAcP does not mention how the Swedish Nuclear Regulator SSM deals with recommendation of the ENSREG fact-finding team in regard of the flooding risk (in particular of the Emergency Control Centre) The evaluation of possible extreme sea water levels is still ongoing. The long time allowed to perform all measures is not justified in regard of the threat of an external flooding of the plant.

Routines regarding extreme weather events have not been established yet, indicating shortcomings in the safety culture. The protection against extreme weather conditions seems to be insufficient.

In total, the protection against natural hazards is insufficient and it is not clear how long this problematical situation will last.

The implementation of an independent core cooling system by 2020 is the most important safety measures. The need to increase the reliability of core cooling to reduce the probability of a core melt accident has been discussed for more than 10 years.

Ringhals 1 and 2 probably stop operation between 2018 and 2020. Thus, the licensee is likely to apply for an exemption to implement only limited measures to increase the core cooling function but not the required independent core cooling system. However, the regulator SSM cannot accept this approach as justified. .

No date was provided on when the implementation of the necessary back-fitting measures of the spent fuel pools will be finished. The NacP does not set a deadline for the necessary improvement of the containment filtered venting system and the solution of the hydrogen issue. Thus, it has to be assumed that both will remain an open issue for the next years.

The updated NAcP provides only very general information. Thus, in most areas it is nearly impossible to assess the envisaged safety level of the Ringhals NPP. Several measures have been done, but they consist only of paperwork. For other analyses, it is not mentioned, which additional measures have to be implemented and which time schedule has been set.

Apparently very long periods of time for the remedy of recognized risks of the NPPs are the standard approach in Sweden, though highly irresponsible. ,

The next years will see the prolongation of the status quo: If an external event hits all four units simultaneously, the staff at the NPP will not be able to cope with a severe accident at all four units at Ringhals site in parallel. This might result in very serious consequences: Large radioactive releases from the reactor cores and the spent fuel pools.

Obviously the Swedish Nuclear Authority (SSM) and the operator intend to have Ringhals NPP operating for several more years with the known shortcomings. In view of the existing risk and insufficient safety culture, the units have to stop operation as soon as possible – at least until the reinforcement against earthquake and protection against flooding is performed as well as all other known deficiencies are remedied.

10 Temelín NPP, Czech Republic

Temelín NPP consists of two units containing pressurized water reactors (PWR) of the type VVER 1000/V320. They are in commercial operation since 2003 (unit 1), 2003 (unit 2). During construction, several technical modifications were implemented to achieve "western" safety standards. The Temelín NPP is located in South Bohemia, about 25 km north of České Budějovice.

10.1 Czech National Action Plan (NAcP)

The NAcP of the Czech Republic defines 76 actions/activities for Dukovany and Temelín NPPs [SUJB 2012]. All measures contained in the NAcP are to be completed by the end of 2015. However this is not the final implementation date of necessary backfitting. Those measures which consist of performing a study or analyses may result in the need to identify new measures. The NAcP explains: "many of listed measures are already in an advanced stage of implementation since they were proposed before the Fukushima events on the basis of Periodic Safety Reports results." This could be the reason why in some cases the context between ENSREG recommendation and the implementation activities is not easily understood.

After having visited the Temelín NPP, the ENSREG fact-finding team pointed out that the regulatory authority State Office of Nuclear Safety (SUJB) has a good and open communication with the licensee (CEZ). They agreed on a safety enhancement program (that includes the stress tests recommendations) as a condition for the next 10-year licence.[37] Among them is a comprehensive safety enhancement program to be implemented in the next years. [ENSREG CZ 2012].

The timeframe to implement the improvement measures is until end of 2017. According to the Rapporteurs' Report, a challenge remains in implementing measures for which the timeframe has been shortened after Fukushima compared with the original one. It was emphasised that some measures scheduled for long term were identified during the workshop as crucial ones, like analyses for maintaining the integrity of the containment and cooling of the molten core. [ENSREG RR-CZ 2014]

The updated NacP is the second revision of the original NacP. [SUJB 2014] It has been prepared on the basis of the ENSREG documents in order to supplement the information requested for the ENSREG National Action Plan Workshop held in April 2015. It contains some information corresponding to ENSREG´s ToR.

It is stated the response to the findings contained in the report of the first ENSREG NAcP workshop held in Brussels in 2013 was already reflected in revision 1 of the NAcP, (links between the NacP and the recommendation by ENSREG). Furthermore, it is stated although the schedule was and still is ambitious, it has not been modified and it is met. All actions are being implemented as scheduled.

No actions were removed, but eight additional measures (77-84), which emerged from a detailed analysis of ENSREG documents made in the period from May to September 2013, have been added to the NAcP.

There are also given some explanation to action 49 (strategy and schedule for implementation of measures for preservation of long-term containment). It is also explained that based on the results of this action, the completion time of the action 50 (Implementation of measures for maintaining long-term containment integrity according to selected severe accident management strategies) was set.

10.2 Efforts to Remedy the Weaknesses the Czech Stress Tests Described

According to SUJB, the seismic resilience of buildings and selected parts of the NPP proved that

37 Current valid licences were issued by SÚJB for the unit 1 on October 4, 2010 and for unit 2 on May 25, 2012. Both licences are valid for 10 years

relevant safety systems and structures significantly exceed the value of DBE. Secondary effects of earthquakes were to be assessed by 2014. Furthermore, a seismic PSA including earthquakes, induced floods or fires with a proposal for remedial measures are to be performed by 2015. (No. 4; No. 70)[38]
According to the updated NAcP, these activities are finished.
However, the outcomes of these assessments are not provided. It is also not mentioned which remedial measures are proposed by the operator and which additional measures are required by SUJB.

The reinforcement of the fire brigade building to withstand earthquakes was to be completed by 2014 (No. 2).
According to the updated NAcP, this action has been finished.
However, the figure of the earthquake severity the fire brigade building should be able to withstand is not provided. Note: The fire brigade at the Temelín NPP is very important to cope with a severe accident.

Furthermore, an assessment of the consequences of the seismic hazard for the site (e.g. damaged of the infrastructure) was to be performed in 2012 (status 2013: in progress). (No. 45)
According to the updated NAcP, this action is finished.
However, no further details are provided.

The availability of regional weather forecasts and predictions for the shift engineer decision was to be ensured by 2013. (No. 5)
According to the updated NAcP, this action is finished.

To increase the resistance against rainfall, the flood protection of the diesel generator (DG) station was to be improved by 2012 (status 2013: in progress). (No. 9)
According to the updated NAcP, the measure is implemented.

Procedures for managing extreme conditions at the site regarding wind, temperature, snow, and earthquakes were to be completed by 2013. (No. 8)
Issuance of a new procedure for coping with extreme conditions at sites (wind, temperature, snow, and earthquake) was to be done by 2013 (No. 52).
According to the updated NAcP, both actions are finished.
However, it is not mentioned whether the recommendation by the ENSREG peer review team has been taken into account*:* The ENSREG peer review team emphasised that the procedures for special handling of weather related threats need to be elaborated and some specific additions might be necessary to the emergency management procedures. It was emphasised that the considerations for extreme low temperatures may be too simple, not taking into account the realistic related effects, e.g. station blackout. Thus, some more refined analyses and verification of current analyses are necessary. Note: The sufficiency of procedures is very important, because the prevention of an accident depends on the action of the staff.

The stress tests revealed that safety margins of external hazards are not sufficiently evaluated. First the methodology for the evaluation of design resistance to natural hazards needs to be developed. A guidance on natural hazards assessments, including earthquake, flooding and extreme weather conditions, as well as corresponding guidance on the assessment of margins beyond the design basis and cliff-edge effects is to be developed by 2015. (No. 12)
According to the updated NAcP, this action is in progress.
However, it is not mentioned which time schedule will be set for the assessment of design resistance against extreme natural hazards. It has to be expected that several backfitting measure will be necessary, but it will probably take years to remedy the weaknesses.

Because the ultimate heat sink (UHS) is dependent on power supply, loss of UHS is an inevitable

38 Number according to the updated NAcP

consequence of station black-out (SBO). The time available to recover the loss of the heat sink before fuel damage in the worst case is only 2.5 hours (coping time). The time until the water in the spent fuel pools starts boiling (SFP) is 2 hours, while the time available until the fuel is uncovered is 20-30 hours.

To ensure an alternative heat sink (for core cooling and heat removal), the plan foresees pumping water from fire trucks into the steam generators (SG) via the emergency feed-water system. This water will evaporate in the secondary side of the SG and the steam will be released into the atmosphere.

- Back-up water supply into the SG from external mobile equipment using external connection points was to be done by 2013. (No. 14)
- Provisions of back-up coolant supply into depressurised reactor and storage pools with additional and sufficient sources of coolant (deadline 2014). (No. 16)
- Procurement of fire brigade trucks equipped with necessary devices to cope with selected severe accident (deadline 2013) (No. 84)

According to the updated NAcP, these actions are finished.
However, the fire trucks constitute the Czech response to the following ENSREG recommendation calling for "provisions for the bunkered of ´hardened´ systems to provide an additional level of protection ... designed to cope with a wide variety of extreme events including those beyond the design basis." The prevention of a severe accident depends strongly on sufficient actions of the staff.

The coping time could be prolonged by feeding the steam generators (SG) from feedwater tanks relying on gravity.[39] But only an analysis about gravity feeding use for SG in emergency operation procedures (EOPs) was required by 2014. (No. 73)
According to the updated NAcP, this action has been finished.
However, neither the outcome of the analysis nor the implementation of measures is mentioned.

The updated NAcP lists the following measures (provisions) to prevent Station Black-out (SBO) and to cope with a SBO situation and the consequent loss of ultimate heat sink to prevent core melt accidents:

- An additional stable source of power supply (SBO-DG) to increase resistance against station black-out (SBO) scenario (deadline 2014). (No. 18)
- Alternative measures to ensure recharging the batteries in case of SBO and measures to extend battery discharging time (deadline 2014). (No. 20)
- An alternative fuel filling for long-term operation of diesel generators (DG) including providing of fuel sources (alternative supply of diesel fuel from a tank truck) (deadline 2013). (No. 22)
- Preparation and validation of procedures for the use of the safety DG of the other unit in case of an SBO (deadline 2013) (No. 79)
- Alternative methods of monitoring key parameters necessary for accident management (deadline 2012). (No. 24)
- Provision for heat removal from the I&C systems for long-term monitoring of key parameters during SBO (deadline 2015). (No. 26)
- Provision for heat removal from the key safety components during SBO (loss of ventilation) (deadline 2015) (No. 30)

39 This measure is implemented at the other Czech NPP (Dukovany) and could prolong the coping time for about 10 hours.

- Provision of alternative mobile devices for alternative pump and power supply (deadline 2014) (No. 38)
- Implementation of an organizational measure to exclude the mid-loop modes of operation during shutdown unit state (deadline 2012) (No. 28)
- Alternative supply of selected valves from mobile power supply sources (deadline 2015) (No. 76)
- Selected valves power supply reconnection to batteries for containment isolation during SBO (deadline 2012) (No. 82)

According to the updated NAcP, all measures are finished.
However, all these actions/activities belong to "design issues": Limited improvement measures depending mainly on actions of the staff to remedy design deficiencies have been performed.

The following activities to remedy design issues are also listed:

- Summarisation of existing documents that prove long term MCP seal tightness in SBO situation, and additional analyses (if found necessary).(deadline 2013) (No. 80)
- Analysis of off-site power connections reinforcement and subsequent reinforcements by 2013, modification if needed by 2015 (No. 74)
- Feasibility analysis of heat transfer from the spent fuel pool (SFP) without an additional water supply (deadline 2014) (No. 81)
- Feasibility study based on existing analyses that prove flow paths and access availability. (deadline 2014) (No. 83)

According to the updated NacP, this paperwork is done.
However, the outcome of the studies is not mentioned. Probably the studies conclude that no further actions are necessary. The safety is demonstrated on the paper only.

Provisions of periodic verification of the functionality and periodic practicing of using the alternative mobile devices are to be done by 2015 (No. 42 and No. 43*)*
According to the updated NacP, these actions are in progress.
However, as long as the functionality of the alternative mobile devices during severe accident conditions is not assured, the prevention of a severe accident could fail.

Today, in case of a severe accident with core melt, the <u>retention of the molten core</u> inside the vessel is not possible. The design of the VVER-1000/V320 containment and the reactor cavity are such that any water supplied to the containment through the spray system or other means would not reach the reactor cavity. The peer review team stated: In general, the core melt coolability, stabilisation and termination of severe accidents is still an open issue for the Temelín NPP.

The current <u>severe accident management (SAM)</u> includes instructions to avoid containment overpressure in case of a severe accident for using ventilation systems which were not originally intended for venting: this unfiltered release would lead to the emission of large amounts of radioactive products into the environment. The installation of a filtered venting system is depending on the selected strategy for molten corium stabilization. Analysis and a proposal for a strategy and schedule for implementation of measures for preservation of <u>long-term containment integrity</u> (to stabilize melt and prevent overpressure) are to be done by 2014. (No. 49)
According to the updated NAcP, this activity is completed. It is explained that the results of analyses have shown that an effective strategy for stabilizing the corium and maintaining long-term containment integrity is spilling corium leaked from the reactor pressure vessel and its flooding by coolant, thus ex-vessel cooling of the corium (ExVC). It was analytically demonstrated that long-term control of pressure in the containment is possible by way of heat removal (using design, diverse or

alternative systems). It is explained that the necessity of installing a filtered venting to ensure long-term integrity of the containment due to the release of non-condensable gases generated during ExVC has not been confirmed.
Furthermore, since the in-vessel retention (IVR) strategy is preferable in terms of severe accident management, the study of effectiveness and applicability of the IVR strategy will continue in parallel. The schedule of implementation steps of ExVC was developed.

The deadline for the implementation of measures for maintaining long-term containment integrity according to selected severe accident management strategies is 2022. (No. 50)
According to the updated NacP, as part of this action the strategy for containment heat removal will be developed and then implemented into SAMGs. Within the action, specific technical solutions will be designed and the method of implementation of measures for ExVC will be elaborated.
However, it is not explained whether SUJB consider the year 2022 as being an adequate deadline for an urgent measure to protect containment integrity during severe accidents. Note, the ENSREG peer review team stated: Urgent implementation of the recognised measures to protect containment integrity is a finding of the peer review that national regulators should consider. Furthermore, the installation of a containment filtered venting system is not envisaged.

ENSREG emphasized the need for additional investigations of the potential for re-criticality of the molten core for the relevant SAM strategies.
However, the (updated) NAcP does not mention the issue of re-criticality.

The habitability of the main and emergency control rooms (MCR/ECR) in case of containment failure during a severe accident was not analysed. Such analysis was to be performed by 2013. (No. 58)
According to the updated NAcP, the analysis is done
However, the outcome of the analysis is not mentioned. It is not explained why measures are only necessary for the Dukovany NPP but not for the Temelín NPP.

The existing hydrogen removal system is designed for design basis accidents (DBAs) only. The installation of additional passive auto-catalytic recombiners designed (PARs) for severe accident conditions is planned for 2014 (Unit 1) and 2015 (Unit 2). (No. 47)
According to the updated NAcP, the project is in progress.
However, it is not mentioned whether PARs will be implemented to prevent hydrogen explosions during severe accidents in the area of the spent fuel pool. This was recommended by ENSREG.

The verification of the correctness of assumptions about the functioning of the SAM equipment during beyond design conditions and external risks, including possible measures to ensure functionality according to severe accident management guidelines (SAMGs), was to be completed by 2014. (No. 51)
According to the updated NAcP, this activity is completed.
However, the results are not provided. It is not stated that all assumption are verified but is also not mentioned that additional measures are necessary.

An upgraded probabilistic safety analysis (PSA) Level 2 for the identification of plant vulnerabilities, quantification of potential releases related to extreme external conditions is to be done by 2015. (No. 69)
According to the updated NAcP, the project is in progress.
However, actually, the results of the PSA should have been the basis of the development of the severe accident management (SAM).

Severe accident management guidelines (SAMGs) for accidents during shutdown conditions and in the spent fuel pools (SFP) were to be developed and implemented by 2014. (*No. 56*)
According to the updated NAcP, this activity is completed.

Sufficient number of personnel available during multi-unit accidents is to be ensured by 2013. (No.

41)
According to the updated NAcP, this activity is completed.
However, it is not mentioned whether it is necessary to increase the number of personnel. The sufficient number of personnel is very important because the prevention of a severe accident depends on the quick response of the staff.

The following measures concerning the severe accident management (SAM) were to be done (deadline 2014):

- System setup of SAM procedures and guidelines verification and validation (No. 54)
- System setup of trainings for severe accident management according to SAMG, including multi-unit accident. (No. 55)

According to the updated NacP, these actions are finished.
However, actually, only the start of the necessary improvements is finished. It is not mentioned in which time schedule the validation is done or the trainings are performed.

It is also explained, but also without providing further information, that analysing of conditions and severe accident scenarios based on the current "state of art" and the results of experiments from research of materials behaviour during severe accident is “in progress”. This action has no specific deadline, it is explained the analysing is going on “constantly”.

The following measures concerning the severe accident management (SAM) are (deadline 2015):

- During the preparation of EDMG guidelines for the use of alternative technical means an update of SAMG will be performed including extensions of SAMGs by incorporating long-term activities in accordance with the findings of EPRI - ETE,
- Processing of guides for the use of alternative technical means (FLEX, EDMG, etc. …)
- Analyses of potential accident scenarios resulting in large volumes of contaminated water including definition of remedial measures.

According to the updated NacP, these actions are in progress. .
However, no further information is provided.

10.3 Weaknesses the Czech NAcP Ignored

The original design basis earthquake (DBE) was derived from a comparison of different approaches including deterministic and probabilistic assessments which uses a subjective expert judgement which was not validated. The hazard is being re-evaluated using modern standards; however, the results are still to be validated. The design basis earthquake (DBE) is defined by peak ground accelerations PGA=0.1 g, which are comparable to I=7°MSK. [40]

According to the SUJB, this figure already includes a sufficient margin to the maximal peak ground acceleration PGA of 0.08 g. The national stress tests report concludes: “*There are no tectonic structures within the Czech Republic that would be able to generate strong earthquakes. The evaluation of the historical data and long-term monitoring revealed that the site of the Temelín NPP is seismically very quie*t.” Several international expert studies already found his assessment of seismic risk in Temelín to be insufficient and not reaching the state of the art. Initiated by the Joint EU-Czech Republic Parliamentary Committee, the Czech and Austrian experts intensively discussed this topic in 2007/2008. This resulted in implementing two Czech-Austrian projects (“Interfacing Projects“, CIP and AIP) which are currently being conducted and will deliver a data base for the seismological assessment of the site.

40 10,000 years recurrence interval, 95% non-exceedance probability

The seismicity issue is just one example for how CEZ and SUJB do not take the lessons from Fukushima and the very idea of stress tests seriously: both still refuse to consider events and sequences beyond the design basis when defining the plants ability to withstand accidents. Another example is the assessment of the plant´s ability to cope with a station blackout (SBO) by excluding external and internal hazards. The following SBO definition was used by CEZ in the operator report and taken over by SUJB in the national stress tests report: „*No design accident or failure was registered immediately before or after the SBO; the following in particular are excluded: Seismicity, fire, floods. All systems in the power plant, besides those systems that caused the loss of power supply for own consumption, continue to function or are able to function*."

In the course of comprehensive discussion procedure (Melk-process follow-up), which concerned Temelín 1+2, a number of issues were discussed extensively between Czech and Austrian experts in a series of expert workshops. [BMLFUW CZ 2014] Most of these issues have been resolved. However, regarding the high energy pipelines of the secondary circuit (main steam and feedwater pipelines), some questions remained. It is important to have adequate protection against the break of the high energy pipelines of the secondary circuit. The purpose of the discussion during the Melk-process follow-up was to make sure that the safety case for these pipelines conforms to EU requirements and practice. The last discussion took place in a dedicated workshop in March 2008. Despite the fact that a considerable amount of information was provided at this workshop, the Austrian experts could not completely follow the safety case for the high energy pipelines. According to the Austrian experts, information regarding the following points would be required for complete clarification:

- Catalogue of load cases which were considered,
- Details regarding the selection of possible locations of pipe breaks,
- Details regarding the methodology and results of new stress calculations,
- Information regarding the requirements for the application of the "No Break Zone" concept and justification of the application of this concept to the whole pipe system.

In July 2000, an anonymous witness informed the Czech office of Greenpeace that while working on the Temelín construction site, he participated in a repair of one of the **welding seams** directly between the primary cooling circuit and the reactor of unit 1. He claims that the main pipe was connected 180° wrong. It was ordered to cut directly on the seam of the reactor vessel, turn the pipe and re-weld it. The indicated welding seam was later identified by SUJB as the seam number 1-4-5.
Greenpeace organised several meeting between the witness and international experts. The conclusion was that the witness was credible and the story needed intensive follow-up. In September 2000, Greenpeace informed the Czech regulator SUJB of the case, a team of SUJB inspectors decided to start an investigation into the matter. Also in September 2000, the regional police opened an investigation. In the next years, there were some investigations concerning the welds, but not the specific welding seam 1-4-5. [GREENPEACE 2006]
Although a lot of experts and also the court have been involved, the case is not closed yet. Thus, on one hand there is probably an additional risk linked with the operation of the Temelín NPP. But and probably more worth, the issue shows deficiencies in the safety culture of the operator CEZ and the nuclear regulator SUJB. The issues show that SUJB plays an active role in covering information on this issue. With that, the role of SUJB as an independent nuclear regulator is questionable.

10.4 Conclusions

The discussion about the seismic hazard assessment of the Temelín site has not been concluded yet; an earthquake could cause a severe accident. The seismicity issue is one example showing how the NPP operator CEZ does not take the lessons from Fukushima and the idea of the EU stress tests seriously and the nuclear regulator SUJB does not intervene. This fact led the peer review team to formulate a number of recommendations; however the regulator continues to ignore them.

The stress tests revealed that the plant´s existing safety margins of external hazards have not been sufficiently evaluated. Therefore the weaknesses are not known, and adequate upgrading measures cannot be required. The guidance on assessing the design resistance against extreme natural hazards will be performed in 2015. However, the time schedule for completing the assessment was not determined. In addition it will probably take several additional years to remedy the weaknesses.

Currently the units of NPP Temelín are not prepared to withstand an accident caused by a natural hazard like an earthquake which obviously could affect both units. The idea of having fire trucks supplying water needed to cool the core under accident situations during e.g. an earthquake is unacceptable and reveals a dangerous approach to safety culture.

Currently it is not clear whether technical back-fitting of the Temelín plants can achieve the required safety level; however, the operator and the Czech authorities seem not to intend implementing the hardware applied at other plants.

In the past few years, only limited improvement measures – depending mainly on actions of the staff – have been performed to remedy design deficiencies. The outcome of studies (e.g. concerning the heat transfer from the spent fuel pool (SFP) without any additional water supply) is not mentioned. Probably the studies conclude that no further actions are necessary. Thus, the safety is demonstrated on paper only.

The deadline for the implementation of measures for maintaining long-term containment integrity (ex-vessel cooling) during a severe accident is 2022. However, no explanation is given why the nuclear regulator SUJB considers the year 2022 as being an adequate deadline for the implementation of an urgent measure. Urgent implementation of measures to protect the containment integrity is a key finding of the stress tests.

The prevention of a severe accident depends on the quick response of the staff. Furthermore, the functioning of the SAM equipment during beyond design conditions and external risks is still not assured. Thus, the prevention of a severe accident could fail.

The heavy reliance on fire trucks and action undertaken by the plant staff during a severe accident for cooling the reactor is an unacceptable measure in the light of the fact that already after 2.5 hours without cooling, fuel damage sets in. Temelín NPP has no means to cope with a severe accident at this point because it lacks both the measures to cool the molten core and the filtered containment venting system. Thus, a severe accident with a major radioactive release would result.

Although a lot of experts and also the court have been involved, the case of faulty welding seam between the reactor pressure vessel and the main pipe of the primary circuit is not closed yet. Thus, on one hand there is probably an additional risk linked with the operation of the Temelín NPP. On the other hand, the issue shows shortcomings in the safety culture of the operator CEZ and the nuclear regulator SUJB.

All in all, we recommended to shut down Temelín NPP immediately – at least until all open issues will be solved sufficiently (e.g. seismicity) and appropriate hardware for severe accidents management (e.g. devices for molten core stabilisation and filtered venting) will be implemented.

11 Wylfa NPP, UK

Wylfa NPP, in operation since 1971, is located on the North coast of the island of Anglesey in North Wales. The adjacent Irish Sea provides the ultimate heat sink. The two units at Wylfa were both scheduled for shut down at the end of 2012, but the operator Magnox Ltd. decided to shut down unit 2 in April 2012 so that unit 1 could continue operating until 2014 [WNN 2012].

A periodic safety review (PSR) for Wylfa was submitted to the Office for Nuclear Regulation (ONR) in September 2013.[41] The review covers the years 2014 to 2024 and includes power generation to no later than December 2015, defueling and initial decommissioning. [WNN 2014b]

Magnox reactors are cooled by pressurised carbon dioxide gas (CO_2); the moderator is graphite. The fuel is natural uranium clad in a magnox (magnesium non-oxidising) alloy. Wylfa 1 is the last Magnox reactor still in operation.

11.1 UK National Action Plan (NAcP)

The Office of Nuclear Regulation (ONR) explained that the NAcP has been developed from a number of UK ONR reports produced in response to Fukushima. The NAcP is therefore not a stand-alone report; it is rather a summary of the current status of, and future activities that are planned for, implementation of the lessons learnt [ONR 2012a].

The general approach to progressing the work described in the NAcP report has been the same for all types of the UK’s NPP. These are Magnox, Advanced Gas Cooled (AGR) and Pressurised Water Reactors (PWR).

However, the ONR stated, differences do occur due to the shorter life of the last operating Magnox reactor (Wylfa 1). Less focus has been placed on long-term study work which might not report back within the time of operation. ONR underlines as a consequence a number of prudent improvements have already been implemented which have tended to be fairly straightforward measures designed to provide an immediate safety benefit [ONR 2012b].

The UK has established a list of 19 Stress Test Findings (STF), 25 interim recommendations (IR) and 11 final recommendations (FR) from the national stress tests report that meet the recommendations of the ENSREG action plan. Deadline for all actions was the end of 2014, a majority of the actions were planned for 2013. Most actions are studies, assessments or reviews.

The Rapporteurs‘ Report pointed out that recommendations of the peer review country report which were not clearly addressed in the NacP (for example the recommendations regarding design basis earthquake or design basis flood), were included in the country presentation and described in more detail in the ensuing discussions during the ENSREG workshop in April 2013. The report highlighted that the methodologies for the re-evaluation of hazards margins to confirm the absence of cliff edges remain a topic of discussion. [ENSREG RR-UK 2014].

It is explained that the updated NAcP provides details of the current status in relation to all operating reactors and, where appropriate, the planned completion time of each individual item. As anticipated, there are a range of longer-term improvements or on-going activities that will need to be delivered over timeframes extending beyond those for the production of this report. It is stated that Annex 2 includes information according to ENSREG´s ToR. [ONR 2014] But this Annex gives only some general information, which is not direct linked to the subjects of the ToR.

In the updated NacP provides an update on the status of work being carried out by the operator (EDF NGL and Magnox) to address the 19 STFs. The status of work aimed at addressing the peer review outcomes and the timescales and milestones against the compilation of recommendations are

41 A PSR is required to be submitted every ten years and includes a review of the safe operation of the site for the next ten years.

summarised in three other tables. [ONR 2014] However, the delays of the implementation are not shown in any of the tables.

11.2 Efforts to Remedy the Weaknesses the UK Stress Tests Described

- Several uncertainties exist with regard to the calculation of design basis earthquake (DBE). There is no satisfactory evidence of capability of all UK NPPs for earthquake beyond the design basis. The UK regulator followed the recommendation to introduce a specific program for additional review regarding the design basis, adequate margin assessment and identifies specific potential plant improvements.
However, for Wylfa only a seismic margin study is performed.

- A systematic review of the potential for seismically induced fire was completed (*30/06/2013*). **However, because an adequate seismic hazard assessment is lacking, the results are not reliable.**

- Wylfa does not have an automatic seismic shutdown system. Therefore the operator has to initiate the reactor trip manually in response to a signal from the seismic monitoring system.

- The currently available design basis flood (DBF) assessments of NPP sites in the UK did not take into account the recent tsunami research work. However ONR believes that these studies are unlikely to significantly affect previous understanding of maximum credible tsunami heights.

- To evaluate the flooding hazards, independent reports have been commissioned by ONR. According to the updated NacP, the reviews of the flooding studies for all sites have been postponed for two years to the 30/06/2015.
The operator Magnox did not undertake a full flooding margin assessment for Wylfa. Only a review of the existing study was conducted, resulting modifications were implemented. **However, without any appropriate assessment of the flooding hazard, it cannot be evaluated whether the flood protection is sufficient. Quite the opposite has to be assumed regarding the general shortcomings of flood assessment in the UK. Nevertheless, ONR is satisfied with this approach.**

- Advanced warning systems for deteriorating weather as well as the provision of appropriate procedures to be followed by operators when warnings are made have been implemented (31/03/2013).

- Additional generators for emergency electrical on-site supplies (DC and AC) were provided and the carbon dioxide (CO_2) and fuel stocks on site were increased.

- Regarding provision of alternative means of cooling, Wylfa has only increased the on-site water stocks in hardened structures, i.e. a water tanker to transport water from a nearby freshwater source to the site was purchased. ONR assessed this as an appropriate approach considering the remaining operating time of the plant.

- Resilience enhancements to assist operator access were implemented (31/12/2013).

- Additional pumps to support reactor boiler feed and general duties were provided (31/12/2013).

- The review of the on-site emergency facilities with regard to resistance against external hazards and working conditions in case of a severe accident was done (30/06/2013).

- The necessary improvement of the robustness of the spent fuel pools (SFP), the implementation of backup equipment to ensure the integrity in the event of boiling or external

impact, is not required for Wylfa. It is mentioned that for the Magnox fuel pool the time for the onset of boiling is significantly higher than 72 hours.
However, in case of water draining, the time until fuel damage will occur is considerable lower.

- The necessary enhancement of the main control room (MCR) and the emergency control room (ECR) is not required for Wylfa.

- The reactor is fitted with an iodine absorption device that may be used to remove radioactive iodine from the primary circuit gas and can, therefore, mitigate releases to the environment to some degree.
However this system is only designed for DBA and is not comparable to a filtered venting system. But a backfitting measure is not required.

- A Level PSA 2 was performed (*30/09/2013*), but only with a limited scope.

- The implementation of severe accident management guidelines (SAMGs) including all plant states and accidents initiated in the spent fuel pools was to be completed by 31/12/2013. *According to the updated NAcP, the completion is postponed to 30/06/2015.*

- Magnox has reviewed and updated the reactor Symptom Based Emergency Response Guidelines (SBERGs) and Severe Accident Guidelines (SAGs) and used a similar approach to account for recently procured Back-up Equipment (BUE). Magnox has also produced fuel route accident management guidelines.

- The SAM exercises and training (originally to be completed by 31/12/2013) are also postponed to 30/06/2015.

- Although it is recognised that the gas cooled reactors cannot generate hydrogen in the same way as that which occurred at Fukushima the formation of carbon monoxide is credible and the fire/explosion risk has been assessed as part of the reports with the conclusion that this does not pose a fire/explosion risk.

11.3 Weaknesses the UK NAcP Ignored

The Wylfa 1 is in operation since 1971. Both the ENSREG but also the UK stress test report did not recognize material degradation as the main contribution to safety problems. Ageing effects which cause material degradation are not considered in the stress test report. Specific ageing effects for Wylfa could trigger dangerous incidents or aggravate accident situations. The combination of external impacts (for example: earthquake) and material degradation can have significant impacts on the development of accidents.

There are also design deficiencies of the outdated reactor type:

- Wylfa does not have a secondary containment. The massive concrete reactor pressure vessel is the last barrier to retain radioactive emissions from the reactor core. Containment function relies on the stability and leak-tightness of pipings and welds penetrating the reactor vessel wall.

- The support and safety systems are very simple compared to the complex systems of light water reactors. They generally fall short of modern standards due to their lack of diversity and separation, particularly the electrical systems.

- A fire risk exists, since a significant mass of graphite is located in the core which can ignite after an air intrusion. Air intrusion after pressure vessel failure, and subsequent graphite ignition, could lead to a large release [HIRSCH 2005].

11.4 Conclusions

The operator obviously does not have much interest in improving the safety of the old Wylfa reactor. The Office of Nuclear Regulation (ONR) shares this approach towards the only still operating Magnox in UK and this lack of interest is mirrored by the ENSREG peer review team.

The operator Magnox did not undertake a full flooding margin assessment for Wylfa. Only a review of the existing study was conducted, resulting modifications were implemented. However, without an appropriate assessment of the flooding hazard, it is not possible to evaluate whether the flood protection is sufficient. Quite the opposite has to be assumed regarding the general shortcomings of flood assessment in the UK. Nevertheless, ONR is satisfied with this approach.

An adequate seismic hazard assessment is also lacking. ONR discarded investigating the natural hazard issue as not worth the effort because Wylfa 1 nearly reached the end of its operational lifetime. Nevertheless the operation time was prolonged for another year.

It is irresponsible to assume that in a NPP of this age and this amount of deficiencies all safety relevant components will stay intact during an external impact (e.g. an earthquake) or under severe accident conditions. Nevertheless, improvements of severe accident management are limited to the use of mobile equipment. Although envisaged measures are very limited, some of the measures are postponed.

Overall this approach is not acceptable in the light of the design weaknesses (e.g. lack of a secondary containment and lack of diversity and separation of systems particularly of the electrical systems) and negative effect of ageing of the very old NPP, which has been in operation for almost 45 years by now.

The operator but also the Nuclear Safety Authority accept the following situation: The natural hazard issue is not investigated thus the protection against hazards is insufficient, at the same time the severe accident management which would be crucial if such a hazard occurs cannot provide an adequate response. The argument put forward for the irresponsible approach is the short operational time left for this reactor. The consequence of the reactor not fulfilling the needed safety level and upgrading it considered as not worth the effort leave only the one option: immediate shutdown of Wylfa 1.

12 Conclusions

The Fukushima catastrophe was the horrible result of decades of mistaken safety philosophy, a very lax safety regulation under strong industry influence on the regulator – which is the case not only in Japan. The first shock led to the honest attempt to change this, to also include events which are definitely possible but were kept out of the safety cases by using probabilities. This safety philosophy was based on the rule that an event could be ignored, i.e. the plant did not have to show it would cope with it, when the probability of occurrence was assessed as too low.

On 12 October 2012, Tokyo Electric Power Co (TEPCO) admitted that the company had failed to prevent the Fukushima accident, reversing its earlier statement that the accident could not have been foreseen. A TEPCO task force has identified several factors that had led to the accident in March 2011 [NW 18/10/2012]:

- First, the management assumed a severe accident was extremely unlikely in Japan, and feared that retrofitting safety systems would increase anxiety among the public.
- TEPCO also feared safety retrofitting would require a costly shutdown period.

Basically all circumstances leading to the Fukushima accident exist for the European NPP as well – only the tsunami risk does not apply for all NPP but e.g. for several UK NPPs. However the risk of flooding events or of earthquakes exists to a different extent for nearly all NPPs. Also common to all NPPs: the operators insist on the low probabilities to avoid high investments and anti-nuclear activities of the public, very much the same reasons TEPCO used until Fukushima in Japan.

The EU tried to respond to this “new experience” of Fukushima by conducting the stress tests and assuming that the results will lead to higher safety. Four years later, this report investigated the outcomes of the stress tests procedures, the very concrete measures each nuclear safety authority will require its operators to implement and until which date.

It is evident that some countries treated this task rather as a formality or paperwork than a plant safety upgrade program. This was one of the conclusions of the critical review of the NAcP in 2013. This study announced the hope that “the ENSREG peer review hopefully will insist on introducing additional measures to the national plans in those cases where the national regulator required less safety measures than the stress tests peer review recommended.”

Now two years later, one of the conclusions of the report at hand is that the whole ENSREG exercise has changed to paperwork. The hope expressed in the previous study has not been fulfilled.

In general, there are different possibilities for operator and nuclear authority to remedy the shortcomings the stress tests have revealed:

- A quick response, but without any guarantee that the measures are sufficient (e.g. Wylfa, UK).
- A comprehensive evaluation of possible hazards and protections measures, which will take more than ten years (e.g. Gravelines and Cattenom, France).
- Business-as-usual (e.g. Temelín, Czech Republic). The idea of the stress tests is more or less ignored. Instead the already ongoing measures are listed, major hardware improvement avoided.

None of those possible scenarios increase the nuclear safety to an acceptable level. Many plants would have to undergo long outages while serious upgrades are implemented at the plants, causing enormous costs. If investment is rather avoided or if the plant cannot be upgraded, there is only one responsible solution: permanent shut down, which for several NPP is the only safe option. This applies in particular to those plants where significant improvements cannot be achieved by the planned deployment of mobile equipment only or by having plants on the grid in the current status for many more years while evaluations and assessment are under preparation and again later back-fittings would start. In France for example, this is officially scheduled to take over ten years.

The measures to cope with severe accident are heavily relying on the “new magic solution” to severe deficiencies at the plants due to design or the conditions at the site: mobile equipment, which is easy to plan and store in the plant and therefore a cheaper solution compared to comprehensive back-fitting measures. But under severe accident conditions, it is very unlikely that the mobile equipment can be put to work as quickly as necessary; to rely to such a large extent on manual actions is in regard of the consequences of a severe accident irresponsible.

Limited back-fitting measures do not significantly improve the safety level because they cannot compensate the increasing threat of hazards (e.g. by climate change) and of ageing effects.

Comprehensive plant modifications which would actually improve the safety level are technically impossible or would be done only in exchange for prolonged operation times, at the same time carrying the risks of ageing plants as mentioned above.

Conclusions of the review of the updated NAcPs

- Transparency is another important tool to control nuclear risk; while ENSREG certainly recognizes this fact, not all national nuclear regulators and operators act accordingly to fulfil this need of higher transparency. Unfortunately the degree of transparency has strongly decreased during the stress tests procedures.
- Nearly no information is provided with the updated NAcPs. Some countries only presented the status of implementation without further information. For some countries the structure of the NAcP is very different compared to the original NAcP. Thus, it is nearly not possible to identify the progress. The degree of transparency decreased during the stress test procedure.
- At many instances the operators negotiated very beneficial deals for their plants by using the argument of the short remaining operation time of the plants. The regulators did not insist on necessary back-fitting measures because the operators agreed on fixed shut-down dates. For the Muehleberg NPP for example, the operator was able to avoid expensive measures after limiting the remaining operation time to five more years.
- Some of the unknown risks concerning natural hazards have changed to known risks (for example the threat of earthquake for the Krško NPP) – but neither the operators nor the nuclear authority take this seriously enough as to either conduct very serious upgrading or shut-down the plant soon!
- The risks of the old NPPs have not been significantly reduced – but the public knows more about the additional risks of natural hazards.
- The largest part of stress tests consisted of desktop and paper work (e.g. France). There is no guarantee today that all envisaged measures will be actually implemented at all French NPPs – however, as long as the discussion continues, even the operation of the most dangerous NPPs is considered – wrongly – justified in expectation of the implementation of the hardened safety core in 10 years.
- A key issue, which was unclear two years ago, was how comprehensively the ENSREG´s peer review of the national action plan will be conducted. This could have been seen as an opportunity to force the nuclear regulators to formulate mandatory requirements which need to be fulfilled in a rather stringent time schedule; in contrast to the years or even decades currently planned in many countries. This could make operators decide to shut down old and unsafe nuclear power plants NPP instead of investing into extensive modernisation measures. However, at the end of the stress test procedure it is clear that ENSREG has not intervened in any case. The peer review of the updated NAcP was more or less a formal review than an evaluation of the remaining risks. The summary report of the ENSREG workshop of April 2015 only highlighted good practice and did not mention the grave problems at many plants.

- Thus, it is not surprising that operators and national regulators do not take the ENSREG recommendations as serious as to follow up them up.
- The evaluations of the EU Stress Test focused strongly on the robustness of plants beyond their initial design basis. This was a new and therefore important field of analysis, which is usually not covered in detail in the safety analyses of nuclear power plants. As a result valuable information was obtained. However, the information does not have so much consequences. Although considerable risks are known, it was pointed to the low probability of the extreme event or of the limited operation time.
- The stress tests did not focus on important shortcomings in the original design basis of European nuclear power plants. While the operator and national regulator had to discuss the conformance of the plant with its design basis, they were not required to consider the design's compliance with modern standards such as the WENRA Safety Objectives for New Power Plants.
- The design deficiencies of older plants were not fully covered by the results of the EU Stress Test. For example, for a loss of electrical power, important factors such as the physical separation or protection of the emergency power supply system were not analysed in detail, even though the Fukushima disaster clearly showed that design flaws such as placing all emergency diesel generators and switchyards in the basement of the building without protection against flooding of the site can have a severe impact on the safety of a plant.
- Countries in which the power supply strongly depends on nuclear power plants are "forced" to operate their plants despite the known risks like, e.g. Czech Republic, France and Belgium.
- Possible improvements as suggested by the operator were to be taken into account in the regulator's assessment, making it difficult to judge the plant's actual status. Whether or not certain improvements will in the end be installed, is not clear today. Several necessary measures, and in particular the most important ones, were postponed or even cancelled in the last two years (for example at Muehleberg , Krško and Tihange) And it has to be expected that further measures will be cancelled – in discussions between the operators and regulator – in an intransparent procedure behind closed doors.
- The prevention of hydrogen explosion is one of the most important lessons learnt from the Fukushima accident. However, most operators and several regulators concluded after performing analyses there is no explosion risk in their specific reactor. Remaining uncertainties are analysed until they "disappear" – they will resurface during the next accident.
- Due to the very low electricity prices of the past years, the economics of nuclear power plant operation are very strained. Thus the operator need to avoid any investment , for the remaining operation time or has to get the licence for operation time extension in exchange for as little upgrades as possible.

This assessment of the EU stress test results leads to a very serious and worrisome conclusion: Until now no lessons learnt from the accident at Fukushima.

At all European nuclear power plants severe accidents can occur – any time.

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