Post-
Fukushima
accident

Switzerland

Peer review country report

Stress tests performed on European nuclear power plants

ENSREG
European Nuclear Safety Regulators Group
Stress Test Peer Review Board

1 GENERAL QUALITY OF NATIONAL REPORT AND NATIONAL ASSESSMENTS

The accident at the Fukushima nuclear power plant (NPP) in Japan on 11th March 2011 triggered the need for a coordinated action at EU level to identify potential further improvements of NPP safety. On 25th March 2011, the European Council concluded that the safety of all nuclear plants in EU Member States and participating neighbouring countries (Switzerland, Ukraine) should be reviewed, on the basis of comprehensive and transparent risk and safety assessments - the stress tests. The stress tests consist in three main steps: a self-assessment by licensees, followed by an independent review by the national regulatory bodies, and by a third phase of international peer reviews. The peer review also consists of 3 steps: an initial desktop review, three topical reviews in parallel (covering external initiating events, loss of electrical supply and loss of ultimate heat sink, and accident management) and the country visit. There are seventeen individual country peer reviews.

Switzerland has a total of five NPP units at four different sites: Beznau with two units (KKB1 and KKB2), Gösgen (KKG), Leibstadt (KKL) and Mühleberg (KKM) with one unit each:

- The two units at Beznau are Pressurized Water Reactors (PWRs), supplied by Westinghouse, with a net output of 365 MWe each. Commercial operation of KKB started in 1969 and 1971, respectively; these are the oldest operating units in Switzerland.
- The Gösgen NPP is a PWR, supplied by Siemens KWU, with a net output of 985 MWe. Commercial operation of KKG started in 1979.
- The Leibstadt NPP is a Boiling Water Reactor (BWR), supplied by GE, with a net output of 1165 MWe. Commercial operation of KKL started in 1984.
- The Mühleberg NPP is a BWR, supplied by General Electric (GE), with a net output of 373 MWe. Commercial operation of KKM started in 1972.

All these NPPs have been modernized and refurbished during their lifetimes.

The Swiss National Report (CH-NR) has been prepared on the basis of the Final Reports of the Licencees, and addressed NPPs and spent fuel pools, which are located on the plant sites. The co-located fuel storage facilities have not been evaluated in the course of this exercise.

In general, Switzerland submitted a very comprehensive national report, which reflected the analyses undertaken and their outcome. In the course of the visit, additional explanations were provided in the form of detailed presentations.

A draft country review report for Switzerland was prepared during the Topical Review in February 2012 in Luxembourg, based on the CH-NR, discussions on the three topics have been held with Swiss representatives. The draft report was delivered to Switzerland in advance of the peer review. The Swiss regulator provided comments to the report in advance of the visit along with additional information on the open issues. This then served as a basis for the peer review team visit. The visit encompassed discussions with the regulator as well as representatives of all operating NPPs. As a part of the visit, a detailed tour of the Beznau NPP took place, which provided additional information and clarifications, including observation of specific areas and equipment of interest.

The topics for the Beznau site visit where delivered to Switzerland in advance and during the course of the plant visit all the locations requested by the peer review team were made accessible. Unhindered access has been granted and sufficient explanations provided.

The Country Report was finalized at the end of the country review, and agreed between the peer review team and the national regulator. The main findings of the peer review are specified at the end of each topical chapter.

The peer review team would like to commend the regulator and the operators and in particular all those colleagues who were directly involved in the review, for their good cooperation and mutual respect.

1.1 Compliance of the national reports with the topics defined in the ENSREG stress tests specifications

The CH-NR covered all topics defined by ENSREG and the ENSREG specification was followed in regard to structure. Due to the variety of NPP designs the report did not provide detailed descriptions of design features (details are provided in the Licensees reports). The contents of the report is balanced and well organized.

1.2 Adequacy of the information supplied, consistency with the guidance provided by ENSREG

The information presented is generally in agreement with the ENSREG guidance.

Necessary information has been provided concerning the design basis, margins and cliff edge effects for earthquakes and flooding.

The CH-NR provides general information on the safety systems. Missing details needed to fully understand their robustness are available in the operators' reports. The safety layers of electrical power supply are especially well covered. The approach in defining "three safety trains"[1] that are supporting the defence in depth discussion is worth noting. Also useful is the information on the requirements and practice in performing Periodic Safety Reviews (PSRs) and Probabilistic Safety Assessment (PSA).

The information supplied is adequate concerning severe accident management. The details and some comprehensive information that were missing in the CH-NR have been clarified during the Topical Review meeting (e.g. for Beznau site multi-unit event information). Additionally, the regulatory framework and requirements regarding severe accident management was also clarified during the peer review visit to the country.

1.3 Adequacy of the assessment of compliance of the plants with their current licensing/safety case basis for the events within the scope of the stress tests

There was no evidence to indicate that the plants would not be compliant with their current licensing basis. At the time of the NPPs construction, the design basis did not include many of the requirements that were added over subsequent years. Also, the original licencing basis did not include the regulatory requirements for beyond design basis accidents, which were added later. In order to comply with these additional requirements, all the NPPs were subject to significant modifications and upgrades.

The assessment of compliance of NPPs with their current licensing basis, within the areas that are contained in the stress tests specification, has been inspected by the Swiss federal Nuclear safety Inspectorate ENSI. In this sense, as reported by ENSI, all the NPPs were found to be compliant with the regulatory basis. Nevertheless, before being allowed to resume power operation, KKM was requested to implement remedial measures, which were approved by the regulator in summer 2011.

1.4 Adequacy of the assessments of the robustness of the plants: situations taken into account to evaluate margins

The assessment of the robustness of the NPPs, including available margins with respect to seismic events and flooding, is considered adequate. The analyses undertaken to quantify the available margins to seismic events and flooding were up to date, thorough and in accordance with ENSREG specifications. The assessment of extreme weather related phenomena has not been performed with the argument that the margins available to the aircraft crash and explosions are such that they envelope any of the extreme weather phenomena. As mentioned in the CH-NR, ENSI recognises that a comprehensive determination of extreme weather hazards needs to be followed-up.

[1] The safety trains mentioned here is a very specific Swiss terminology depicting different success paths to bring the plant to a safe shut down condition that are designed to cope with specific events

All situations required by the ENSREG specifications were assessed with respect to loss of power supply and loss of ultimate heat sink. Corresponding margins and cliff edges have been determined. In some cases, the margins related to loss of Ultimate Heat Sink (UHS), have not been evaluated as they are considered to be enveloped by Station Black Out (SBO).

Regarding severe accidents, the assessment is considered to be adequate.

1.5 Regulatory treatment applied to the actions and conclusions presented in national report

The regulatory review of the actions and conclusions presented by the Licensees was visible and is in certain cases quite broad. Each Licensee action has been evaluated by ENSI or is at least commented on. In the context of the stress tests, ENSI was proactive in the whole process. Most of the analyses has been reviewed in detail by ENSI; in some cases supported by TSOs. In the CH-NR, there is a clear distinction between input information that has been validated by ENSI and those, which have been supplied by the Licensees without being reviewed by ENSI.

By order of 18 March 2011, ENSI issued, as immediate measures, the establishment of an external storage facility containing portable equipment for accident management by 1 June 2011 (Reitnau facility; as a part of the country visit, the review team witnessed the existence and the available material in the facility). In addition, the back-fitting of two physically separate connections for the external spent fuel pool supply has been ordered by 2012. Also, ENSI ordered a design reassessment with regard to earthquakes, external flooding and combinations thereof in order to demonstrate compliance with dose limits. This work is to be completed by 30 June 2011 and 31 March 2012, respectively.

Further to this, ENSI performed topical inspections, e.g. on spent fuel pool cooling and integrity, protection against flooding and filtered containment venting systems.

Reflecting the outcome of the analyses and inspections, ENSI has already ordered safety improvement measures to be implemented in all NPPs. Further measures are subject to the results of analyses, which is ongoing.

2 PLANT(S) ASSESSMENT RELATIVE TO EARTHQUAKES, FLOODING AND OTHER EXTREME WEATHER CONDITIONS

2.1 Description of present situation of plants in country with respect to earthquake

2.1.1 DBE

2.1.1.1 Regulatory basis for safety assessment and regulatory oversight

The regulatory system is stipulated by the Swiss Federal legislation, ordinances and the ENSI guidelines. Fundamental requirements regarding external hazards are part of the Nuclear Energy Ordinance (NEO), the Ordinance of the Federal Department of the Environment, Transport and Communications (DETEC) on Hazard Assumption and the Evaluation of Protection Measures against Accidents in Nuclear Installations (DETEC-O). The DETEC-O stipulates hazard assumptions for accidents which originate inside and outside the plant, as well as the radiological and technical criteria for proof of adequate protection against accidents. Accordingly, hazards due earthquakes must be determined with the help of probabilistic hazard analysis. For proof of adequate protection against natural events, account must be taken of hazards with an exceedance frequency of 10^{-4} per year.

2.1.1.2 Derivation of DBE

The maximum acceleration values for the safe shutdown earthquake (SSE) and, in some cases, for the operating basis earthquake , vary according to the specific plant. These acceleration values are specified for selected reference elevations (bedrock surface, foundation of reactor buildings , ground surface) and are derived from the acceleration spectra assigned in each case. The peak ground accelerations are reflected in three hazard levels:

– H1: Hazard, which the plant was originally designed to withstand (horizontal Peak Ground Acceleration (PGA) on the bedrock ranging from 0.12g to 0.15g), based on a deterministic approach;

– H2: Hazard for which the plant was re-qualified at the end of the 1970s based on a probabilistic approach. There was no exceedance frequency at that time, but it corresponds roughly to an exceedance frequency of 10^{-4} per year (PGA 0.15g-0.20g, may be identical with H1). This has been used for the 'stress test' analysis;

– H3: New hazard to be derived from ongoing PEGASOS Refinement Project (PRP), based on probabilistic seismic hazard analysis (Senior Seismic Hazard Analysis Committee SSHAC, level 4), which is considered to be 'state of the art' by the Regulator. It includes a recently updated paleoseismological data-base and uses a solid scientific basis. Intermediate results of PRP, which will be submitted in March 2012 to the Regulator, will be used to reassess the Design Bases. Licensees are requested by ENSI to demonstrate that the NPPs can cope with the intermediate PRP hazards. Final results of PRP will be submitted by the end of 2012.

2.1.1.3 Main requirements applied to this specific area

The currently applicable hazard level H2 is characterized by PGA for the SSE, determined on a probabilistic basis, with an exceedance frequency of 10^{-4} per year.

The Regulator will, in the near future, request all Licensees to demonstrate that the NPPs can cope with the H3 hazard.

2.1.1.4 Technical background for requirement, safety assessment and regulatory oversight

The Swiss NPPs were originally designed for H1 level hazards, based on individual underlying assumptions and requirements that essentially corresponded to the state-of-the-art during the various periods when they were planned and built. Later (end of the 1970s) a new probabilistic assessment of the seismic hazard was made, corresponding roughly to 10^{-4}/y exceedance frequency (H2) for the SSE.

At the end of the 1990s, the operators were asked to re-determine the seismic hazard in accordance with the latest methodological fundamentals, and in particular to provide a comprehensive quantification of the uncertainty of the calculation results. The seismic hazard was re-determined on the basis of a probabilistic method (SSHAC, level 4) developed in the US (NUREG/CR-6372). This project, called PEGASOS, was initiated by the NPP operators in order to implement requirements of ENSI. Based on the PEGASOS results, ENSI has required stricter seismic hazard assumptions to be incorporated in the plant-specific PSA.

2.1.1.5 Periodic safety reviews

Seismic safety is reviewed every 10 years within the framework of the PSR. Since the start of PSRs in 1970, a single methodology was used for all sites. During the re-assessment of the seismic hazard assumptions at the end of the 1970s (hazard level H2), the designs were reviewed. In particular, the robustness of the safety equipment against earthquakes was increased at the older plants. As part of the PSR process, continuous compliance of the seismic design with the current requirements is also reviewed. The focus is on structural changes of the plant and on new knowledge regarding seismic hazard, regulations, calculation methods, materials and structural design.

2.1.1.6 Conclusions on adequacy of design basis

ENSI confirms that adequate design bases are in place to manage SSE for all NPPs. The latest PSAs already take into account stricter seismic hazard assumptions. Furthermore the follow-up PRP was launched which will present its results by the end of 2012. Seismic integrity of the Spent Fuel Pools (SFPs) has been demonstrated for the H2 hazard with margins. The present design basis for the SFP cooling system at KKB and KKM appears inadequate (H1 instead of H2). However, KKM shows for the SFP cooling system compliance with H2 hazard. ENSI has prescribed the H3 as the new design basis and requested to back-fit the SFP cooling systems up to H3 hazard for KKB and KKM.

The peer review team considers that taking account of enhancements during PSR, the Design Basis Earthquake (DBE) is adequate for all plants, with the exception of the SFP cooling system at KKB.

2.1.1.7 Compliance of plant(s) with current requirements for design basis

The CH-NR states that comprehensive programs for maintenance, recurring tests and inspections, system and component function tests and monitoring of ageing are in place to monitor and ensure the proper functioning of Structures, Systems, and Components (SSC). It also states that as a part of the PSR the condition of the NPPs and their operational management is reviewed to ensure compliance with legal and regulatory requirements as well as the provisions of the licenses. The CH-NR states further that compliance of the plant condition with the approval bases is examined in the course of ongoing supervision by the authority. According to the CH-NR, the seismic resistance of the containment venting at KKG is below H2. ENSI requested to the Licensee to confirm the qualification level and to perform back-fitting if necessary.

SFP cooling at KKB and KKM were initially seismically qualified against H1 hazards. However, KKM also showed compliance with H2 hazard. The Regulator requested to back-fit the SFP cooling up to H3 hazard for both NPPs. Back-fitting measures are planned for KKM and KKB (injection system finished by 2012 and cooling system by 2015).

2.1.2 Assessment of robustness of plants beyond the design basis

2.1.2.1 Approach used for safety margins assessment

The Licensees have determined the seismic safety margins for each fundamental safety function. The CH-NR documents the margins determined for the safety relevant systems and buildings. IAEA safety guide NS-G-2.13 was used. The seismic robustness for the safety equipment (SSC) was determined in each case, expressed by the HCLPF value (high confidence of low probability of failure). For accelerations below the HCLPF value, it was assumed in the analyses that the probability of seismic failure is less than 1%. The robustness of a safety train is determined by the safety equipment with the lowest HCLPF value. The robustness of the overall system is derived from the safety train with the highest HCLPF value. The safety margin is defined by the ratio of the plant's HCLPF value (PGA HCLPF) to the peak ground (horizontal) acceleration value (PGA) for hazard level H2.

2.1.2.2 Main results on safety margins and cliff edge effects

The CH-NR provides quantitative information about safety margins. The analysis describes the margin assessments in the context of H2. The safety margins show that several robust safety features are available in all Swiss NPPs in order to bring the plants into a safe shutdown state, even after an earthquake, which exceeds hazard level H2. HCLPF values reported for the safety equipment are currently being verified by ENSI. It also appears from the CH-NR that, except for KKM, the seismic robustness of the SFP in Swiss NPPs can be rated as high and that the newer NPPs, KKG and KKL, have spent fuel pool cooling systems which display a high safety margin in relation to an earthquake of hazard level H2. ENSI has required that all the spent fuel pools as well as their connections must be systematically reassessed by March 2012 with respect to the H3 hazard. Regarding the integrity of the containment in case of a severe earthquake, ENSI considers that there is a need for more detailed examination of the seismic robustness of the isolation of the containment or the primary circuit. ENSI also considers that measures to improve the earthquake resistance of the containment venting systems in case of beyond design basis accidents should be reviewed at KKG and KKL.

2.1.2.3 Strong safety features and areas for safety improvement identified in the process

According to ENSI, there is currently no need for further improvement measures identified beyond the back fitting of SFP cooling systems in the older NPPs (KKB, KKM), which has already been requested, and the additional injection capabilities for the SFP. ENSI identified a need for the following additional investigation: robustness of isolation of containment and of isolation of primary circuit system and robustness of the containment venting system at KKG and KKL. ENSI also requested further study regarding the need for automatic scram, triggered by seismic instrumentation for all NPPs.

In ENSI's view, flooding induced by a severe earthquake does not lead to a hazard for the KKB, KKL and KKG NPPs. According to present knowledge the seismic safety margin for the Wohlensee dam wall is limiting at KKM with regards to the seismic robustness. Following a breach of the Wohlensee dam, it is expected that the cooling water intakes of the special emergency system would be clogged. The flood height was already covered by the original design. ENSI have already requested an alternate heat sink diverse to the water intake of the river Aare (2015), so that a breach of the Wohlensee dam will not be limiting in the future.

The team recognizes the significant efforts carried out to update in depth the seismic hazard assessment in Switzerland, which would lead to identification of possible safety improvements.

2.1.2.4 Possible measures to increase robustness

The Gösgen NPP found in its stress test analysis that the supporting structures for cables and the control stations in the main control room should be seismically upgraded. Moreover, there is an examination of the potential extent of improvements to the seismic robustness of the emergency diesel generator units, and to the fixtures for auxiliary equipment.

2.1.2.5 Measures already decided or implemented by operators and/or required for follow-up by regulators

Targeted back-fitting measures to improve the seismic resistance of safety related SSCs have been implemented in the past on the basis of knowledge gained from the PSAs. This continuous process is being advanced still further at KKG by planned improvement measures. At KKB, a new set of Emergency Diesel Generators (EDGs) that are robust against earthquake are being installed.

Comprehensive reassessment of seismic hazard is currently being finalized (PRP) and the results are expected by the end of 2012. Retrofitting of SFP cooling systems at KKB and KKM are planned.

The immediate measures after the Fukushima accident include the development of a central Swiss earthquake and a flood-resistant external storage facility with additional operational resources (Reitnau storage), as well as the back-fitting of two physically separated connections for the external spent fuel pool supply at all the NPPs (without the need to enter the SFP area).

2.1.3 Peer review conclusions and recommendations specific to this area

The CH-NR describes the Design Basis in an accurate way and is considered to be acceptable in comparison with international standards. The report references the PSR as an important tool for improving the seismic safety. Quantitative margins to cliff edge effects are identified. More information on possible measures to be taken will be identified in the forthcoming PEGASOS refinement project and out of the analyses related to the open points already defined by ENSI. The team recognizes the significant efforts carried out to update in depth the seismic hazard assessment in Switzerland, which would lead to identification of possible safety improvements.

A Seismic Monitoring System is installed at all NPPs. ENSI requires a feasibility study for the need of installation of an automatic scram system triggered via the seismic instrumentation.

SFP cooling at KKB and KKM were initially seismically qualified against H1 hazards. KKM showed however compliance with H2 hazard as well. The Regulator requested to back-fit the SFP cooling up to H3 hazard for both NPPs. ENSI requested to confirm the seismic resistance of the containment venting at KKG (below H2 according to the CH-NR) and to perform back-fitting if necessary.

The development of an earthquake and flood-resistant external storage facility with additional operational resources (central Swiss external storage facility in Reitnau), is considered a good practice.

2.2 Description of present situation of plants in country with respect to flood

2.2.1 DBF

2.2.1.1 Regulatory basis for safety assessment and regulatory oversight

Hazards due to flooding must be determined with the help of probabilistic hazard analysis. For proof of adequate protection against natural events, account must be taken of hazards with a frequency greater than or equal to 10^{-4} per year. In accordance with ENSI's specified requirements, the licensees were basically required to take account of three hazard levels:

- H1 Flooding hazard that the plant was originally designed to withstand;
- H2 Flooding hazard for which the plant was re-qualified (may be identical with H1);
- H3 New results for the flooding hazard derived from studies carried out in connection with the general license applications for new nuclear power plants or the new deterministic proof of safety for a flood corresponding to an exceedance frequency of 10^{-4}/y.

The current hazards were updated recently in the general license applications for new nuclear power plants (2008) or the new safety demonstration for flooding as required by ENSI (2011).

2.2.1.2 Derivation of DBF

At KKB, KKL and KKM the Design Basis Flood (DBF) was originally determined on the basis of dam and/or weir breach scenarios. The DBF of KKG was based on a 10^{-3}/y flood (flooding hazard H1). The flooding hazard at KKM was reanalyzed in 1991 pursuant to the application for an unlimited-term operating license and/or the increase in power. This analysis produced a lower maximum flood level for the dam breach scenario, which was also originally limiting. This H2 flooding hazard is now the basis for the KKM-design. According to the studies relating to the new H3 flooding hazard, it is no longer the weir breach scenarios, but (as a new feature), the naturally-induced flood with a frequency of 10,000 years that would lead to the highest flood levels for KKB and KKL. The new flooding hazard H3 has been derived either considering a 10^{-4}/y flood or, in case of KKM-site, an extreme flood scenario, which actually gives rise to a bigger discharge than the 10^{-4}/y floods.

2.2.1.3 Main requirements applied to this specific area

The currently applicable hazard level H3 is determined on a probabilistic basis, with an exceedance frequency of 10^{-4} per year.

The special emergency systems constitute another safety train that is primarily intended to control accidents due to external events. Special design features of the special emergency systems include their functional independence and physical separation from the conventional safety systems, and an autarkic operation of at least 10 h without manual intervention. These special emergency systems shall function even in the event of a design base flooding.

2.2.1.4 Technical background for requirement, safety assessment and regulatory oversight

The discussion on the technical background presented in the section 2.2.1.1 to 2.2.1.3.

2.2.1.5 Periodic safety reviews

The need to update the flood hazard assessment is checked during each PSR, which are conducted every 10 years. Recent updates of the flood hazard assessments have been performed between 2008 and 2011.

2.2.1.6 Conclusions on adequacy of design basis

The design basis against flooding is considered adequate and consistent with current European good practices.

2.2.1.7 *Compliance of plant(s) with current requirements for design basis*

The Swiss nuclear power plants display adequate protection against the 10^{-4}/y flood. According to ENSI, all NPP comply with the current requirements for the design basis. Recent back fitting measures carried out at KKM have allowed to comply with the regulatory requirements.

2.2.2 Assessment of robustness of plants beyond the design basis

2.2.2.1 *Approach used for safety margins assessment*

A margin assessment has been reported for each site. The approach for the assessment is mainly focusing on 10^{-4}/y flood and presents the difference of that level compared to the level the site can withstand before any major damage occur. All sites are also evaluated with an extra 20% river flow to demonstrate safety margins.

2.2.2.2 *Main results on safety margins and cliff edge effects*

All plants give an estimate of the flood levels to be expected in case of a 10^{-4}/y flood. According to their analyses, the water level remains several meters below the plant site at KKL or below the level where special emergency systems will be affected (KKM, KKB, KKG).
All sites consider the consequences of a discharge, which substantially exceeds the 10^{-4}/y flood (by 20% or more). No cliff-edge effect is identified for any plant in this regard. The consequences of the failure of individual or multiple hydraulic installations (e.g. dams) are also considered by all Licensees. Only KKM states that a simultaneous breach of several dam walls may trigger a cliff-edge effect as this situation could possibly lead to higher flood levels than those on which the design is based.

2.2.2.3 *Strong safety features and areas for safety improvement identified in the process*

All Licensees demonstrated margin of 20% river flow beyond the DBF. A recent re-assessment of the flood hazard was carried out.
For all NPPs except KKL, ENSI has identified as open point the impact of total debris blockage of hydraulic engineering installations (e.g. upstream dams), and has requested additional analyses accordingly.

2.2.2.4 *Possible measures to increase robustness*

For KKB, the improvements mentioned below will increase the robustness of SFP-cooling against DBF because safety train 1 is not flood protected and there is currently no safety train 2 for the SFP cooling:

- Installation of an additional independent flood protected spent fuel pool cooling system with coolant supply from the protected special emergency well;
- Extension of the in-plant accident management measures for injection into the spent fuel pools via an existing alternative pool cooling system, and via a new flood protected pool cooling system;

KKL states that no measures to increase robustness of the plant are necessary. KKG plans to build a flood protection wall to prevent water ingress through a breach in an embankment in combination with the preparation of a shut-off bulkhead for access via the power plant road, which would simplify the accident management measures. KKM plans to install a diverse flood protected SFP cooling water system, part of safety train 2.

2.2.2.5 *Measures already decided or implemented by operators and/or required for follow-up by regulators*

For KKG the following improvements have been implemented:

- Introduction of an automatic advance flooding alarm to guarantee timely prior warning
- Additional sealing of building shells, air inlets and doors, etc., of buildings with equipment used for the safe shutdown of the plant

- Specification of the organizational and administrative measures to be implemented in case of a "flood" accident in the emergency procedures
- Preparation for the erection of dam bulkheads
- Installation of 'flood valves' to seal ventilation intakes

For KKM the following improvements have been implemented:

- Provision of mountable flood protection walls for protection against flooding of the auxiliary cooling water pumps in the pump building, and enhancement of the relevant operating instructions.
- Provision of mobile pumps to inject water into the diversified heat sink intake structure.
- Implementation of an additional injection option (intake shaft) into the diversified heat sink intake structure.
- Back-fitting of three special vertical pipes on top of the diversified heat sink intake structure to ensure the cooling water supply for the diversified heat sink.

2.2.3 Peer review conclusions and recommendations specific to this area

Hazards due to flooding have been determined with the help of probabilistic hazard analyses. For proof of adequate protection against natural events, an account must be taken of hazards with a frequency greater than or equal to 10^{-4} per year. Flooding scenarios covered consist in river flood, dam and weir breaches, ground water rising. All NPPs have recently updated the flood hazard analyses. The design basis against flooding is considered adequate and consistent with current European good practices. KKB, the plant that was visited by the review team, appeared to have a very good volumetric flood protection.

All Licensees demonstrated a margin of at least 20% river flow beyond the DBF. KKM and KKG have identified and implemented a number of improvements of the robustness against external flooding.

2.3 Description of present situation of plants in country with respect to extreme weather

2.3.1 DB Extreme Weather

2.3.1.1 Regulatory basis for safety assessment and regulatory oversight

The loads resulting from extreme weather conditions were determined at the same time as the applications for construction licenses were submitted (1960s and 70s), using the then valid methods based on the standards of the Swiss Association of Architects and Engineers (SIA). Depending on the location and (for example) the altitude, the SIA standards additionally take account of the various assumed snow or wind loads, in combination with the resultant operational loads. In particular, the determination of the hazard assumptions is stipulated in the current regulations by the DETEC-O. According to this ordinance, the operators must prove that the loads that could occur on the basis of 10^{-4}/year exceedance frequency can be dealt with.

2.3.1.2 Derivation of extreme weather loads

All the final reports (except the KKB report), explicitly state the expected maximum wind speed for an excess frequency of 10^{-4} per year. In ENSI's view, it can generally be stated that class I buildings for all the plants are designed against greater loads than those to be expected in case of extreme winds or tornadoes. This is especially true of the reactor and special emergency buildings that are protected against the impacts of aircraft crashes, earthquakes or explosions. In particular, the function of the second safety train is ensured in these cases. All operators examine the potential effects of extreme weather on the risk of core damage as a part of the PSA.

Considering a conservative assumption on the tornado class, the resultant dynamic pressures at KKG are slightly higher than for extreme wind gusts, however, are still covered by other load cases such as earthquake or aircraft crash. Likewise, flying debris ("wind missiles"), are covered by the case of an aircraft crash. At KKM, the 10^{-4}/year tornado is covered by the Swiss civil engineering design standard, hence poses no problem. KKB and KKL did not mention any tornado occurrence frequencies in their final reports and additional analyses have been consequently requested by ENSI.

Regarding the extreme rainfall, in addition to the site drainage system, the topography of both KKL and KKM allows rainwater to be naturally drained out of the areas containing safety related buildings. For KKB and KKG, the rainwater flow corresponding to a 10^{-4}/year exceedance frequency remains lower than the drainage system flow capacity. For extreme temperatures, the Swiss civil engineering design standard has been applied during the initial construction. At the moment there is no demonstration of the adequacy of the design basis extreme temperatures with the 10^{-4}/year regulatory requirement and ENSI has requested consequently additional analysis to the Licensees.

2.3.1.3 *Main requirements applied to this specific area*

To proof adequate protection against natural hazards, account must be taken of events with a frequency greater than or equal to 10^{-4}/y.

2.3.1.4 *Technical background for requirement, safety assessment and regulatory oversight*

The Licensees' final reports on the determination of the relevant hazard assumptions make special reference to the plant-specific PSA, to the Safety Analysis Reports for the new nuclear power plants on existing sites for which applications were submitted (and have now been suspended), and to the data made available by MeteoSwiss (the Federal Office of Meteorology and Climatology).

2.3.1.5 *Periodic safety reviews*

As part of the PSR, which is conducted every 10 years, the condition of the NPPs are examined to determine compliance with legal requirements, with the provisions of the licenses and with the official stipulations contained in ENSI permits. Finally, compliance of the plant condition with the licensing base is also examined as part of ongoing supervision, and during inspections by, and technical discussions with, the supervisory authority.

During each PSR, the Licensees check if the hazard analyses for extreme weather need to be updated.

2.3.1.6 *Conclusions on adequacy of design basis*

Extreme weather design bases for Swiss NPPs are defined in current requirements by a 10^{-4}/year exceedance frequency. This is consistent with practices at international level.

2.3.1.7 *Compliance of plant(s) with current requirements for design basis*

The Regulator concludes that the plants comply with their original design basis. ENSI has however requested a demonstration of the adequacy of the design basis extreme weather, including temperatures, with the more recent 10^{-4}/year regulatory requirement.

2.3.2 Assessment of robustness of plants beyond the design basis

For extreme weather conditions, only KKM and KKG provide safety margins for extreme winds, based on the design basis. In addition KKG provides a corresponding assessment for extreme snow loads. The Licensees do not report margins for the other extreme weather conditions. ENSI has requested all Licensees to demonstrate that the NPPs can comply with the 10^{-4}/year regulatory requirement. Nevertheless, extreme weather events are considered in plant specific PSAs even when their frequency might be below 10^{-4}/year. Winds and tornadoes are quantified in all PSAs.

2.3.2.1 *Approach used for safety margins assessment*

There is no quantitative information about safety margins.

2.3.2.2 Main results on safety margins and cliff edge effects

An evaluation of the safety margins for extreme weather conditions is not provided in the CH-NR. This holds for the cliff edges as well. However, the fact that the NPPs are designed to cope with aircraft crash is believed to envelope extreme winds and tornados.

2.3.2.3 Strong safety features and areas for safety improvement identified in the process

No specific improvements have been identified for extreme weather conditions.

2.3.2.4 Possible measures to increase robustness

Based on the operators' statements, ENSI concludes that buildings important to safety are adequately protected against extreme weather conditions. There are still some points open regarding the determination of the individual hazards.

2.3.2.5 Measures already decided or implemented by operators and/or required for follow-up by regulators

There is no complete and comprehensible proof of the precise determination of the hazards and their impact on the plants at this stage. ENSI has requested the proofs of protection against extreme weather conditions, including combinations thereof.

2.3.3 Peer review conclusions and recommendations specific to this area

Specific assessments of the extreme weather conditions beyond design bases have only been undertaken in PSAs for extreme winds and tornadoes. ENSI therefore identified an open point for a comprehensive assessment of the related hazards.

Combinations of extreme weather conditions are identified, but they are not analyzed in detail. ENSI has recognized this issue and will follow it up in regard to protections against extreme weather conditions, including combinations thereof.

The margins to the extreme weather design basis have not been estimated within the process. In general, the margins are likely to exist mainly due to the design of the Swiss NPPs covering also events such as explosions and aircraft crashes that are enveloping most of the conditions of extreme weather events (e.g. wind and tornadoes). Margins for heavy rains likely exist due to NPP site topography and design of the drainage systems.

The peer review team recommends considering the assessment of margins with respect to extreme weather conditions exceeding the design bases, e.g. by extending the scope of future PSRs.

3 PLANT(S) ASSESSMENT RELATIVE TO LOSS OF ELECTRICAL POWER AND LOSS OF ULTIMATE HEAT SINK

3.1 Description of present situation of plants in country

3.1.1 Regulatory basis for safety assessment and regulatory oversight

For this topic of the EU stress test, the fundamental provisions of the Nuclear Energy Act regarding the principles of nuclear safety and the operators' responsibilities for the safety of their NPPs apply, as well as do the fundamental requirements in the NEO and the Ordinance of the DETEC-O.

In the CH-NR it is stated that the ENSI-Guideline R-101 contains requirements concerning SBO and loss of UHS. Furthermore the ENSI-guideline R-103 contains additional requirements but is not explicitly mentioned in the CH-NR.

The contents of the CH-NR suggest that the regulatory basis for safety assessment and regulatory oversight are in agreement with good international practice.

3.1.2 Main requirement applied to this specific area

The Swiss NEO defines the principles for the design of the safety functions of NPPs. These include, in particular, the single failure criterion, the principles of redundancy and diversity, the functional and physical separation, the automation principle and the conservatism in design. However, in regard to compliance with these design requirements, the principle applied to existing NPPs is to back fit the safety functions to the extent that is necessary, which is applied on the basis of experience and the state-of-the-art. First three safety layers are conventional (i.e. non safety related). Specific safety requirements are applied to higher safety layers.

The 1E safety classification for existing nuclear power plants is addressed in the guideline ENSI-G01; this guideline refers to IEEE 308/323/344/379/384/603 US standards. Such classification implies the seismic categorisation of equipment. This applies to the safety layer 4.

Concerning UHS, the main requirement issued by ENSI for all Swiss plants is to have an additional water supply, in the form of emergency wells and/or emergency cooling towers; this could be classified as a full-scale alternative heat sink, according to the ENSREG specifications.

3.1.3 Technical background for requirement, safety assessment and regulatory oversight

The technical background in Switzerland is basically deterministic; the applicable regulations and standards must be fulfilled. PSA mainly is considered as a complementary tool. The use of PSA in Switzerland is thus comparable with the one in other countries.

For severe accidents, risks of core damage and of radioactive releases are determined in Level 1 and Level 2 PSAs. PSA is required to be a living document and is subject to continuous update and improvement. ENSI reported that the probabilistic safety objectives recommended by the IAEA for existing plants are complied with.

Additionally, all operational events need to be analyzed and the operational experience feedback is used to improve safety in NPPs. This requirement is based on the NEO requiring operators to keep track of operating experience in comparable plants and assess its significance for their own plants.

3.1.4 Periodic safety reviews (regularly and/or recently reviewed)

PSRs are required by law every 10 years at the latest. ENSI reported that PSR have been conducted at the different NPPs within the required periodicity. These reviews have led to numerous improvement measures in the past. It is mentioned in the CH-NR that the results of the last PSR have been taken into account for the stress test assessment.

3.1.5 Compliance of plants with current requirements

There is no information indicating that Swiss NPPs are not compliant with current requirements. ENSI has concluded that the statutory requirements on safety provisions needed to fulfil the fundamental safety functions are met.

Currently, the SBO as defined in the ENSREG specification is not a regulatory requirement. Nevertheless, ENSI concluded that the SBO scenario can be managed by the four Swiss NPPs.

3.2 Assessment of robustness of plants

The robustness of Swiss NPPs is based on the three safety 'trains' (different shutdown success paths), concept that can bring a plant into a safe shutdown state.

1. The first train contains the conventional safety systems used to control the accident
2. The second consists of the special emergency systems (with functional and physical separation and an autarkic operation for at least 10 hours without manual intervention)
3. The third train covers the preventive accident management measures

The protection of Swiss NPPs against Loss Of Off-site Power (LOOP), is based on already-mentioned multiple safety layers, redundancy of diesel generators, autonomy of such diesel generators, diversity with hydroelectric supplies, and the mobile equipment already available on-site and considered in safety layer 6.

All plants possess an additional cooling option (water source), which contributes to the robustness.

3.2.1 Approach used for safety margins assessment

In the scope of evaluation of safety margins, the design bases analysis was taken into account. These analyses were reviewed during the regular licensing process. For stress test purposes, additional analyses were performed, especially for estimating specific coping time. On all additional analyses, ENSI performed detail review and assessment and independently recalculated all the results. In the CH-NR, ENSI position on licensee analyses, the results and proposals are clearly stated.

The general approach adopted in assessing the safety margins with respect to the loss of electrical power and loss of heat sink aspects is to firstly describe the relevant systems available, together with the associated level of redundancy and diversity of equipment. Secondly, the timescales by which various safety functions need to be established by this equipment in order to prevent significant fuel damage are presented. Finally the level of autonomy with respect to fuel or coolant supplies is quantified. For each accidental scenario, the operator's results are described followed by ENSI response.

3.2.2 Main results on safety margins and cliff edge effects

In accordance with the ENSREG specifications, the CH-NR has considered 3 scenarios involving sequential loss of electrical power supplies. These scenarios are the LOOP supply , the LOOP supply and emergency electrical power supply (SBO) and the loss of all AC power supply (the "SBO" as defined by ENSREG specification). It is assumed that direct current (DC) continues to be supplied in these three scenarios.

All electrical components involved in emergency and special emergency electrical power supply systems (except the Hydro backed supplies) have a 1E classification and are qualified against earthquake.

3.2.2.1 Loss of off-site power (LOOP)

This scenario is within the design basis and can be handled in different ways with the different safety layers available. All sites have the possibility to operate in an island mode, in the case whereby the plant losses main grid supplies. If this option is not successful, the following two safety layers are the emergency diesels (and for 2 sites direct and secured underground connections to the nearby hydro power plants) and the special emergency diesels (part of safety train 2). The last resort would be the on-site mobile diesel generators and the power generators stored in the central Swiss Reitnau storage, available since June 1, 2011.

All Swiss NPPs fulfil the minimum period of autonomy of 72 hours (3 days) as mentioned in the ENSREG specification in case of a LOOP scenario. However, emergency DGs (ordinary back-up AC sources) have fuel for two days (KKB) and three days or more (KKG, KKL, KKM) in the same building. Special emergency DGs (diverse back-up AC sources), have supplies for 10 days (KKB) or at least three days (KKG, KKL, KKM) in the same building. On site fuel stocks are sufficient for at least five days at all Swiss NPPs. It was also confirmed that lubricant oil for diesel generators was not an issue during this period of time. Directly connected (buried cable) emergency hydroelectric power supplies (KKB, KKM) or emergency power connections (KKG, KKL) from the nearby HPPs improves possibility to restore the power supply. Hence, the LOOP scenario is covered by multiple and diversified supply options in all Swiss NPPs.

The CH-NR concludes that the Swiss NPPs fulfil the minimum period of autonomy of 72 hours (ENSREG specifications) with redundant and diverse means of supplying electricity.

3.2.2.2 Station blackout

For SBO scenarios two different stages are provided: loss of the ordinary AC sources and loss of all diverse AC sources. For the first stage bunkered special diesel generators (safety train 2) are available. NPPs' own local reserve of fuel is sufficient to operate the special emergency DGs for a proven period of more than nine days.

The first stage of the SBO scenario can be managed by the four Swiss NPPs in accordance with their design and is compliant with the Swiss regulations. Even before the events at Fukushima, where several units at the same site were simultaneously affected by a severe accident, potential for improvement regarding the emergency supply had been identified at KKB (replacement of existing emergency hydropower plant with emergency DG in separate buildings protected against earthquake and flooding).

In this scenario, the autonomy time of the batteries of the special emergency domain (safety train 2) is not an issue, as they are recharged by the special emergency diesel in operation. The autonomy time of other batteries, supplying the emergency and safety lightning and the communications infrastructure, has been estimated to be at least 4 hours, and extends in most cases from 7 to 9 hours.

The SBO scenario is within the design basis and can be safely managed by all Swiss NPPs for a period of time exceeding 72 hours. Safety train 3 (on site mobile diesel generators) and equipment held in the out site Reitnau storage, are additional remaining safety layers in place to cope with accident situations.

The second stage, a total loss of AC power scenario (total SBO), falls into the scope of beyond design basis accident. The remaining sources of power are DC power from batteries. Credit can also be given for the relevant accident management measures in place (safety train 3 and associated on site mobile diesel generators), and the equipment held at the external central Swiss Reitnau storage (which can be transported by air to NPPs in a short period of time).

The battery systems for the special emergency systems (safety train 2) meet the single failure criterion. The autonomy time is always more than 4 hours, and in some cases up to 20 hours. These times have been verified, in some cases by tests in all cases by calculations. Restoring the special diesel emergency feed or connecting mobile emergency power units can recharge the batteries. In this latter case, the time necessary to establish the connection ranges between 1 and 2 hours. On site diesel and oil stocks are sufficient to ensure several days of operation to the mobile emergency diesel generators.

In case of a total SBO scenario, the available battery systems ensure a sufficiently long bridging period until the supply from the AM diesel generators is established.

Taking account of the power generation units that can be procured in the vicinity, multiple emergency electrical supply options are available at all the plants. According to the information provided, additional mobile AM diesel generators with external air cooling are deployed for the emergency electrical measures as part of the total SBO scenario. This means that these units are not dependent on an external supply of cooling water. ENSI will follow up the development of a comprehensive strategy for the deployment of the AM emergency diesel on-site.

3.2.2.3 Loss of Ultimate heat sink (UHS)

River water is used as the primary UHS for the conventional safety systems (safety train 1) at all Swiss NPPs. Alternative cooling options are available for all sites via a second intake structure and/or well water. The cooling water supply for special emergency systems (safety train 2) is provided by special emergency wells for 3 sites and a special emergency river intake for the fourth one (consisting of the cooling water outlet).

In the event of the loss of the primary UHS, different options are available depending on the plants:

- KKB and KKL, safety train 1 can still be supplied by the emergency wells. It is also possible, as an alternative option, to supply cooling to the plant using the special emergency systems (safety train 2), which are connected to the special emergency wells.
- At KKG site, the loss of the first river water intake supplying safety train leads to the automatic switchover to another fully independent river water intake. However, in the event of a loss of primary UHS scenario, it is assumed that the river can't provide the water supply. In this instance, cooling to the plant is ensured by the special emergency systems, which are connected to the special emergency wells (safety train 2).
- At KKM, safety train 1 is no longer available in the event of the loss of primary UHS. Safety train 2 is then supplied from the special emergency intake (cooling water outlet), pumping water from the river. KKM relies on the river for supplying both safety train 1 and 2. Loss of the primary UHS assumes loss of both intakes and in consequence the loss of water supply for safety trains 1 and 2. ENSI reported that this case has been considered, and has required the plant to back-fit a full-scale alternative to the river supply for safety train 2.

In the loss of primary UHS scenario, ENSI concluded that the fulfilment of the safety function is ensured at all plants for an unlimited period of time with the equipment held on site.

The CH-NR includes considerations for the case of the loss of primary and alternate heat sinks. At KKB and KKL sites, the CH-NR then considers that the primary UHS (river) and the alternate cooling capability (emergency wells) are lost. A second alternate cooling capability consisting of specially protected emergency wells is available and supply safety train 2 with cooling water. No time restriction applies to this case. At KKG, the CH-NR assumes that the first and second river water intakes are lost (both used for safety train 1), and indicates that the special emergency wells are available to provide water to safety train 2. No time restriction applies to this case.

At KKM, the loss of the two water intakes from the river leads to the failure of safety train 1 and 2. Accident management measures must be initiated (safety train 3), in order to remove heat from the reactor and the SFP. The various water stocks available in on site tanks give sufficient time for operator actions to utilise other water reserves (fire extinguishing system network, hilltop reservoir, river...). The plant can be kept in safe conditions for 72 hours without any external support.

3.2.2.4 Loss of primary UHS with SBO

The combination of a first stage SBO and the loss of primary UHS do not represent an additional aggravating condition compared to the first stage SBO. The scenario is covered by the special emergency conditions, compliance with the safety functions is ensured by safety train 2 (special emergency systems for electricity supply and cooling).

For the simultaneous occurrence of a total (second stage) SBO and loss of UHS, the loss of UHS doesn't represent an aggravating factor as compared to the total SBO. The core damage is prevented by the initiation of accident management measures at an early stage, when automatic measures are still in progress. The intention is to use on site stored mobile operational resources of the fire brigade in order to inject water into a steam generator (SG) (for PWR) or into the reactor pressure vessel (BWR). Available sources are potable water, fire extinguishing networks or various reservoirs.

At PWR plants, the decay heat can be discharged to the atmosphere via spring loaded main steam safety valves, using the water reserve in the SG. One of the SG is vented to allow water supply from mobile fire extinguishing pump or firewater tender vehicle. For this purpose, main steam relief valves are opened locally by hand. The inventory of the feed water tank (not seismically qualified) is also gravity fed into the SG, providing several hours of cooling. This procedure allows the PWR plants to be kept in a safe shutdown state for more than 72 hours. Alternatively, mobile fire pump could be used to feed the SGs.

Prompt implementation of these accidental measures is important, as only 50 minutes are necessary for drying out SG; depending on sites, damage to the fuel occurs after 1,8 to 2,5 hours.

The possible measures available for cooling the core in the cold shutdown state, when the primary circuit is opened, include gravity feed from the RWST and connections available for the mobile firewater pump. In case those fail, the top of the active fuel would be reached in about 2 hours during the mid-loop operation.

At BWR sites, heat is removed via the relief valves into the water reserve of the suppression pool. The stock of coolant in the reactor pressure vessel is automatically supplemented by steam driven high pressure feed system, supported by batteries. The internal stock of coolant is adequate for about 20 hours. Operation is limited by batteries capacity (given for 14 h/KKM and 5h/KKL). The aim of the accident management measures is to inject water in the reactor pressure vessel using means similar to the ones described for PWR. In the event of no water being supplied to the core, damage to the fuel would occur after 25 to 30 minutes from power operation and about 8 to 14 hours in cold shutdown state with vessel head removed.

At three sites, safety train 3 (accident management measures), must be initiated in order to restore cooling to the SFP. Due to the large water inventory, and considering the most unfavourable case of a core freshly unloaded, damage to the fuel is not expected to occur before at least 72 hours. At the KKG site, safety train 2 can be used to cool the SFP via special emergency well water-cooling.

Additional equipment is available on site in order to ensure core cooling over the long term. Mobile diesel generators are available and can be connected within 1 to 2 hours to supply safety train 2 and/or recharge batteries. Other mobile diesel generators are held on the external central Swiss Reitnau storage facility: they can be transported by helicopter and deployed on sites.

The CH-NR concludes that numerous provisions have been implemented in the past at Swiss NPPs in order to provide adequate core and SFP cooling in the event of a total SBO and prevent damage to the fuel.

3.2.3 Strong safety features and areas for safety improvement identified in the process

With respect to the adequacy of protection against SBO, ENSI have concluded that SBO scenarios can be managed by the four Swiss NPPs in accordance with their design and in compliance with the requirements of the Swiss regulations. Also for Loss of UHS, ENSI has concluded that all Swiss NPPs are designed so that the "failure of the primary ultimate and alternative heat sink" scenario can be withstood, both as regards core cooling and SFP cooling.

The ENSI requested and NPPs already implemented numerous improvement actions.

The safety train concept and a strong defence in depth contribute to the robustness of the plant. There are 3 independent paths to bring and maintain the plant in a safe shutdown state, one being fully autonomous for at least 10 hours. The number of safety layers for power supply is significant and diverse options are available. An external storage was set up in 2011 and can provide in a timely manner additional diesel generators.

Three sites have an alternate cooling source consisting of specially protected deep-water wells that would provide water in the event of the loss of the primary ultimate heat sink.

3.2.4 Possible measures to increase robustness

Different measures have been decided by ENSI to increase the robustness of Swiss NPPs. One of the sites (KKM) has no alternate cooling source and ENSI has required the installation of a new seismically qualified water source as an alternative to the river for safety train 2.

The cooling of the SFP is not secured by water supply from alternate cooling source at two plants (KKB and KKM); to increase robustness, ENSI has required these two sites to implement additional specially protected systems for SFP cooling. In order to increase the number of options available for SFP cooling, all sites will also have to back-fit a physically separated additional feed for the pools (used by mobile means from outside the building).

The figures regarding the autonomy of the diesel generators with regards to fuel and oil indicate at least 72 hours for the safety train 2. Fuel transfers across the site seem to be necessary to top up the diesel generator tanks EDGs (safety train 1). The means used to perform these actions should be assessed.

It appears that all measures to operate the Reitnau central Swiss storage facility and to provide additional EDGs in a timely manner are being defined. The overall concept and the plant specific strategies regarding integration of the equipment stored off site in the existing AM procedures, are under investigation and will be reviewed by ENSI in 2012 (part of the actions list).

3.2.5 Measures (including further studies) already decided or implemented by operators and/or required for follow-up by regulators

The ENSI position with regards to the measures envisaged following the stress test process is very clear (measures identified and deadlines defined). These safety improvements have been required in Regulatory documents (orders). ENSI has been prompt to require measures and some have already been implemented (Reitnau external storage for instance).

The following measures have either been implemented or are planned:

In three plants, at least one medium-sized mobile AM emergency power unit (at least 120 kW / 150 kVA) is available locally, i.e. in the plant itself (status as at mid-2011). At KKG, units of this sort must first be requested from the immediate vicinity and transported to the plant because the previously foreseen local KKG emergency power unit was transferred to the external Reitnau storage facility. Since the end of October 2011, two large mobile units (approx. 890 kW) have been available at KKB. According to additional information, KKG plans to procure local power generation units (size: approx. 500 kVA), and KKM replaced the current AM diesel generator with a substantially larger unit of the order of 1000 kVA (mid of March 2012). This provisional information will be confirmed and specified in more detail by the relevant plants during 2012.

At all four Swiss NPPs, provision is made for recourse to the AM emergency power units at the central Reitnau storage facility. These are two fully transportable power generation units (167 kVA each), and one (500 KW) unit that must be assembled at the plant. The requirement for assembly following transport, it is due the weights of the combined unit exceeding the lift and carry capacities of the available helicopters.

All operators keep, or plan to keep, additional mobile AM diesel generators both on site and in the external Reitnau storage facility. ENSI will follow up on the development of a comprehensive strategy for the targeted deployment of the mobile accident management emergency diesels in order to secure selected direct current and/or alternating current consumers in the long term under total SBO conditions.

No measures are envisaged at the KKG and KKL sites to increase the robustness of the plants in case of loss of the ultimate heat sink. At KKB and KKM, the installation of a new independent SFP cooling system is planned. At KKM, an alternative cooling source for safety train 2 will also be installed. In August 2011 KKG has already installed a larger diesel tank.

ENSI reported that back fitting of physically separated additional make up for the SFP will be implemented by 2012, at the latest.

ENSI`s open points are indirectly connected to the loss of UHS response: impacts of a total debris blockage of water intake and development of a comprehensive strategy for the targeted deployment of the mobile accident management emergency diesels in order to secure selected direct current and/or alternating current consumers in the long term under total SBO conditions.

3.3 Peer review conclusions and recommendations specific to this area

The conclusion from the peer review is that the CH-NR for topic 2 is generally satisfactory, and in agreement with ENSREG guidance. Swiss NPPs seem very robust, prompt to react and develop adequate strategies.

The requirements applied to SBO are specified in the ENSI guidelines. Seven layers of electrical supply are available, which is remarkable. Also three safety trains assure different success paths to bring the plant to a safe shut down condition. The implemented design features as reported by the licensees indicate considerable robustness against SBO.

Provisions against loss of UHS are an outstanding strength in the Swiss NPPs. Three NPPs have three alternate cooling source possibilities (two water intakes and special wells in KKG; one water intake per unit, emergency well, and special emergency well in KKB; one water intake, emergency wells and special emergency wells in KKL). KKM has two water intakes, which cannot be considered as completely alternate cooling sources.

ENSI required a seismically qualified alternative cooling source for KKM. The NPP has undertaken their analysis taking into account the conditions specified in the ENSI order. For two plants, backup cooling of the SFP will be provided.

4 PLANT(S) ASSESSMENT RELATIVE TO SEVERE ACCIDENT MANAGEMENT

4.1 Description of present situation of plants in Country

4.1.1 Regulatory basis for safety assessment and regulatory oversight

The NEO contains internationally recognized safety principles; the DETEC-O stipulates hazard assumptions for accidents, which originate in and outside the plant, as well as radiological and technical criteria for proof of adequate protection against accidents. The ENSI guidelines formalize the implementation of legal requirements. The Emergency Protection Ordinance describes the duties and tasks of the operators, of ENSI, of other Federal organizations, and of the cantons, regions and communes in case of a nuclear emergency. This regulatory basis, on different levels also applies to severe accident management provisions, measures and procedures.

Thus, in Switzerland there appears to be an adequate regulatory basis for safety assessment and regulatory oversight of severe accident provisions. This is further confirmed by the claim in the Swiss national report that a comparison, performed by ENSI for IAEA IRRS mission of the Swiss regulations to the IAEA Safety Requirements NS-R-1 (design) and NS-R-2 (operation) confirmed that the Swiss regulations are up to-date and fully in line with established international standards. ConcerningWestern European Nuclear Regulator Association (WENRA) Reference Levels, 20% of them still need to be incorporated in ENSI regulation. During the country visit it was confirmed that WENRA Reference Levels related to severe accident management (Issue LM) are included in the Swiss regulations, but further work remains to incorporate all RLs in Issue F into regulatory documents.

ENSI has played an active role in the aftermath of the accident of Fukushima to identify issues to be addressed and to order operators to implement necessary improvements. Special inspections have also been performed on mobile equipment, spent fuel pools and venting systems.

4.1.2 Main requirements applied to this specific area

Swiss severe accident management related regulations contain specific numerical requirements e.g. PSAs, dose limits, etc. Requirements applicable to Severe Accident Management (SAM) which arise from the Swiss regulatory basis include the following:

– Swiss NPPs must have their own emergency response organization which can resort to specially protected emergency rooms and its own means of communication. The structure of the emergency response organization is stipulated in the emergency preparedness procedures, which are approved by ENSI. Use of the prepared operational resources is regulated in accident instructions and emergency procedures.

Severe accident management shall be developed for full power as well as for shutdown conditions. The transition from the prevention (Emergency Operating Procedures (EOP)) to the mitigation of core damage (Severe Accident Management Guidelines SAMG) shall be clearly defined. The technical basis and negative consequences of actions of the SAMG shall be clearly documented. SAMG shall be validated with the help of emergency exercises.

– All NPPs are required to examine and take account of the behavior of the instrumentation under severe accident conditions in the SAMGs.

– Operators should procure and install appropriate means of external emergency communication in order to communicate with ENSI, the National Emergency Operation Centre and the organizations designated by the concerned cantons.

– According to NEO, existing NPPs should be back-fitted to the extent that is necessary on the basis of experience and the state-of-the-art in back-fitting technology and, beyond that, insofar as it results in further reduction of risk and is appropriate. Plant modifications are assessed in the context of the regular licensing procedure followed by ENSI.

4.1.3 Technical background for requirement, safety assessment and regulatory oversight

On a general level, ENSI integrates the findings from the deterministic and probabilistic safety assessments into its decision-making processes. Probabilistic evaluation is incorporated into the assessment of requested plant modifications, the evaluation of operational experience and the determination of the component importance in relation to safety. International standards and plant-specific analyses of the phenomena to be expected in case of severe accidents as well as knowledge gained from the Level 2 PSA were incorporated into the development of the SAMGs. Initiating events covered by the Swiss PSAs include internal events (fires, loss of coolant, failures of heat removal), as well as external events (earthquakes, accidental aircraft crashes, floods). Level 1 PSA covers power and non-power operation while Level 2 PSA covers power operation for all NPPs and also low power and shutdown states for KKB, KKG and KKM (in part); the KKL low power and shutdown states Level 2 PSA will be completed in 2013. PSA studies for shutdown states cover also the SFP. Finally, in liaison with the supervisory authority, AM procedures (as well as the corresponding training), are optimized by integrating the experience gained from emergency exercises. Exercise scenarios involving core damage are periodically included in the program for the emergency training.

4.1.4 Periodic safety reviews

The emergency protection measures (including SAMG) at the NPPs are regularly (re)assessed by the operators in the PSRs (periodicity of 10 years) and reviewed by ENSI.

4.1.5 Compliance of plants with current requirements

On the basis of its assessment, ENSI has concluded that the emergency response organization of the nuclear power plants, meet the requirements of ENSI guidelines and of IAEA Safety Standard GS-R-2, the Radiological Protection Ordinance and the NEO. The SAMGs have been validated by the Licensees and reviewed by ENSI.

The operators' emergency documents (e.g. the definition of an emergency, types of emergency, priorities in case of emergency, overview of emergency alarms, emergency response organization, general and special tasks of severe accident management or of the emergency staff, radiological self-protection and checklists for correspondence with the authorities), have been reviewed by ENSI and have been assessed as generally acceptable.

ENSI also regularly inspects the NPP external means of communication and AM equipment. The preparedness and suitability of the emergency response organization is reviewed at regular intervals during emergency exercises with ENSI as an observer. Furthermore, ENSI confirmed that for Swiss NPP all the WENRA Reference Levels are already implemented.

4.2 Assessment of robustness of plants

4.2.1 Adequacy of present organizations, operational and design provisions

4.2.1.1 Organization and arrangements of the licensee to manage accidents

At all NPPs, the Emergency Response Organization (ERO) comprises the emergency director (usually the plant director), the emergency staff (heads of relevant specialist departments) and additional emergency bodies. A minimum level of staffing, with qualified personnel, is assigned at the plants on a 24-hour basis in order to initiate alarms and the first measures required in case of an emergency. All employees of Swiss nuclear power plants are members of the respective ERO, so the plants can always draw on a sufficiently large pool of specialists for their ERO.

In cases of emergency, the emergency staff is summoned by the stand-by engineer (Pikett Ingenieur) together with the entire ERO. According to ERO of the NPPs the operator must identify and assess an accident, initiate appropriate measures to manage it and quickly inform the responsible authorities.

During an emergency, all Swiss nuclear power plants can have technical support from the relevant reactor suppliers. This is ensured by agreements between the plants and the reactor suppliers.

In addition to the Main Control Room (MCR), at least one Emergency Control Room (ECR) is available as a standby control room for the shift teams at all the Swiss NPPs. In three plants, this is the special emergency control room, whereas several protected emergency control rooms are available at KKL. Following a study of the consequences of the Chernobyl accident, the Swiss NPPs have already provided proof of sufficient protection against radiation exposure of the shift staff in the main MCR as well as in the ECR. The protection of emergency buildings against external events such as earthquakes or floods is a point already included in the "Lessons Learned" report on the Fukushima accident and will be followed up in the frame of ENSI forthcoming oversight activities.

In Switzerland, the internal communication systems used for emergency communication in relation to nuclear safety are classified as safety-relevant, and they are subject to mandatory permits. In most of these systems, the fixed-position and mobile components are set up so as to protect them against flooding. Some of the systems can be regarded as robust in the event of seismic impacts, as has been confirmed by specific studies and flanking measures. Due to the events related to the accident at Fukushima in March 2011, the means of communication are being analyzed again in relation to extreme natural events.

In 2011, the Swiss licensees created a flooding-proof and earthquake-resistant external storage facility at Reitnau, based on ENSI's requirement from the 18^{th} of March 2011. The storage contains comprehensive set of equipment needed in case of emergencies, such as mobile diesel generators, pumps, cables, fire hoses, tools and protective clothing. There is an agreement with the Swiss Army to have helicopters transporting the equipment to the plant sites. About 8 hours should be planned as the time between calling up the emergency equipment and its availability on site. Also, local authorities can offer their assistance with transport by road. Part of the review team visited the storage and considered it very impressive. The establishment of such a storage facility, in a short period of time, is commendable.

4.2.1.2 *Procedures and guidelines for accident management*

The structure of the emergency response organization, the behavior of the operating staff in emergencies, the definition of types of emergencies and tasks, areas of responsibility and authority in case of an emergency are stipulated in the emergency preparedness procedures and the associated documents. According to ENSI, for all Swiss NPP's, the emergency equipment available at the sites and the technical facilities required for its use, are appropriately coordinated with the accident management measures established in written procedures.

All NPPs have written decision-making aids, covering power operation as well as shutdown states, for preventing core damage (EOPs) and managing severe accidents (SAMGs) with the aim to terminate core degradation, ensure containment integrity, and mitigate radiological releases. SAMGs are based on international standards and plant-specific analyses of the potential phenomena (such as H_2 or steam explosions). In addition, knowledge gained from the Level 2 PSA was also incorporated into their development. The SAMG are reviewed regularly, especially in connection with PSR or emergency exercises, in order to identify potential improvements. Transition from EOPs is clearly structured and validated with the help of exercises.

4.2.1.3 *Hardware provisions for severe accident management*

As part of Accident Management (AM), measures **before occurrence of fuel damage** are in place at all sites and are incorporated into EOPs. Those measures include actions made by reactor safety systems as well as by mobile equipment and include for instance depressurization of the SG without external power or of the reactor pressure vessel (RPV), supply of borated water from the SFP to RPV and coolant supply via the fire extinguishing system. Swiss NPP are equipped with special (bunkered) emergency systems with independent power supply, located in separate buildings and designed against external events.

Measures as part of SAM **after occurrence of fuel damage,** are established and incorporated into the SAMGs at all NPPs. Provisions to mitigate the risk of H_2 deflagrations or detonations in the primary containment are NPP dependent and include igniters, thermal or passive autocatalytic recombiners, mixing systems, nitrogen inertisation and containment venting. Hydrogen concentration measurement instrumentation is also provided. The minimal time for which hydrogen instrumentation is battery backed up is of 4h. It is recommended that the regulator considers assessing the opportunity of requiring more reliance on passive systems for hydrogen management for severe accident conditions.

At all NPPs, filtered containment venting systems are also used to prevent containment failure due to overpressure. This system consists of a passive train that is secured by a rupture disk in normal operation, and an active train secured by motor and hand-operated valves. To enable the controlled discharge of radioactive substances, valves in the active train may be opened either from the control room or manually from a radiologically protected area. Filtered containment venting rupture disk isolation strategy is plant specific and is part of the study on optimization. The filters have a reduction factor of 100 for iodine and 1000 for aerosol. It is recommended that the regulator considers further studies on the hydrogen management for the venting systems.

Regarding the prevention of re-criticality, injection of borated water is preferred if it is available. However, the adopted SAMG strategies allow for injection of non-borated water into the RPV when all sources of borated water are unavailable and the core has melted.

To prevent basemat melt-through, provisions have been made (and are considered by ENSI as appropriate) to allow for flooding of the containment at KKB, KKL and KKM. As there is no possibility to discharge water into the cavity prior to vessel failure, this possibility is not considered for KKG and cavity flooding is realized through the RPV failure.

High pressure core melt scenarios are prevented by depressurization means like fast cool down via steam generators (PWR) and reactor vessel depressurizations (PWR, BWR).

All NPPs have permanently installed connections for alternative injection into the RPV and/or into the steam generators (secondary-side).

On each NPP site, the available emergency equipment includes mobile emergency power units, mobile motor-driven pumps and standard fire brigade equipment as well as radiation protection equipment.

As result of the Fukushima lessons learned, the flooding-proof and earthquake-resistant external storage facility at Reitnau has been put in place since June 2011, containing various operational resources for emergencies that can readily be called upon, including mobile motor-driven pumps, mobile emergency power generators, hoses and cables, radiation protection suits, tools, diesel fuel and boration agents. This equipment is maintained operable through regular testing.

Each NPP has adequate diesel fuel to operate the permanently installed emergency diesel generators and special emergency diesel generators for a period of at least 3 days. The possibility exists to supplement these stocks from the external storage facility at Reitnau. Finally, in relation to water sources, margins are provided by the fact that all Swiss NPPs are located on rivers. Moreover, two NPPs have water sources in the form of reservoirs at higher elevations that can be used in an emergency.

4.2.1.4 Accident management for events in the spent fuel pools

In case of a failure of the systems used in operation for cooling the SFPs, permanently installed alternative systems to restore a cooling circuit are used. Except KKM, all the plants also have permanently installed connections for emergency injection into the SFP. At KKB, and KKM, it is necessary to implement manual measures in the storage pool area, e.g. to establish hose connections or to operate valves. By contrast, the injection into the SFP at the KKG and KKL plants is effected by means of a connection that is permanently installed in the annular space and then via pipes in the independent pool cooling system. If no cooling circuit is available, heat is removed by vaporization and accident management measures are implemented with the help of mobile operational equipment kept available on-demand on site, such as fire extinguishing pumps, fire water tender vehicles and fire brigade hoses. In order to counteract the incipient evaporation phenomena, which could affect the implementation of accident management, back-fitting measures consisting in the installation of filling level indicators in the MCR and ECR are planned for all the plants. Implementation of temperature measurements reported in the control rooms has been also requested.

With current equipment, cooling of fuel assemblies in the storage pools is ensured for 72 hours without external technical support in case of extreme naturally induced impacts leading to a total failure of the SFP cooling systems.

As the SFPs at the KKB and KKL plants are located in separate buildings, the accident management measures for SFP cooling can be implemented regardless of containment conditions. In those plants where the SFPs are located outside the primary containment (KKB, KKL, KKM), no specific measures have currently been prepared in order to counteract the release of H_2 following a Zr-water reaction in the SFPs. In case of a total failure of SFP cooling, KKL and KKM do not expect any uncovering of the fuel assemblies in the storage pools that could lead to major releases of activity, on account of the large water reserve for the SFPs and the prolonged periods thereby available to bring alternative water injections into operation. At KKB, no release of H_2 is expected as long as the fuel assemblies remain covered and the fuel does not heat up beyond 800°C. Hydrogen management outside the primary containment is followed by ENSI as part of the Lessons Learned action plan.

4.2.1.5 Evaluation of factors that may impede accident management and capability to severe accident management in multiple units case

Multi-unit events are covered for KKB (the only site with more than one unit), and arrangements have been tested repeatedly, even before the Fukushima accident. The issue is however also part of the ENSI check list for further assessment.

An evaluation of accessibility in high radiation area is already available for Swiss NPPs, but additional studies are planned for different accident scenarios, as part of the ENSI Lessons Learned action plan.

ENSI considers that effects of infrastructure destruction and flooding should be further discussed and a specific checkpoint has been identified.

It has been recognized that while having extensive multiple on site emergency facilities (e.g. command centers), there are no Licensee's near-site or off site emergency management centers in Switzerland.

4.2.2 Margins, cliff edge effects and areas for improvements

4.2.2.1 Strong points, good practices

During the peer review process, the following strong points have been identified:

- The ENSI issued a comprehensive report on lessons learned after Fukushima.
- SAM has been addressed in national regulations and the main components of SAM were in place before the Fukushima accident,
- SAMGs are available for both power and shutdown states,
- Effective AM strategies are available in case of prolonged SBO.
- Long-term scenarios are covered in procedural guidance's.
- SFPs outside the containments are addressed by SAMGs.
- Multi-unit events (for KKB, the only site with more than one unit) and arrangements have been tested repeatedly even before the Fukushima accident.
- The central storage facility (Reitnau) with AM equipment.
- Filtered containment venting, with active and passive activation.
- ECRs are protected against external events, including filtered air supplies. Manual actions can be performed from radiologically protected areas.
- Re-criticality in the SFP is unlikely. Possibility for injection of non-borated water, e.g. with fire pumps through prepared connections. 6 tons of boron is available for SAM.

4.2.2.2 Weak points, deficiencies, areas for improvements

Although the instrument power supply is available after battery depletion through accident management DG connection via cables, which can be connected within 1-2h, the battery capacity will be reassessed, as a possible area for improvement.

ENSI's review of the stress test exercise by the licensees has identified the absence of a comprehensive listing (including indications of time) of conditions that weaken accident management measures or which limit their effectiveness and/or success. However, the accessibility of operation areas will further be investigated for various accident management scenarios, taking into account also the interface between safety and security

Concerning instrumentation, the ENSI has concluded that no comprehensive evaluation of the instrumentation required in order to initiate and implement the individual accident management measures (prior to a containment integrity failure), was undertaken by any of the operators for the stress test. However, all the plants have met the requirement to examine and take account of the behaviour of the instrumentation under severe accident conditions in the course of the introduction of SAMG, which has led ENSI to regard the instrumentation as generally adequate. The availability of the instrumentation necessary for SAMGs will be further reviewed as part of the ENSI action plan on Lessons Learned.

4.2.3 Possible measures to increase robustness

4.2.3.1 Upgrading of the plants since the original design

All Swiss NPPs, have since the 1990s, a filtered containment venting system to mitigate the consequences of a severe accident. Since the 1980s, systems to prevent H2 explosions have been gradually back-fitted in all NPPs. Since the 1990s, alternative feed lines to the reactor pressure vessel and the primary containment have been gradually back-fitted in all the NPPs for the purposes of Accident Management.

To complement the existing emergency procedures, written decision-making aids to mitigate the effects of severe accidents, SAMG have been developed over the last ten years using also the Level 2 PSAs in all NPPs, both for power and for low power and shutdown states.

In addition to these back-fitting measures, numerous further upgrade measures have been implemented in the past (including the bunkered systems, filtered containment venting systems, etc.); their overall aim was to continue improving the provisions at the individual levels of the "defence in depth" concept.

4.2.3.2 Ongoing upgrading programmes in the area of accident management

Prior to the EU stress tests, ENSI requested the back-fitting of a new and specially protected SFP cooling system in connection with the review of SFP cooling for the two oldest NPPs. Targeted accident management measures for SFP cooling are stipulated in procedures at all Swiss NPPs.

4.2.4 New initiatives from operators and others, and requirements or follow up actions from Regulatory Authorities: modifications, further studies, decisions regarding operation of plants

4.2.4.1 Upgrading programmes initiated/accelerated after Fukushima

As a direct consequence of the Fukushima accident, ENSI issued three orders to the Swiss NPPs in which immediate measures and additional re-assessments were required. The immediate measures included setting up an external storage facility for emergency equipment for the NPPs, including the necessary plant-specific connections and back-fitting of feed lines for the external supply of the SFPs. The re-assessments to be conducted immediately focused on the design of the Swiss NPPs in respect of earthquakes, external flooding and a combination of both events. Additional analyses were requested for the coolant supply for the safety and auxiliary systems and the spent fuel pool cooling. At KKB and KKM the installation of a new independent SFP cooling system is planned and has to be implemented until 2015. The analyses to improve the seismic robustness of venting systems are in progress or planned.

In addition, ENSI has ordered a number of evaluations and back-fitting measures at the Swiss NPPs. In the area of accident management the following actions have been decided:

- Submission of operators' reports on protection against H_2 deflagrations and explosions in the area of the spent fuel pool (Report required on 31/3 2012).
- Statement by ENSI with the review results on the reports submitted on 31.03.2012 concerning protection against H_2 deflagrations and explosions in the area of the spent fuel pools (Statement required by 30/6 2012).
- Back-fitting of connections for mobile external emergency equipment (Implementation foreseen before 31/12 2012).

Also in the longer time perspective, ENSI has required a number of safety improvements. On the basis of internationally accessible information, ENSI has carried out an analysis of the events at Fukushima and has published the results in four reports. These reports provide detailed descriptions of the causes and consequences of the sequences of events at Fukushima, analyses of the contributory human and organisational factors, and statements on the Lessons Learned and specific checkpoints that can be derived from these findings. These checkpoints will be followed up in the coming years on the basis of key thematic issues in the frame of ENSI oversight activities. Checkpoints related to accident management identified by ENSI include:

- The availability of the instrumentation required for accident management, including spent fuel pool level and temperature displays in MCR and ECR.
- In studies on H_2 combustion, pressures were until now mainly calculated on the basis of complete adiabatic isochoric combustion in the primary containment. It is standard that the computer codes normally used for this purpose model combustion with a H_2 concentration of 10% in the relevant control volume. Although this procedure largely corresponds to the international state-of-the-art, it neglects, for example, the fact that H_2 may accumulate locally in higher concentrations, which can

lead to more energy-rich combustion and hence to higher pressures. Further analysis is therefore required by ENSI.

- Information regarding the supply of power and compressed air for maintaining containment isolation in the case of long lasting SBO was not available in the initial KKB and KKG reports. Information from KKL shows the various protective measures for maintaining containment integrity. During the country visit, KKB, KKG and KKL informed that the closed position of the containment isolation valves would be maintained in case of loss of both instrument air and power supply. However, this issue will be under review by ENSI.

4.2.4.2 Further studies envisaged

ENSI has identified open points related to severe accident management. From the point of view of risk minimisation, ENSI will follow up on the extent to which the current deployment strategies for the venting systems in severe accidents should be retained. Filtered containment venting rupture disk isolation strategy will also be part of this optimization study. Furthermore, ENSI will follow up on whether restoring containment integrity during shutdown in the case of a total SBO represents a time-critical measure. All the aforementioned points will be followed up on the basis of key thematic issues in the frame of ENSI forthcoming oversight activities. It is planned to complete the processing of all these points by 2015.

4.2.4.3 Decisions regarding future operation of plants

Shortly after the Fukushima accident, the Swiss government decided on the long-term phase-out of nuclear power. No new plants are planned to be built, although existing plants are allowed to operate as long as their safety is confirmed.

During the plant visit to KKB, the peer review team was given a presentation in which they mentioned their plans for long-term operation.

4.3 Peer review conclusions and recommendations specific to this area

The Swiss National report complies with the guidance provided in the ENSREG stress tests specifications. It addresses all issues, which are considered essential for management of severe accidents. The regulatory treatment applied to the actions and conclusions presented by the utilities were visible and in certain cases quite broad.

In general, the design and further development of the plants are based on the “defence in depth” concept and in consequence results in good robustness of the plants against severe accidents. More specifically, the SAMGs which are required in regulations seem to have been based on firm foundations, notably on international standards and plant-specific analyses of the potential severe accident phenomena, as well as on knowledge gained from the Level 2 PSA. Furthermore, the SAMGs are well-documented and regularly assessed.

Also, hardware provisions for severe accident management seem to be adequate and appear to have been robustly designed, resulting in significant safety margins, although a few possible improvements have been identified and will be implemented. Indeed, ENSI has ordered a number of evaluations and back-fitting measures at the Swiss NPPs and a number of future studies are envisaged.

No comprehensive evaluation of the instrumentation required in order to initiate and implement the individual accident management measures (prior to a containment integrity failure), has been provided. However, according to ENSI, all plants have met the requirement to examine and take account of the behaviour of the instrumentation under severe accident conditions, in the course of the introduction of SAMG. It is recommended that the regulator assesses the opportunity of requiring more reliance on passive systems for hydrogen management for severe accident conditions. It is also recommended that the regulator considers further studies on the hydrogen management for the venting systems.

The peer review team recognises as good practice the recent creation of a flooding-proof and earthquake-resistant external storage facility at Reitnau. The storage facility houses various operational resources for emergencies, which are readily available and can be supplied to the required location within reasonably short time frames.

List of Acronyms

AM	Accident Management
BWR	Boiling Water Reactor
CH-NR	Swiss National Report
DBE	Design Basis Earthquake
DBF	Design Basis Flood
DG	Diesel Generator
DETEC	Ordinance of the Federal Department of the Environment, Transport and Communications
DETEC-O	on Hazard Assumption and the Evaluation of Protection Measures against Accidents in Nuclear Installations
ECR	Emergency Control Room
GE	General Electric
HCLPF	High Confidence of Low Probability of Failure
ENSI	Eidgenössisches Nuklearsicherheitsinspektorat, Swiss federal Nuclear safety Inspectorate
EOP	Emergency Operating Procedures
ERO	Emergency Response Organization
KKB	Beznau NPP Unit
KKG	Gösgen NPP Unit
KKL	Leibstadt NPP Unit
KKM	Mühleberg NPP Unit
LOOP	Loss Of Off-site Power
MCR	Main Control Room
NEO	Nuclear Energy Ordinance
NPP	Nuclear Power Plant
PRP	PEGASOS Refinement Project
PSA	Probabilistic Safety Assessment
PSR	Periodic Safety Reviews
PWR	Pressurized Water Reactor
RPV	Reactor Pressure Vessel
SAM	Severe Accident Management
SAMG	Severe Accident Management Guidelines
SBO	Station Black Out
SG	Steam Generator
SIA	Swiss Association of Architects and Engineers
SSC	Structures, Systems, and Components
SSE	Safe Shutdown Earthquake
SSHAC	Senior Seismic Hazard Analysis Committee
SFP	Spent Fuel Pools
UHS	Ultimate Heat Sink
WENRA	Western European Nuclear Regulator Association