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Eidgenössisches Nuklearsicherheitsinspektorat ENSI
Inspection fédérale de la sécurité nucléaire IFSN
Ispettorato federale della sicurezza nucleare IFSN
Swiss Federal Nuclear Safety Inspectorate ENSI

CNS

Implementation of the obligations of the
Convention on Nuclear Safety

July 2016
Switzerland's Seventh National Report
to the Convention on Nuclear Safety

Implementation of the Obligations of the Convention on Nuclear Safety

Switzerland's Seventh National Report to the Convention
in Accordance with Article 5

July 2016

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Foreword

Switzerland signed the Convention on Nuclear Safety (CNS) on 31 October 1995 and ratified the Convention on 12 September 1996, which then came into force on 11 December 1996. In accordance with Article 5 of the Convention, Switzerland has prepared and submitted country reports for the regular Review Meetings of Contracting Parties organised in 1999, 2002, 2005, 2008, 2011, and 2014, and for the Second Extraordinary Meeting in 2012. The corresponding Review Meetings at the IAEA headquarters in Vienna were also attended by a Swiss delegation.

This seventh report by the Swiss Federal Nuclear Safety Inspectorate (ENSI) provides an update on Switzerland's compliance with the obligations of the Convention. In addition, the report gives due regard to issues and trends in nuclear safety, such as those identified by the Contracting Parties at the sixth Review Meeting, at the Organisational Meeting and in the Principles agreed upon in the Vienna Declaration on Nuclear Safety (VDNS).

The report begins with general information about Switzerland, a brief history of the country's nuclear power programme and an overview of its nuclear facilities as well as a short description of Switzerland's waste disposal programme and site selection process for geological repositories. The chapter «Summary and Conclusions» provides an overview of the contents of the report and its conclusions on the degree of compliance with the obligations of the Convention, followed by a comprehensive overview of the status of nuclear safety in Switzerland as of March 2016. The numbering of the ensuing chapters in the report matches that of the CNS Articles 6–19. The comments for each section indicate clearly how Switzerland complies with the key obligations of the Convention.

The implementation of the Principles in the Vienna Declaration on Nuclear Safety is reported upon under a separate chapter. Furthermore, a subchapter of the Summary and Conclusion gives answers to the Challenges identified by the Special Rapporteur on Fukushima during the sixth Review Meeting. Appendix 1 contains a list of abbreviations used in the text; appendix 2 provides a list of ENSI's guidelines currently in force.

Introduction

Country and State

Switzerland is located in the middle of Europe and is surrounded by France to the west, Germany to the north, Austria and Liechtenstein to the east and Italy to the south. With a total surface area of 41 285 km^2 – more than half of which is mountainous – and a population of just over 8.2 million, Switzerland is a small, densely populated country. The sources of the Rhine, Rhone and Inn rivers are in the Swiss Alps. Switzerland has four official languages: German, French, Italian and Rhaeto-Romanic, the latter being spoken by some 0.5% of the Swiss population. About 24% of current residents are foreign nationals.

Structurally, Switzerland has evolved into a federal state with 26 member states, known as cantons. The federal authorities are responsible under the Constitution for certain central functions. At each level, a significant number of political rights are guaranteed to the people. All other legislative power remains with the cantons, which retain therefore a high degree of autonomy. Municipalities also enjoy considerable rights of self-government.

The Federal Council consists of seven ministers of equal rank, acting as the federal government. Ministers are elected by the Swiss Parliament. The Parliament consists of two chambers: The National Council represents the population as a whole. It has 200 members elected for a term of four years. The Council of States has 46 members representing the Swiss cantons. The electorate has the constitutional right to introduce and sanction changes to the Federal Constitution and a right to vote in referendums on federal legislation. The electorate can also request changes or additions to the Federal Constitution through a popular initiative signed by at least 100 000 voters. Any change to the Constitution must be submitted to an obligatory national referendum. If a minimum of 50 000 voters challenge a decision by parliament to pass a new federal law or change an existing law, the issue is put to a facultative national referendum. The federal rules on popular initiatives and referendums are replicated in cantonal constitutions.

In 2014, Gross Domestic Product in Switzerland per capita was approximately CHF 78 000 (EUR 70 000). The most important economic sectors are banking, tourism, mechanical engineering, chemical and pharmaceutical industry, foodstuffs, watches and medical technology. Its major export partners are Germany, USA, China, Italy, France, United Kingdom and Japan.

Total energy consumption in Switzerland was about 825 770 TJ in 2014. Electricity consumption accounts for about 25% of energy consumption. The main sources of electricity in Switzerland are hydroelectric (2014: 57%) and nuclear power (38%).

Background to nuclear power in Switzerland

Until the late 1960s, Switzerland generated electricity exclusively from hydropower and did not resort to fossil fuels since the latter were not available as a natural resource in Switzerland. By the mid-1950s, there was interest in the use of the relatively new nuclear energy technology to cover the increasing demand for power. In accordance with the general policy on electricity production, it was left to the private sector to promote and use nuclear energy. However, it was recognised that any nuclear programme would require a legislative framework to ensure safety and radiation protection. It was further recognised that such legislation should be exclusively at the federal level. As a result, an Article was added to the Swiss Constitution, which was approved by a vote of the Swiss population in 1957. The Atomic Energy Act came into force in 1959 based on this Article.

In 2005, Switzerland enacted a new Nuclear Energy Act and its related ordinance to replace the Atomic Energy Act of 1959. Under the new Nuclear Energy Act, the unconditional authority of the Federal Council to grant general licences for new nuclear power plants (NPP) was abolished with decisions on general licences for new NPPs being subject to a facultative national referendum. In addition, the Federal Government is leading the site selection process for geological waste repositories.

As nuclear power production is part of the private sector, there is no national nuclear programme as such. During the 1960s, a series of projects for NPPs were initiated and four of them were realised. This resulted in the current five operating units, which were commissioned between 1969 and 1984. Several other projects were cancelled.

Licensing procedures for three new units at existing sites were on going in Switzerland before the events at Fukushima occurred in 2011. ENSI was involved in the procedures and had issued the three corresponding safety evaluation reports (SER). The safety evaluations focused on the reassessment of the potential hazards related to the specific site characteristics. Shortly after the Fukushima accident, the Federal Council suspended these procedures. Over the course of 2011, the Federal Council and the Swiss Parliament decided to phase out nuclear energy by prohibiting the building of new plants, while the existing plants are to continue operating for as long as they can safely do so.

In 2013, the operator of Mühleberg NPP decided to shut down the plant at the end of 2019 for entrepreneurial reasons.

The regulatory authority

The first experimental nuclear reactor started operation in Switzerland in 1957. At this time there was no regulatory authority established in Switzerland. The canton in which a reactor was located was responsible for its safety. The first nuclear regulator in Switzerland was the Swiss Federal Nuclear Safety Commission set up in 1960. Between that date and 1982, its secretariat evolved in several stages into an independent authority. In 1964, the Federal Council decided to create the Department for the Safety of Nuclear Facilities, which later became the Swiss Federal Nuclear Safety Inspectorate. The duties of the regulatory body were formally defined in an ordinance published in 1982. Until the end of 2008, ENSI was part of the Swiss Federal Office of Energy (SFOE).

The fact that ENSI reported directly to SFOE contravened the independence stipulated in both the Swiss Nuclear Energy Act of 2005 and the Convention on Nuclear Safety. The Act on the Swiss Federal Nuclear Safety Inspectorate ENSI – approved in 2007 – created a statutory framework for making ENSI formally independent of the SFOE. This was achieved on 1 January 2009 when ENSI became an authority constituted under public law. ENSI itself is supervised by an independent body, the ENSI board. The Board is elected by the Federal Council to which it reports directly.

Nuclear power plants

Switzerland has five NPPs – Beznau I and II, Mühleberg, Gösgen and Leibstadt. They are located on four different sites and have four different reactor and containment designs provided by three different reactor suppliers (Westinghouse, General Electric and Kraftwerk Union). Local suppliers contributed to civil engineering, buildings and mechanical and electro-technical equipment. The Beznau NPP is operated by Axpo Power AG, the Mühleberg NPP by BKW AG, the Gösgen NPP by Kernkraftwerk Gösgen-Däniken AG, and the Leibstadt NPP by Kernkraftwerk Leibstadt AG.

The main technical characteristics of the Swiss NPPs are summarised below in Table 1.

Table 1: *Main technical characteristics of the Swiss NPPs (as of March 2016)*

	First generation NPPs			Second generation NPPs	
	Beznau I	Beznau II	Mühleberg	Gösgen	Leibstadt
Licenced thermal power P^{th} [MW^{th}]	1130	1130	1097	3002	3600
Nominal net electrical power P^{el} [MW^{el}]	365	365	373	1010	1275
Reactor type	PWR	PWR	BWR	PWR	BWR
Containment type	Large dry, free standing steel inside concrete building	Large dry, free standing steel inside concrete building	Pressure suppression, Mk I inside concrete building	Large dry, free standing steel inside concrete building	Pressure suppression, Mk III inside concrete building
Normal heat sink	River Aare	River Aare	River Aare	Wet cooling tower (River Aare)	Wet cooling tower (River Rhine)
Number of reactor coolant pumps	2	2	2	3	2
Number of turbine sets	2	2	2	1	1
Number of fuel assemblies	121	121	240	177	648
Fuel	UO_2	UO_2	UO_2	UO_2	UO_2
Number of control assemblies	25	25	57	48	149
Reactor supplier	W	W	GE	KWU	GE
Turbine supplier	BBC	BBC	BBC	KWU	BBC
Site Licence	1964	1967	1965	1972	1969
Construction licence	1964	1967	1967	1973	1975
First operating licence	1969	1971	1971	1978	1984
Commercial operation	1969	1971	1972	1979	1984
Backfitted bunkered automatic ECCS and residual heat removal system since:	1993	1992	1989	Included in the original design	Included in the original design
Filtered containment venting system since:	1993	1992	1992	1993	1993

Abbreviations:

Mk I, Mk III	GE Containment Types Mark I and Mark III
PWR	Pressurised Water Reactor
BWR	Boiling Water Reactor
W	Westinghouse Electric Corporation
GE	General Electric Technical Services Corporation
KWU	Siemens Kraftwerk Union AG (now Areva NP)
BBC	Brown Boveri & Cie, AG (now Alstom)
UO2	Uranium oxide
ECCS	Emergency core cooling system

Because of Switzerland's mountainous landscape, the number of suitable sites for NPPs is limited. Two sites are located near the German border; Leibstadt is situated 0.5 km and Beznau 5 km from the border. The other two sites are located about 40 km from the French and 20 km from the German border respectively. The geographic location of all Swiss nuclear facilities is shown on the map in Figure 1.

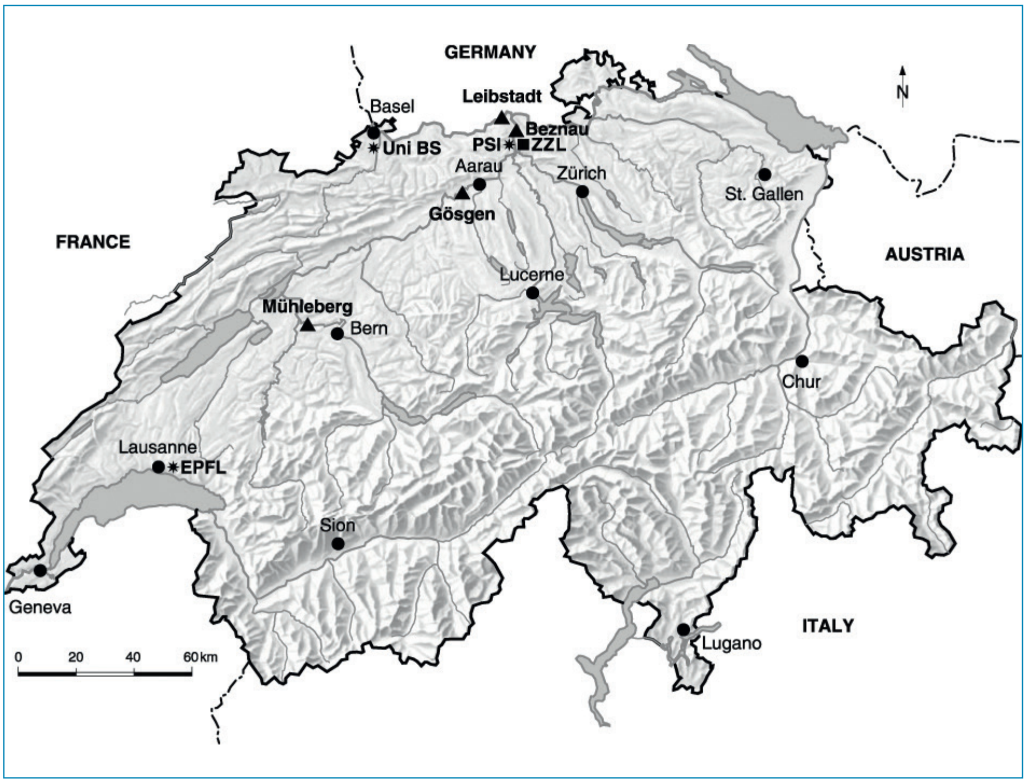


Figure 1: *Geographic location of Swiss nuclear facilities. Triangles mark the NPP sites. Asterisks mark experimental and research installations. Squares mark facilities for nuclear waste management. The dots are major cities.*

Facilities for nuclear education, research and development

Most nuclear research in Switzerland is performed at the Paul Scherrer Institute (PSI). Research at PSI is conducted in collaboration with other national and international research institutes and industry. It covers the following areas: elementary particle physics, biological sciences including radiation protection, solid-state research and material science, nuclear energy research, non-nuclear energy research and environmental research related to energy production, medical research and medical treatment (oncology).
Several nuclear installations are located at the PSI site, of which the Hot Laboratory Facility is the most significant where nuclear safety is concerned. The DIORIT and SAPHIR research reactors are in an advanced state of decommissioning, the PROTEUS research reactor has been permanently shut down; the application documents for its decommissioning have been submitted to the authorities. Another research reactor in Basel was permanently shut down in 2015. Its nuclear fuel has been returned to the United States. Finally, there remains just one small research reactor (P 100W_{th}) used mainly for teaching purposes at the Swiss Federal Institute of Technology (ETH) in Lausanne.

Processing and interim storage of nuclear waste

Swiss legislation requires immediate conditioning of radioactive waste from nuclear installations except for technical optimisation in periodic conditioning campaigns. Consequently, each NPP is equipped with facilities for waste conditioning and interim storage. On-site facilities for storage of spent fuel are located at the Beznau site (dry storage, also for waste) and at Gösgen NPP (wet storage, spent fuel elements only). Both facilities started operation in spring 2008.

In addition to the on-site facilities, there is a centralised storage and conditioning facility (Zentrales Zwischenlager ZZL), owned by ZWILAG, which is located adjacent to the PSI campus. This facility provides interim storage capacity for spent fuel, intermediate and low-level radioactive waste. Any return waste from the reprocessing of Swiss spent fuel in La Hague (F) and Sellafield (UK) is stored here. The facility also contains installations for the conditioning of specific waste categories and the incineration or melting of low-level waste. The Central Interim Storage Facility began active operation in June 2001.
PSI operates the national collection centre for all institutional radioactive waste: waste from medicine, military applications, industry and research. The waste can be treated either at PSI installations or at ZWILAG followed by interim storage at the Federal Interim Storage Facility, which is also located on the premises of the PSI.

Current status of the process to select sites for geological repositories

In 2008, Switzerland started a process to select sites for the final disposal of radioactive waste in deep geological formations. This process is coordinated by the SFOE in accordance with the current nuclear legislation and the legislation on spatial planning. Safety has highest priority in the site-selection process, but the process also considers socio-economic issues. Prior to approval of the selection concept by the Federal Council, the site selection procedure was subject to broad public consultation in 2007, not only in Switzerland but also in neighbouring countries.
Site selection is based on a staged approach, currently expected to end by 2028. Each stage concludes with a broad public consultation in both Switzerland and neighbouring countries. Statements submitted to this public consultation process are summarised and answered in a specific consultation report.
Stage 1, completed in 2011, led to the identification of three suitable regions for the siting of the high-level waste (HLW) repository and six suitable regions for the siting of the low- and intermediate-level waste (L/ILW) repository. Selection was based on safety criteria defined by the regulatory authority. Stage 2 started in 2011. In a first step, the Swiss implementer, Nagra, had to define its needs for future investigations in order to gather sufficient information to reduce the number of siting regions to a minimum of at least two for each repository type. The proposed programme was reviewed by ENSI, revealing that more data collection was required. In a broad consultation, including a large number of stakeholders, the gathered knowledge was reviewed before submission of the proposal for stage 2. In January 2015, Nagra proposed two siting regions for both repository types. The review of this proposal (documented in approximately 200 reports) is currently ongoing.
Stage 3, currently planned to start in 2018, will be based on detailed investigations inside the remaining siting regions, including 3D-seismic investigations and drilling activities, to provide the required database for making the site selection including a detailed safety analysis for each proposed repository. The site-selection process will end with the approval by the Federal Council of the selected sites. This will be followed by the general licensing procedure specified in the nuclear energy legislation. The Federal Council will grant the general licence, which will require approval by the Swiss Parliament. Parliamentary approval is also subject to a facultative national referendum. Currently, it is expected that the repository for L/ILW will become operational in 2050, whereas the repository for HLW will become operational after 2060.

Summary and Conclusions

In the aftermath of the Fukushima Daiichi accident in 2011, the Swiss government decided to phase out nuclear energy; existing plants will continue to operate as long as they are considered safe by ENSI and fulfil all legal and regulatory requirements in this respect. Against this background, Swiss activities for the current reporting period can be summarised under the following points:

Safe Operation of existing plants

In Switzerland, on-going activities regarding safety assessment of the different stages in the lifetime of nuclear installations consist of periodic assessments and assessments of long-term operation for existing Swiss NPPs. Assessments of long-term operation (LTO) have been performed for two Swiss NPPs which have been in commercial operation for over 40 years. A detailed examination demonstrated that the conditions for the taking out of service of an NPP are not yet and will not be reached by these two plants (Beznau NPP and Mühleberg NPP) within the next 10 years. Nevertheless, it is mandatory to continue with the scheduled ageing management, maintenance and backfitting activities.

Shutdown of Mühleberg NPP

In late 2013, BKW Energy Ltd announced that Mühleberg NPP will be decommissioned at the end of 2019. The plant will shut down on 20 December 2019. The single 373 MWe boiling water reactor began operating in 1972. It will be the first Swiss nuclear power plant to be decommissioned. The preparatory work for decommissioning is well under way. For more information, see Article 6.

International peer reviews and cooperation

In April 2015, an IRRS follow-up mission was conducted in Switzerland. The mission concluded that the four recommendations and 16 suggestions for which ENSI was primarily responsible had been implemented but that the Swiss government should give ENSI, as the technical nuclear safety authority, the ability to issue legally binding technical safety requirements and licence conditions on nuclear safety, nuclear security and radiation safety. The IRRS mission report was published on the ENSI website[1]. Also, an OSART follow-up mission to the Mühleberg NPP was completed in June 2014.

Switzerland participated in the European Stress Test and its follow-up activities. Furthermore, in December 2013, Switzerland tabled a proposal to amend Article 18 of the Convention on Nuclear Safety and participated in the ensuing Diplomatic Conference. Switzerland contributed actively to the development of the Vienna Declaration on Nuclear Safety.

Supervisory culture, mission statement and code of conduct of ENSI

In 2011, the ENSI Board initiated an internal project to assess and improve aspects of ENSI's supervisory culture. An internal project with the involvement of the entire personnel was initiated in 2012, in which the existing supervisory culture was analysed. In 2013, the project team developed the goals for ENSI's supervisory culture. During 2014, the necessary measures to achieve continuous improvement in the supervisory culture were defined.

The work related to the «Supervisory Culture» project was included in the update of the ENSI mission statement. The focus was on ENSI's role as a competent authority, the manner of cooperation between ENSI's personnel and aspects of leadership. The basis for the work was primarily the feedback of ENSI employees gained from the supervisory culture project.

The ENSI reports «Integrated Oversight»[2] and «Oversight of Safety Culture»[3] contain basic statements on the supervisory culture of ENSI. The report «Integrated Oversight» is the result of the increasing systematisation of all supervisory activities in recent years. The reports are available to the public.

[1] www.ensi.ch/de/wp-content/uploads/sites/2/2015/08/irrs-follow-up-mission-report-switzerland-2015.pdf
[2] http://www.ensi.ch/en/documents/integrated-oversight/
[3] http://www.ensi.ch/en/documents/oversight-of-safety-culture-in-nuclear-installations/

ENSI issued a Code of Conduct in January 2013. It contains rules of conduct, especially concerning the handling of conflicts of interest, which may arise in connection with the activities of ENSI. It applies to the whole staff of ENSI.
For more information, see Article 8.

Post Fukushima Daiichi Actions

Following the accident in Fukushima Daiichi, ENSI undertook a series of actions to understand the event sequence in Fukushima Daiichi and its causes. The knowledge obtained from analysing the events of the accident at Fukushima Daiichi was reviewed to determine its applicability to Switzerland, and a summary of insights was compiled in an ENSI report entitled «Lessons Learned» in the form of a series of checkpoints. Further points were added on completion of the analyses for the EU stress tests. The processing and implementation of the identified points were updated annually in the Fukushima Action Plan, which was updated and published annually until February 2015. A summary report containing all measures identified and implemented post-Fukushima will be published by the end of 2016. Most of the identified checkpoints were implemented by the end of 2015.

Answers to the requirements of the Guidelines regarding the National Reports under the CNS – INFCIRC/572

Challenges from the Sixth Review Meeting:

The following challenges were identified for Switzerland during the sixth Review meeting of the CNS:

Nuclear phase-out and decommissioning ENSI guideline G17 – Decommissioning of nuclear facilities to be published in 2014

Activity performed in this regard:

In April 2014, ENSI brought a new guideline into force that stipulates the requirements for the decommissioning of nuclear installations in Switzerland (ENSI-G17). It also specifies the detailed requirements for the application documents regarding decommissioning. The guideline is in accordance with the Western European Nuclear Regulators' Association (WENRA) Safety Reference Levels (SRL) and the respective IAEA Safety Standards on decommissioning. It has been translated and is available in English on ENSI's website (www.ensi.ch/en/documents/g17-decommissioning-of-nuclear-installations/).

For more information, see Article 7.

First permanent shutdown of a Swiss commercial power reactor (Mühleberg NPP) in 2019

Activity performed in this regard:

BKW Energy Ltd. announced in late 2013 that Mühleberg will be permanently shut down at the end of 2019. The single 373 MWe boiling water reactor began operating in 1972. It will be the first Swiss nuclear power plant to be decommissioned.

On 18 December 2015, BKW submitted the application documents (the final decommissioning plan) to decommission its NPP to the Department of the Environment, Transport, Energy and Communication (DETEC). The application comprises the main report detailing the decommissioning project's conceptual framework and three sub-reports: accident analyses and emergency protection measures; the environmental impact report; and the security report.

During the preparation for the decommissioning of Mühleberg NPP, the Swiss Confederation has established a cross-institutional monitoring group. All stakeholders are members of this group: Swiss Federal Office of Energy, (SFOE), the Federal Office for the Environment (FOEN), the Canton of Bern, ENSI and BKW. Three subgroups were formed with respect to technical aspects, legal procedure and communication. In March 2015, the communication subgroup organised three public events near Mühleberg NPP. In total, more than 800 people visited these events and showed much interest in the decommissioning plan, funding, costs, and waste treatment and disposal. In April 2016, these public events were repeated.

The requirements for the final decommissioning plan are described in the Nuclear Energy Act, the Nuclear Energy Ordinance and in ENSI's technical guideline G17. The decommissioning guideline ENSI-G17 is in accordance with the WENRA SRLs and the respective IAEA Safety Standards on decommissioning.

The submitted documents will be reviewed by the authorities. Based on the authorities' advisory opinions, DETEC will issue the decommissioning order that regulates the decommissioning process. BKW expects the decommissioning order in mid-2018 – more than one year before final shutdown. This approach should ensure that any potential appeal procedures can be finalised before the plant's planned shutdown on 20 December 2019.

The decommissioning of Mühleberg NPP will be a first of its kind in Switzerland. According to the plans of BKW, performing certain preparatory dismantling activities while spent fuel is still on site will reduce the time for decommissioning to about 11 years.

For more information, see Article 6.

Backfittings for remaining operating time period of Mühleberg NPP

Activity performed in this regard:

In late 2013, the licence holder BKW decided to decommissionMühleberg NPP in 2019 for entrepreneurial reasons and cancelled the planned backfitting programme for long term operation (LTO). The Inspectorate issued a formal order to establish binding conditions for operation until 2019, requesting alternative measures to be implemented. On this basis, the licence holder submitted in 2014 an alternative backfitting programme, which was evaluated by the Inspectorate. The following main backfitting measures are planned or have already been installed:

- In October 2012, an IAEA OSART mission to Mühleberg NPP took place. The review team acknowledged the fast and thorough response to recent significant external operating experience events, including important plant modifications (see Article 19).
- In 2015 the licence holder finished the installation of the new emergency system to feed cooling water from the hilltop reservoir into the emergency cooling water system. The backfitting measure also included hose connectors inside the bunkered emergency building to ensure an additional accident management cooling water supply with mobile pumps.
- In 2015, Mühleberg NPP completed backfitting measures to reduce the internal flooding hazard by installing bypass lines with flow limiter, check valves and orifices into the piping of the RCIC system, the CRD system, the auxiliary condensate system, and the firewater system. The plant also performed backfitting measures to reduce fire hazards in the reactor building.
- By the end of the 2016 outage, Mühleberg NPP will have backfitted an additional, earthquake and flood resistant single line for emergency water injection into the reactor pressure vessel. The system is located in a new building separate from other safety systems.
- A new emergency cooling system for the spent fuel pool will be installed by the end of 2016. Water supply is ensured from the bunkered cooling water system and from the hilltop reservoir. In 2020, the emergency cooling system for the spent fuel pool will be converted into a safety system.

For more information on backfittings, see articles 6, 14 and 18.

Information on staff situation, their competence and motivation for the remaining operating time of Mühleberg NPP

Activity performed in this regard:

The decision to shut down the Mühleberg NPP at the end of 2019 has not led to a fall in staff numbers at Mühleberg. The plant has developed a concept that ensures that the Mühleberg staff have a perspective for their work life after decommissioning.

For more information, see Article 11.

Description of significant changes to Switzerland's national nuclear energy and regulatory programmes and measures taken to comply with the Convention's obligations

As a result of the events in Fukushima Daiichi, Switzerland has decided to phase out nuclear energy. Therefore, no nuclear new builds are planned.

The nuclear phase-out is being discussed as part of the parliamentary debate on the Energy Strategy 2050, which will require a partial revision of the Nuclear Energy Act. Following these discussions, both chambers of the Parliament have decided to refrain from restricting the operational lifetimes of the Swiss nuclear power plants. Beyond that, the Parliament also rejected a proposition by which the operators of NPPs have to submit LTO concepts to ENSI before the completion of 40 years of operation (and then again on a 10-year basis).

New regulatory guidelines issued by the Inspectorate have been introduced. By involving the stakeholders and the broad public in the procedure of issuing guidelines (especially hearings), the regulatory process is transparent. Furthermore, each new regulatory guideline includes the related international WENRA and IAEA requirements. (See Introduction, Articles 7 and 8.)

Mühleberg Nuclear Power Plant – Source BKW Energie AG

Actions taken on Challenges Identified by the Special Rapporteur on Fukushima Daiichi

Challenge 1: How to minimize gaps between Contracting Parties' safety improvements?

Swiss legislation requires continuous improvement of safety in nuclear power plants. Whenever new findings are known, which would help to achieve a further increase in safety, the plant operators are obliged to implement appropriate backfitting measures. These principles are enshrined through Article 22, clause 2, letter g of the Nuclear Energy Act. The licence holder shall: «backfit the installation to the necessary extent that it is in keeping with operational experience and the current state of backfitting technology, and beyond insofar as further upgrading is appropriate and results in a further reduction of risk to humans and the environment».

In December 2013, ahead of the sixth CNS Review Meeting, Switzerland submitted the following proposal to amend Article 18 of the CNS:

«Nuclear power plants shall be designed and constructed with the objectives of preventing accidents and, should an accident occur, mitigate its effects and avoiding releases of radionuclides causing long-term off-site contamination. In order to identify and implement appropriate safety improvements, these objectives shall also be applied at existing plants.»

The proposal did not reach consensus during the sixth Review Meeting but the Contracting Parties decided to call a Diplomatic Conference to further discuss the amendment proposal. The outcome of the Diplomatic Conference was the Vienna Declaration on Nuclear Safety, a set of principles derived from the originally submitted amendment proposal.

For more information see the subchapter on the implementation of the Vienna Declaration as well as Articles 6, 14 and 18.

Challenge 2: How to achieve harmonised emergency plans and response measures?

Switzerland is a party to the Convention on Early Notification and the Convention on Assistance. Switzerland has bilateral agreements covering notification and information exchange with its neighbours in the event of a nuclear accident. Although Switzerland is not a member of the European Union, it is part of the European Community Urgent Radiological Information Exchange Network ECURIE.

Because the Leibstadt and Beznau NPPs are close to the national border, special plans have been agreed upon with Germany. These plans are designed to ensure the same level of protection on both sides of the border for the public and the environment. They also seek to harmonise procedures. Dedicated telephone lines exist for communication between authorities. Plans and procedures are updated regularly by bilateral working groups as part of the German-Swiss Commission for the Safety of Nuclear Installations (see Article 17, Clause 4). Emergency plans are not only tested at the national level. German authorities at both the local and federal level take part in exercises at the Leibstadt and Beznau NPPs. Switzerland participates in exercises at the French NPPs of Fessenheim and Bugey, which are located some 30 km and 70 km from the Swiss border respectively.

In case of an accident at an NPP, long-term consequences may extend beyond planning zones and so Switzerland has intensified its collaboration with France and Austria. For France, an expert group on nuclear emergency matters has been set up as part of the «Commission Franco-Suisse». For Austria, there is a yearly exchange of information. The «Commissione Italiana-Svizzera» is a bilateral Swiss and Italian committee that oversees the exchange of information with Italy on an annual basis.

Emergency plans and procedures must be regularly improved and adapted to reflect new challenges and changing situations. Experts from several Swiss authorities take an active part in these activities. Switzerland also participates in working groups of the Heads of the European Radiological Protection Competent Authorities (HERCA) and WENRA on emergency preparedness.

Finally, in order to improve the emergency response system at the national and international level, members of the Inspectorate and the National Emergency Operations Centre (NEOC) actively support the activities of the OECD/NEA working party on Nuclear Emergency Matters.

Switzerland participated actively in the development and implementation of the HERCA-WENRA Approach for a better cross-border coordination of protective actions during the early phase of a nuclear accident[4].

For more information, see chapter 16, clause ii.

Challenge 3: How to make better use of operating and regulatory experience, and international peer review services?

International peer-reviews:

Article 2, paragraph 3 of the ENSI ordinance, requires ENSI to undertake periodic international review missions.

In April 2015, an IRRS follow-up mission (FU) was conducted in Switzerland. The mission concluded that the four recommendations and 16 suggestions from 2011 for whose implementation ENSI was mainly responsible were fulfilled but that the Swiss government should give ENSI, as the technical nuclear safety authority, the ability to issue legally binding technical safety requirements and licence conditions on nuclear safety, security and radiation safety. The IRRS mission report was published on the ENSI website. (See Articles 8 and 19.)

ENSI experts regularly participate in IRRS missions and 9 experts have been nominated to the IAEA IRRS expert pool. IRRS participations with ENSI experts in recent years were: 2011 Germany (FU), Slovenia, South Korea; 2012 Sweden; 2013 Czech Republic, Belgium; 2014 The Netherlands, France, South Korea (FU); 2015 Armenia; 2016 Japan and Sweden (FU).

A follow-up OSART (Operational Safety Review Team) mission visited the Mühleberg NPP in June 2014. The OSART review team found that eleven recommendations had been successfully addressed

[4] http://www.wenra.org/media/filer_public/2014/11/21/herca-wenra_approach_for_better_cross-border_coordination_of_protective_actions_during_the_early_phase_of_a_nuclear_accident.pdf

and a satisfactory progress was reported for a further ten recommendations. By the end of 2014, Mühleberg NPP had completed a further six of these outstanding recommendations. ENSI required that the Mühleberg NPP should submit the final report on the implementation by the end of September 2015. In February 2016, ENSI concluded that Mühleberg NPP has completed all recommendations from the OSART mission.

Due to the fact that WANO has increased the periodicity of its inspections from every 6 to every 4 years, it is becoming increasingly difficult, in particular for smaller NPPs, to host OSART missions every 10 years.

Operating and regulatory experience:

ENSI is continuing the development of its systematic collection of data from international operating experience feedback (OEF). The internal ENSI process for international OEF collection has been improved and two new IRS (joint database on international event reporting system of the IAEA and OECD/NEA) national coordinators have been nominated. Further sources of OEF data are systematically addressed, namely information from events in Germany and the International Nuclear Event Scale (INES) event notifications. Information obtained from bilateral (with France and Germany) as well as multilateral cooperation is also fed into the process (e.g. quarterly bulletin from and contribution to the European Clearing House, KWU Users Group (KWURG), tripartite commission with regulators in Belgium and France). The analysed information is logged in a traceable way, including the conclusions of its applicability to the Swiss NPPs and possibly the measures taken. Further improvements aim at disseminating Swiss OEF through IRS reports in a more timely manner and ENSI is participating actively in the OECD/NEA/CSNI «Working Group on Operational Experience» (WGOE) and the «Working Group on Human and Organisational Factors» (WGHOF).

Challenge 4: How to improve regulators' independence, safety culture, transparency and openness?

Independence:

ENSI is an independent organisation (separate from the SFOE) controlled by its own management board (ENSI Board) and with its own budget. This gives the Inspectorate complete flexibility over budget decisions and independence when recruiting personnel.

Safety Culture:

In 2012 an ENSI-wide project was initiated to assess the safety culture within ENSI, to identify shortcomings between the current and the target state and to define necessary corrective actions. The target state was developed within the framework of several workshops including all staff members. Finally, the project team submitted a list of 15 proposals for measures and about the same amount of recommendations to the management. While the implementation of the measures is still on-going supervised by the Staff of the Directorate, one of the major outputs of the project was a new Mission Statement. In combination with the code of conduct, this document sets the guidelines for all kind of activities within the Inspectorate.

Transparency and openness:

After the accident in Fukushima Daiichi, ENSI created a section responsible for communication. The six staff members are responsible for the organisation of the information activities and are working closely with the management.

Under the Nuclear Energy Act (Article 74), the Inspectorate «shall regularly inform the general public about the condition of nuclear installations and any matters pertaining to nuclear goods and radioactive waste» and «shall inform the general public of any special occurrences». In addition to that, the Inspectorate is obliged to respond to questions from parliament on nuclear safety and the work of the regulatory body. As a federal authority, ENSI is subject to the Federal Act on Freedom of Information in the administration. According to this law, all ENSI documents are made public with a few exceptions, such as security-related information, personal data or trade secrets.

In addition to annual reporting (consisting of the Regulatory Oversight Report, the Research and Experience Report, the Radiation Protection Report and the Financial Report), it publishes reports on current topics – e.g. earthquakes, plane crashes, disposal of radioactive waste etc.

Challenge 5: How to encourage all countries to commit and participate in international cooperation?

International cooperation is a cornerstone in the independent oversight activities of ENSI. Accordingly, ENSI applies considerable resources for its international commitment and participates actively in around 50 IAEA and OECD-NEA committees and working groups. ENSI is extensively involved in European associations of regulators such as WENRA, which ENSI has chaired since the end of 2011, and HERCA where ENSI is chairing the Working Group on Emergency Preparedness and Response. Within WENRA, ENSI is also chairing Working Group on Waste and Decommissioning (WGWD).

Since 2016, ENSI is representing Switzerland on the IAEA Commission on Safety Standards and ENSI is represented in all IAEA Safety Standard Committees including the new Emergency Preparedness and Response Standards Committee (EPReSC) and the Nuclear Security Guidance Committee (NSGC). Memoranda of Understanding have been signed with the Canadian Nuclear Safety Commission (CNSC) to further strengthen cooperation within the field of nuclear safety. ENSI has already concluded similar bilateral cooperation agreements with Germany, France, Italy, Austria, the USA, Finland and the EU.

Switzerland has yearly meetings of its bilateral commissions with its neighbours Germany, France, Italy, and Austria. In September 2014, ENSI implemented a comprehensive strategy for international cooperation[5] with other countries and international organisations. The aim of the strategy is to improve nuclear safety and security on a continuous basis and to strengthen nuclear supervision in Switzerland through active participation in the international exchange of regulatory information and experience.

Actions taken in Switzerland in the light of the Fukushima Daiichi accident

Directly after the reactor accidents in TEPCO Fukushima Daiichi on 11 March 2011, ENSI ordered measures for a review of the safety of the Swiss nuclear power plants. The measures were set out in several formal orders issued by ENSI. The first three orders (dated 18 March, 1 April and 5 May 2011) called for immediate measures and additional reviews.

The immediate measures comprised the establishment of a joint external emergency storage facility (Reitnau storage) for the Swiss nuclear power plants, including the necessary plant-specific connections for accident management (AM) equipment, and the backfitting of feeds for the injection of water into the spent fuel pools from the outside. The additional reviews covered the in-depth design reassessment of the Swiss NPPs in respect of earthquakes, external flooding and a combination thereof. A review of the coolant supply for the safety and auxiliary systems and the spent fuel pools was also requested.

It should be noted that in respect of the external hazards, ENSI requested the operators to update the hazard assumptions making use of the latest scientific results and state-of-the-art analysis techniques. Thus, for the seismic hazard, intermediate hazard curves as determined from a SSHAC (Senior Seismic Hazard Analysis Committee) Level 4 process (the so called PEGASOS Refinement Project) were adopted; for the flooding hazard, the most updated simulation and transport techniques were used in order to take into account phenomena such as debris transportation, clogging, etc. For extreme weather hazards, a request was issued to perform a probabilistic hazard analysis in order to determine the 1E-4/y (mean) hazard curve, as is necessary for all external hazards according to the Swiss legal and regulatory framework.

[5] http://www.ensi.ch/en/documents/strategy-for-international-cooperation/

In parallel with these investigations by the operators, ENSI carried out topical inspections, which in 2011 included reviews of the existing cooling systems for the spent fuel pools, protection against external flooding and the systems for filtered containment venting. Topical inspections were continued during 2012; they covered the plants' strategies in case of a prolonged loss of the power supply, the processes and documented requirements for assessing external events, and the emergency rooms available in the Swiss plants. The radiation protection equipment available on site, which is a basic prerequisite for coping with a serious accident, was inspected at all the nuclear power plants during 2013. Radiation protection equipment is also essential so that the emergency rooms can be used by the emergency response organisation in the longer term.

The results of ENSI's reviews have confirmed that the Swiss nuclear power plants have a high degree of protection against the effects of earthquakes, flooding and combinations thereof, and that appropriate precautions have been taken against loss of the power supply and the heat sink. All the analysed accidents are brought under control, taking into account the most updated hazard assumptions. This means that the basic statutory requirements for fulfilling the fundamental safety functions (control of reactivity, cooling of the fuel assemblies and containment of radioactive substances) are guaranteed. With a view to further improvements to safety, ENSI nevertheless specified a series of additional requests for substantial backfitting measures. For example, ENSI concluded that all Swiss NPPs shall have groundwater wells as part of their (bunkered) special emergency systems as alternate cooling water sources for severe accidents, except for Mühleberg NPP. Each operator was therefore asked to propose a solution for a diverse ultimate heat sink. Further examples of backfitting include: temperature and level measurements for the spent fuel pools (SFPs); new feeds for water injection into the SFPs from the outside; for the older Swiss NPPs new safety-grade SFP cooling systems; several AM diesel generators (mostly in fixed installation) and water pumps; PARs for non-inertised containments; seismic isolation of several emergency and special emergency diesel generators; increase of the seismic capacity of numerous components (especially electrical cabinets); etc. Also the Wohlensee dam, around 1.5 km upstream of the Mühleberg NPP was reinforced against sliding effects in the event of earthquakes, thus significantly reducing the risk of seismically induced flooding at the NPP site.

In 2013, ENSI started in-depth re-assessments concerning extreme weather hazards and NPP provisions against them, as well as concerning hydrogen management in containment and beyond (order of 22 April 2013). Studies on the extreme weather safety case were submitted by the licensees by the end of 2014 and are currently under review. On the basis of the hydrogen management analyses of the licensees, ENSI concluded that for those plants where no containment inertisation is in place (i.e. for all NPPs except Mühleberg), additional passive means of hydrogen control are recommended. At the same time, issues related to the safety demonstrations were identified which required more detailed consideration by the plant operators, including the necessary modifications to the SAMG (severe accident management guideline). The backfitting of (mainly) passive autocatalytic recombiners in the plants is being monitored by ENSI within the framework of the normal permit-issuing process (on-going). For more information on backfitting measures after Fukushima Daiichi, see chapters 14, 18 and the subchapter on the Vienna Declaration.

Additionally, the knowledge obtained from analysis of the events of the accident at Fukushima Daiichi was reviewed to determine its applicability to Switzerland, and a summary of insights was compiled in an ENSI report entitled «Lessons Learned» in the form of a series of checkpoints. Further points were added on completion of the analyses for the EU stress tests. The processing and implementation of the identified points were updated annually in the Fukushima Action Plan. The last Fukushima Action Plan[6] was released in February 2015 and most of the identified checkpoints were implemented by the end of 2015.

By the end of 2016, ENSI will publish a summary report on all activities that have been performed within the framework of the Fukushima Action Plan, thus concluding ENSI's post-Fukushima activities.

[6] http://www.ensi.ch/en/documents/action-plan-fukushima-2015/

Summary of the detailed answers to Articles 6–19 of the Convention

Article 6 – Existing nuclear installations

The general safety level of Swiss NPPs is high. The first generation of NPPs in Switzerland (Beznau units I and II and Mühleberg) – which started operation in the late 1960s and early 1970s – has been the subject of progressive back-fitting following major developments in NPP safety technology as well as in response to the Fukushima Daiichi accident. First-generation NPPs have been the subject of regular safety reviews. Licences for their continued operation were granted on the basis of these reviews. The most recent periodic safety review (PSR) for the Mühleberg NPP was submitted towards the end of 2010 and the Inspectorate's review report was published in 2013. In December 2012, the Inspectorate published its review report on the long-term operation of the Mühleberg NPP. Following the decision to shut down the plant at the end of 2019, the strategy for the long-term operation of the Mühleberg NPP has become obsolete. The review report on the long-term operation of the Beznau NPP was published in 2010. There are no fundamental reasons precluding long-term operation. Several requirements to be achieved in order to ensure safe long-term operation of the plant were defined. The most recent PSR for the Beznau NPP was submitted towards the end of 2012 and the Inspectorate's review report will be published in 2016. The second generation of NPPs (Gösgen and Leibstadt) incorporated various safety and operating improvements in their initial design. Currently the replacement of the analogue control technology of the Gösgen NPP by a modern digital system is in progress. With regard to a similar replacement of the control technology of the Leibstadt NPP a project was started in 2015. In 2015 it was decided to upgrade the bunkered emergency systems of the Gösgen NPP in order to cope with a broader spectrum of external hazards.

All PSRs conducted in Switzerland are being reviewed in depth by the Inspectorate. The final review reports of the Inspectorate are available on the Inspectorate's website (www.ensi.ch).

In conclusion, all Swiss NPPs have undergone the safety review process required under the Convention and have incorporated the improvements identified in the respective safety review reports. The Swiss policy of continuous improvement to NPPs based on the current state of the art of science and technology ensures a high level of safety.

Article 7 – Legislative and regulatory framework

The legislation and regulatory framework for nuclear installations is well established in Switzerland. It provides the formal basis for the supervision and the continuous improvement of nuclear installations. The main legal provisions for authorisations and regulation, supervision and inspection are regulated in the Nuclear Energy Act, the Nuclear Energy Ordinance, the Radiological Protection Act and the Radiological Protection Ordinance. The Nuclear Energy Act and its ordinance came into force in 2005. Safety requirements and regulations are detailed in the more than 40 regulatory guidelines of the Inspectorate, covering all aspects of the lifetime of an NPP, i.e. operation and decommissioning, nuclear waste, transport and disposal, as well as radiation protection and emergency preparedness. The Nuclear Energy Act also provides the legal basis for inspections and safety assessments performed by the Inspectorate, and for the enforcement of applicable regulations and the terms of the licence. The Nuclear Energy Act and the Nuclear Energy Ordinance are well established. Due to the Swiss Government's decision to phase out nuclear energy, the Nuclear Energy Act is currently under revision, to incorporate the phase-out into law. New guidelines issued by the Inspectorate have also been introduced. By involving the stakeholders in the procedure of issuing guidelines (especially hearings) and publishing guideline drafts for public comments, the regulatory process is transparent. Furthermore, each new regulatory guideline includes the related international IAEA and WENRA requirements.

Article 8 – Regulatory body

The Federal Council (federal government) grants general licences. DETEC grants construction licences and operating licences for nuclear facilities. ENSI is the supervisory authority for nuclear safety including radiological protection and nuclear security.

The responsibilities and tasks of the Inspectorate have increased over the last 25 years and so the workforce has gradually increased to about 145, including more than 100 specialists in reactor safety, radiation protection, waste management, etc. In addition, its structure has been adapted to reflect changed requirements.

The Inspectorate is fully independent of organisations concerned with the promotion or utilisation of nuclear energy and the licensing of NPPs. It was made independent of the Federal Office of Energy on 1 January 2009 by act of parliament, is controlled by its own strategic board (ENSI Board), and has its own budget.

The Inspectorate uses a process-oriented management system, which was first awarded ISO 9001 certification in December 2001. In November 2007, it was also awarded ISO 14001 certification (environmental management). The accreditation of the inspection activities according to ISO/IEC 17020 was achieved in 2015. In addition, it is planned to obtain an ISO 54001 certification. The management system applies to all relevant activities and is subject to continuous improvement based on management reviews, international expert missions, evaluation of performance indicators, internal audits and routine checks by the certification agency. As a result, the management system of the Inspectorate is well established and provides effective support for both management and daily operations. The entire system was considered a Good Practice in the IRRS mission of 2011.

In April 2015, a follow-up IRRS mission to the 2011 mission was conducted in Switzerland. The mission concluded that the four recommendations and 16 suggestions from 2011 for whose implementation ENSI was mainly responsible were fulfilled but that the Swiss government should give ENSI, as the technical nuclear safety authority, the ability to issue legally binding technical safety requirements and licence conditions on nuclear safety, security and radiation safety. The IRRS mission report was published on the ENSI website.

Article 9 – Responsibility of the licence holder

The responsibilities of the licence holder for the safe operation of an NPP are explicitly stated in the Nuclear Energy Act. Each NPP has accepted the conditions laid down for operation and a corresponding statement is included in the preamble of the operating manual for each NPP. The Inspectorate conducts a variety of oversight activities (inspections, document reviews, safety reviews, and regulatory meetings) to ensure that the licensees assume full responsibility for the safety of their installations.

The senior management of the Inspectorate meets periodically with the senior management of the licensees, addressing technical, financial and human aspects of the NPPs.

The political discussions about the use of nuclear energy in Switzerland did not noticeably affect the personnel turnover rate in the NPPs. However, the NPPs did start increasingly to adopt a more long-term approach to human resource planning as a means to preserve and further develop the necessary competences in nuclear technology.

Article 10 – Priority to safety

Safety has always been afforded the highest priority by all organisations actively involved in operating, decommissioning and dismantling nuclear installations in Switzerland. To give the highest priority to safety is, by law, a general obligation of each licence holder. All licensees have implemented this obligation in their management system and it is also demonstrated by the commitment of these organisations to external comparison, peer review, and improvement. All Swiss NPPs underwent OSART missions, including follow-up missions. The last OSART mission took place in October 2012. Since 2005, all Swiss NPPs have regularly taken part in the WANO Peer Review Process involving a WANO peer review and a WANO follow-up mission over a cycle of about six years. The Inspectorate also demonstrated a commitment to peer review and improvement, by undergoing an IRRS mission in 2011 and a follow-up IRRS mission in 2015, respectively.

Article 11 – Financial and human resources

NPP operators in Switzerland have sufficient financial resources to maintain a high level of safety throughout the lifetime of a NPP. Should a NPP no longer fulfil the regulatory safety requirements, its licence would be revoked and it would not be able to continue operating. Decommissioning and waste disposal are funded by dedicated funds.

As required by the Swiss Nuclear Energy Act, corresponding ordinances and regulatory guidelines, the installations have sufficient qualified staff capable of managing and controlling nuclear installations. Over the reporting period, staffing levels have remained largely stable at all Swiss NPPs.

NPP personnel receive regular education and training. Ongoing training is provided so that personnel keep abreast of advances in science and technology and plant modifications. All Swiss NPPs operate plant-specific full-scope replica simulators.

Article 12 – Human factors

The obligation of the licensee to establish a suitable organisation (i.e. organisational structures and processes) is firmly embedded in the Swiss legislative framework. The Nuclear Energy Ordinance sets out requirements concerning the organisation that are specified in detail in guideline G07 «Organisation of Nuclear Power Installations». Attention is also given to the safety culture concept. The abovementioned guideline stipulates that the licensee must permanently incorporate measures in its management system to observe, to assess, and to strengthen its safety culture. In addition, the Inspectorate worked to establish a common understanding of the term «human and organisational factors» and on this basis a systemic approach to overseeing these factors.

The Nuclear Energy Ordinance lays down a series of NPP design principles, including a human factor principle: «Workstations and processes for the operation and maintenance of the installation must be designed so that they take account of human capabilities and their limits». The Inspectorate pays particular attention to this principle in its oversight of plant modernisation projects.

All NPPs conduct thorough investigations of human and organisational factors whenever they are identified as the root cause or a contributing factor in events with a relevance to safety.

Article 13 – Quality assurance

All Swiss NPPs have an integrated management system and are certified according to the current standards. All NPPs have incorporated appropriate self-assessment processes in their management systems. The Inspectorate regularly performs inspections on the safety relevant processes of the licensees' management systems to assess the effectiveness of quality assurance measures. Taking into account the difficult economic situation and changes in the nuclear supply industry, which makes the Customer Capability more and more important, ENSI, focussed its oversight in the reporting period on safety relevant processes with contractor involvement (e.g. procurement, skills management).

Article 14 – Assessment and verification of safety

In Switzerland, the review and assessment procedure includes an evaluation of the safety analysis report (SAR), safety-relevant systems, deterministic accident analyses, probabilistic safety analysis (PSA), reports on ageing surveillance programmes together with other safety-related documents if requested by the Inspectorate. As part of the integrated oversight approach (see below), an annual systematic assessment of nuclear safety is conducted for each NPP based on event analyses, inspection results, operator licensing reviews, safety-indicator data and information in the periodic licensee reports. The assessment of the periodic safety review (PSR) by an NPP is documented in a Periodic

Safety Review evaluation report. PSRs are required at least every 10 years. Plant documentation must be regularly updated, including the SAR and PSA. The licence document includes important conditions and operating requirements. The Nuclear Energy Ordinance contains a requirement for a PSA and for PSRs.

An Ageing Surveillance Programme is in place for all Swiss NPPs. This programme serves to collect information on the structures, systems and components of relevance for the monitoring of ageing and understanding of ageing mechanisms in order to maintain safety margins and the safety functions of structures, systems and components throughout the life of a plant. It is a prerequisite for long-term operation.

The following additional points help to ensure that the physical state of an NPP complies with its licence:

- Modifications important for safety require a permit granted by the Inspectorate.
- A plant review must be carried out after each refuelling outage.
- The Inspectorate has an efficient inspection programme in place in order to verify compliance with licensing requirements.

The Inspectorate adopts an integrated oversight approach. To obtain a realistic picture of the safety of each installation, the Inspectorate operates a systematic safety assessment system. Safety relevant information is structured in such a way that there is a distinction between the individual safety provisions as defined in plant documents and their real state and behaviour, together with a distinction in terms of technical and human-organisational aspects. Every piece of data is assigned to fundamental safety functions and to levels of defence in depth and barriers.

The data for each NPP is summarised in a table. Inspection findings, operator licensing reviews, event analysis results, safety-indicator data and information in the periodic licensee reports are evaluated annually as part of the integrated oversight process.

Further reviews and assessments of the design basis are mandatory if events of INES 2 and higher occur in a national or international NPP. As a direct consequence of the major accident in Japan, the Inspectorate issued three formal orders in which the operators of the Swiss nuclear power plants were required to implement immediate measures and to conduct additional reassessments. The Inspectorate ordered immediate measures, which comprised the establishment of an external emergency storage facility for the Swiss NPPs, including the necessary plant-specific connections, and backfitting measures to ensure the provision of external injection means into the spent fuel pools. The additional re-assessments, which were to be carried out immediately, focused on the design basis of Swiss NPPs against earthquakes, external flooding, extreme weather conditions and combinations thereof. Investigations were also requested regarding the coolant supply for the safety systems and the spent fuel pool cooling, taking into account the lessons learnt from the accident in Japan.

Within the scope of the EU stress test performed on the Inspectorate's orders after the Fukushima Daiichi accident, the operators of the Swiss nuclear power plants submitted their reports. The results of the Inspectorate's review confirmed that the Swiss NPPs display a high level of protection against the impacts of earthquakes, flooding and other natural hazards, as well as loss of electrical power and ultimate heat sink.

The complete summary of backfittings initiated after Fukushima Daiichi is given in Article 18.

Article 15 – Radiation protection

Based on the recommendations of the International Commission on Radiological Protection (ICRP), both the Radiological Protection Act and the Radiological Protection Ordinance were revised and came into force in 1994. The Inspectorate has subsequently issued revised versions of most of its relevant guidelines.

Currently, the Swiss Radiological Protection Ordinance is under revision to obtain inter alia compatibility with the new European Safety Directive and the IAEA Basic Safety Standards.

The supervisory and control methods currently applied by the Inspectorate are in compliance with the Convention's requirement to keep radioactive doses to the personnel, the public and the environment as low as reasonably achievable and also to keep the generation of radioactive waste associated with the use of nuclear power at the lowest possible level.

Calculated doses on the base of annual emissions for a virtual most exposed group of the population, including the exposure due to deposition from former years, have always been well below 0.2 mSv per year. Since 1994, values due to annual releases have been below 0.01 mSv per year for all Swiss NPPs. Since 1994 with two exceptions, no individual dose above 20 mSv per year was accumulated by plant personnel or contractors during their work in the Swiss NPPs. Since 1987, all annual collective doses have remained well below 4 man-Sv per unit and all have been kept around 2.0 man-Sv since 1995. The low annual individual and collective doses prove the effectiveness of the measures based on the most recent recommendations of the ICRP (e.g. guidelines, job planning and supervision).

The Inspectorate reviews the radiation planning process of the NPPs as a part of its supervisory duties. Additionally, the Inspectorate reviews all periodical reports of the power plants related to radiation protection measures.

Article 16 – Emergency preparedness

The lessons learned from the accident of Fukushima Daiichi led to the initiation of numerous actions in Switzerland with the aim of improving preparedness and response capabilities both on and off site. On the basis of a report by ENSI, the Federal Council decided on 4 May 2011 to set up an official working group to review emergency preparedness measures in case of extreme events in Switzerland (IDA NOMEX). The report of IDA NOMEX was adopted by the Federal Council on 7 July 2012. As a consequence of IDA NOMEX, the legal basis as well as concepts pertinent to emergency preparedness and response were revised or are in the process of being updated. The scenario used for emergency planning purposes is now characterised by an unfiltered, substantially higher source term than previously assumed. As a consequence, awareness for emergency preparedness and response beyond the outer radius of Zone 2 (i.e. 20 km) has been raised, which is reflected in the revised concept for emergency protection in the event of an accident at a nuclear power plant. Following the IRRS mission in November 2011, the Inspectorate introduced an IAEA-compatible emergency classification system, extended the scope of inspections with regard to emergency preparedness and response at the NPP sites and improved the redundancy of emergency communication means. A national nuclear and radiation emergency plan is also being developed under the leadership of the Federal Office of Civil Protection. Severe accident management guidelines (SAMGs) are available for all plant states at Swiss NPPs. They are generally symptom-based and thus suitable for covering a comprehensive set of scenarios. The use of mobile or accident management equipment to cope with a Station Blackout (SBO) recently received special attention, including topical inspections by ENSI. Effects of damage to infrastructure and communication systems are addressed by IDA NOMEX. The work on the measures suggested by IDA NOMEX will continue.

On-site and off-site emergency plans exist for each Swiss nuclear installation. Emergency planning zones around NPPs are defined. Emergency protective measures, e.g. sheltering and the availability of iodine tablets, have also been established.

There is an automatic dose rate monitoring and emergency response data system (MADUK) around all NPPs in Switzerland. The data is transmitted electronically to the Inspectorate, the National Emergency Operations Centre and the Ministry of the Environment of Baden-Württemberg (Germany). The ANPA system also provides the Inspectorate with online access to measurement data for approximately 25 important plant parameters. The Inspectorate has also set up an automated system for radiological forecasting.

Appropriate channels exist for alerting the public, the National Emergency Operations Centre and neighbouring countries. Bilateral agreements between Switzerland and neighbouring countries covering alerts in the event of an emergency are in place. The preparedness of Switzerland and its response at the international level is regularly verified by its participation in international exercises conducted by the IAEA or ECURIE.

Article 17 – Siting

The licensing procedure includes the steps required to evaluate the relevant NPP site-related safety factors. Under the Nuclear Energy Act and the Nuclear Energy Ordinance, a general licence for a nuclear installation can only be granted if the site is suitable. The decision on whether to grant a general licence is subject to a facultative national referendum. When evaluating the suitability of a potential NPP site, a comprehensive investigation of the external hazards must be carried out as a basis for an appropriate plant design. All site-related factors must be included in a Safety Analysis Report (SAR). Furthermore, the general licence application must include an environmental impact report, a decommissioning concept and other safety-related documents. Applicants for a construction licence must submit an updated SAR, a deterministic safety analysis (which can be part of the updated SAR) and a probabilistic safety analysis (PSA) as described in the section on Article 14. The Inspectorate reviews these documents and publishes the results in a safety evaluation report. Those living in the areas surrounding the site of a proposed NPP (including areas in neighbouring countries) are invited to participate in the comprehensive public consultation conducted as part of the licensing procedure. Switzerland has signed agreements on the exchange of information with its neighbours Austria, France, Germany and Italy and is a signing party of the ESPOO convention. Site-related factors are re-evaluated periodically as part of a Periodic Safety Review. Currently, no new builds are planned as the Swiss Government has decided on a nuclear phase-out in Switzerland in May 2011.

The applicability and effectiveness of the Inspectorate's re-evaluation process has been demonstrated by the probabilistic re-assessment of seismic hazards at Swiss NPP sites (PEGASOS). This project was carried out by Swiss licensees in response to a requirement in the Inspectorate's PSA review process. In 2008, Swiss licensees launched a follow-up project – PEGASOS Refinement Project (PRP) – in order to take advantage of recent findings in earth sciences and new geological and geophysical investigations at existing NPP sites. PRP aims at reducing the uncertainty range of the former PEGASOS results. The PRP was completed and submitted by the end of in 2013. At the end of 2015, ENSI defined new hazard assumptions, based on PRP, called ENSI-2015.

Because of the insights coming from the Fukushima Daiichi accident, ENSI asked the licensees to re-analyse what constituted adequate protection against external flooding for their NPPs taking into account the upgraded site-specific flooding hazard. The results identified some necessary backfits (e.g. improving the water intake's protection against blockage on one site). After implementation of the measures, ENSI concluded that all the Swiss plants have sufficient margins over their design basis. Finally, as regards extreme weather conditions, ENSI defined in greater detail the requirements for the probabilistic hazard analyses and safety case. At the end of 2012, in compliance with an ENSI request to this effect, the plant operators submitted a document illustrating how they intend to build their safety case. The probabilistic hazard analyses and the proof of adequate protection of the plant against extreme weather conditions were submitted to ENSI in 2014. The hazard analyses were reviewed by ENSI in 2015. As a result of ENSI's review, the Swiss NPPs were required to update their hazard analyses. Some provisional hazard values were defined to be used for the proof of adequate protection.

Article 18 – Design and construction

The Swiss NPPs were designed, constructed and backfitted in accordance with the concept of defence in depth. To enhance robustness against extreme external events, all Swiss NPPs have a special independent, bunkered system for shutdown and residual heat removal. The various levels of defence that exist ensure that safety criteria and dose limits for the public are met during normal operation of the

NPP and for all design-basis accidents. In addition, there are appropriate measures to prevent or mitigate the release of radioactive materials into the environment in the case of beyond design-basis accidents. Design, materials and components are subject to rigorous control and scrutiny and regular testing in order to verify their fitness for service. Safety assessments for the long-term operation of first-generation NPPs have been performed as part of the periodic safety reviews. Backfitting is carried out when necessary. All Swiss NPPs possess a filtered containment venting system to mitigate radiological effects on the environment in the most severe accident scenarios.

After Fukushima Daiichi, the protection of the Swiss NPPs and their spent fuel pools (SFP) against external events was reassessed by the licence holders. Furthermore, the Inspectorate ordered all licence holders to immediately implement two physically separated lines/connections for feeding the SFPs from outside the buildings as an accident management measure, and to backfit seismically robust SFP cooling systems in the first generation NPPs. In addition, the Inspectorate conducted several inspections to assess the situation in the Swiss NPPs regarding issues that resulted from the accident management actions performed at Fukushima Daiichi.

Furthermore, as specified in Article 5 of the Ordinance on Hazard Assumptions and the Evaluation of Protection against Accidents in Nuclear Plants (SR 732.112.2), the safety of an NPP must be demonstrated for natural hazards with an exceedance frequency of 10^{-4} per annum. The seismic hazard was reassessed by a SSHAC Level 4 study (as defined in NUREG/CR-6372) in 2004. This study is designated as the PEGASOS project. In order to reduce the uncertainty of the PEGASOS results (mainly with additional data), the PEGASOS Refinement Project (PRP) was initiated. Based on intermediate results of PRP, ENSI requested the licensees to demonstrate seismic safety. The corresponding safety cases were submitted and reviewed by ENSI in 2012. It could be demonstrated that all Swiss NPPs fulfil the requirements. The external flooding analyses were re-assessed in 2011 for flood levels with an exceedance frequency of 10^{-4} per annum. It could be demonstrated that all Swiss NPPs fulfil the requirements. All Swiss NPPs have conducted substantial seismic backfits since commissioning.

To summarise, the Swiss NPPs were designed and constructed on the basis of the IAEA concept of defence in depth. The basic principles regarding redundancy, diversity, physical and functional separation, and automation were integrated in the Nuclear Energy Act, in the Nuclear Energy Ordinance, and in the guidelines issued by the Inspectorate, ensuring that those principles are implemented in the plants as far as reasonable.

Article 19 – Operation

The requirements for the safe operation of Swiss NPPs are specified in the operating licence granted to each NPP. The operation licence includes commissioning approval. The commissioning programme, which requires the approval of the Inspectorate, comprises pre-operational and start-up tests as well as procedures for testing any equipment important for safety. The most important operational procedures are the Technical Specifications, which include the limiting conditions for operation and similarly require the approval of the Inspectorate. The operational procedures for an NPP also cover the maintenance, testing and surveillance of equipment. Engineering and technical support in all fields of relevance to safety is available to all NPP staff.

The Nuclear Energy Act, the Nuclear Energy Ordinance and regulatory guidelines include requirements on the notification of events and incidents. Under the Ordinance, each NPP must use dedicated emergency operation procedures (EOPs) for operational anomalies and emergency conditions. The ultimate objective of EOPs is to bring the plant into a safe operational state. The legislation also requires an extension to EOPs in the form of severe accident management guidance (SAMG). This is designed to prevent or at least minimise any impact on the environment. In all Swiss NPPs, SAMG is implemented covering all relevant operational states. 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. All NPPs have Accident Management (AM) procedures on a variety of measures to deal with scenarios beyond the design basis of the plant. All Swiss NPPs are equipped with special bunkered safety systems designed against extreme external events. ENSI has requested a new safety case to demonstrate that the Swiss NPPs have adequate protection against the 10,000-year earthquake and the combination of this earthquake and a 10,000-year flooding. The necessary analyses were submitted by the licence holders and examined by ENSI. Several open points were identified that require further examination. The existing strategies to cope with Station Blackout (SBO) scenarios have been extended. As a result, additional equipment has been installed or stored on the plant sites and the existing accident management procedures will be adapted accordingly. A flood-proof and earthquake-resistant external storage facility has been in place at Reitnau since June 2011 in order to strengthen the provision for accident mitigation.

The Swiss NPPs have developed their own on-site technical support covering the surveillance test programme, reactor engineering and fuel management, operational experience feedback, plant modifications and safety-related computer applications.

The Nuclear Energy Act, the Nuclear Energy Ordinance and the Inspectorate's guidelines contain requirements on the notification of events and incidents. An important process in Swiss NPPs is the process dealing with non-conformance control and remedial action. It is guided by procedures that form part of the management system. Any non-conformance is reported and discussed at the daily morning meeting held by each NPP and follow up action (e.g. work authorisations) is initiated where necessary. Furthermore, each NPP has a process for handling external operating experience, which screens and evaluates information on external events. The Inspectorate has its own process for assessing events in nuclear installations in other countries.

Each Swiss NPP is required to carry out a PSR at least every 10 years. As part of the PSR, each plant is required to assess in summary form its own operating experience and any important foreign event of relevance to the plant. This review is also assessed by the Inspectorate and its safety evaluation report is publicly available.

In addition to its general inspection activities, the Inspectorate gains further insight into the operations of an NPP through a system of comprehensive operator reporting. Both the Inspectorate and the operators collect operating experience from domestic and foreign NPPs. In some cases, an analysis of a particular operating experience has resulted in important safety-related backfitting or modifications to Swiss NPPs.

The Nuclear Energy Act includes the principle that the generator of radioactive waste is responsible for its safe and permanent management. Thanks to high fuel quality and plant cleanliness, the generation of radioactive waste at NPPs is kept to the minimum possible. The resultant waste is collected and separated. As a general rule, radioactive waste is conditioned as soon as practicable, mostly on site at an NPP or the Paul Scherrer Institute (PSI), but also in part externally at the Central Interim Storage Facility. All procedures for the conditioning of radioactive waste require the approval of the Inspectorate. Each NPP stores spent fuel discharged from reactors on site for several years.

The Nuclear Energy Act prohibits the reprocessing of spent nuclear fuel for a period of ten years starting on 1 July 2006. This moratorium has been prolonged for another 10 years and a permanent ban on reprocessing is being discussed as part of the pending revision of the Swiss Nuclear Energy Act. At present, spent fuel is also stored in transport and storage casks at the Central Interim Storage Facility. The return of waste from foreign reprocessing facilities to the Central Interim Storage Facility started in 2002 and is on schedule. Last shipments are expected before the end of 2016 when no further obligations for waste return to Switzerland will remain. Since July 2006, any spent fuel from the Mühleberg and Leibstadt NPPs has been transported to the Central Interim Storage Facility and stored in dry transport and storage casks. The Beznau NPP operates its own dry storage facility on site, whereas the Gösgen NPP started on-site operation of a separate wet storage facility for spent fuel in May 2008.

All Swiss NPPs underwent Operational Safety Review Team (OSART) missions, including the follow-up missions, and all of them have implemented the recommendations received in the OSART reports. All

Swiss OSART reports are available to the public. In June 2014, the Mühleberg NPP underwent an OSART follow-up mission under its own initiative. All Swiss NPPs also underwent more than one WANO mission at their own initiative; the last one being a follow-up mission at Gösgen NPP.

Implementation of the Vienna Declaration on Nuclear Safety in Switzerland

1. New nuclear power plants are to be designed, sited, and constructed, consistent with the objective of preventing accidents in the commissioning and operation and, should an accident occur, mitigating possible releases of radionuclides causing long-term off-site contamination and avoiding early radioactive releases or radioactive releases large enough to require long-term protective measures and actions.

The principles regarding design and construction of nuclear power plants are enshrined in the Nuclear Energy Act, Nuclear Energy Ordinance and ENSI guidelines (for detailed information on the Swiss regulatory system, see Article 7.) In 2011, the government decided to phase out nuclear power in Switzerland. As a result, no new NPPs are planned.

Article 4, paragraph 1 of the Nuclear Energy Act (NEA) stipulates that «Special care must be taken to prevent the release of impermissible quantities of radioactive substances and to protect humans against impermissible levels of radiation during normal operation and accidents.»

Article 5, paragraph 1 of the NEA stipulates that «preventive and protective measures must be taken in accordance with internationally accepted principles» for the design, construction and operation of nuclear installations. These measures include the use of high-quality components, safety barriers, multiple and automated safety systems, the formation of a suitable organisation with qualified personnel, and the fostering of a strong safety awareness.

The preventive and protective measures stipulated in Article 5 of the NEA provide the minimum requirements for new nuclear power plants.

Furthermore, Article 4, paragraph 3, letter a, entails a dynamic requirement stipulating that precautionary measures «are required in accordance with experience and the state of art in science and technology». The state of the art of science and technology is essentially based on the safety standards set by the IAEA. This way the Swiss national requirements reflect the IAEA safety standards.

In addition, a so-called precautionary principle anchored in Article 4, paragraph 3, letter b, requires precautionary measures that «contribute towards an additional reduction of risk insofar as they are appropriate» beyond the minimal requirements and the state of the art of science and technology.

The Swiss Nuclear Energy Ordinance (NEO) is legally binding and describes the minimal requirements of Article 5 of the NEA regarding design and construction of nuclear power plants in more detail. These requirements apply for new NPPs and, as far as reasonably achievable, for existing NPPs. Article 10 NEO paragraph 1 specifies the requirements regarding single failure and maintenance criteria the principles of redundancy, diversity, physical separation, and functional independence. In letter f paragraph 1 of Article 10 NEO, it is required that safety functions must be initiated automatically, without the need for the operators to take safety related actions within the first 30 minutes after an initiating event. Furthermore, it is stipulated that sufficient margins must be considered in the design and construction of systems and components, that a fail-safe behaviour must be aimed at, and that safety functions should be conducted preferably by passive means.

In Article 8 of the NEO, the requirements regarding the protection of NPPs against internal and external hazards are given. The initiating events to be considered in the design are listed in paragraphs 2 and 3. More specific requirements regarding hazard assumptions and assessment of the degree of protection against hazards are given in the «Ordinance on Hazard Assumptions and the Evaluation of Protection against Accidents in Nuclear Power Plants» (SR 732.112.2). It is required that the safety of an NPP must be demonstrated for natural hazards of a frequency of 10^{-4} per year.

The dynamic requirements (cf. *Article 4, paragraph 3, letter a NEA*) are mainly based on the IAEA safety standards. More detailed guidance for special cases are given in the Inspectorate's guidelines. Due to its dynamic character, the precautionary principle is defined only in exceptional cases in ENSI's regulatory framework. One of these exceptions is guideline HSK-R-103 «Measures against the consequences of severe accidents» issued in 1989, taking into account the lessons learned from the Chernobyl accident. The requirements of that time already include the implementation of means for RPV pressure relief, hydrogen management, filtered containment venting systems, and means for ex-vessel cooling of a molten core.
The dynamic requirement and the precautionary principle in the Swiss legal framework ascertain that new nuclear power plants are designed, sited and constructed consistent with the current international safety requirements. This also complies with the principles in the VDNS.

2. Comprehensive and systematic safety assessments are to be carried out periodically and regularly for existing installations throughout their lifetime in order to identify safety improvements that are oriented to meet the above objective. Reasonably practicable or achievable safety improvements are to be implemented in a timely manner.

In Switzerland, there is a safety assessment in the course of the PSR at least every 10 years. Within these safety evaluation processes, potential improvements are identified and – as appropriate – implemented. Further improvements may be required in the course of the safety assessment regarding long-term operation (for more information on PSR, see Article 14). In addition, there is a systematic assessment of nuclear safety for each NPP based on event analyses, inspection results, safety-indicator data and information in the periodic licensee reports.
The legal requirement for PSRs is stipulated in Article 22, clause 2, letter e of the NEA. The licence holder shall: «in the case of nuclear power plants, carry out a comprehensive periodic safety review». The scope of the PSR is defined in Article 34 of the NEO and specified in guideline ENSI-A03. As part of the PSR, each plant is required to assess its own operating experience and lessons learnt from the operation of comparable NPPs. The scope of this assessment is defined in Chapter 5.2 of ENSI guideline A03. The PSRs are assessed by ENSI and the results are recorded in an assessment report, together with any measures that may be imposed. The report is made publicly available.
The legal requirements for backfitting existing NPPs are analogous to the provisions for new-builds in their structure (minimum requirements, dynamic requirement, precautionary principle). The Ordinance on the Methodology and the General Conditions for Checking the Criteria for the Provisional Taking out of Service on Nuclear Power Plants (SSR.732.114.5) defines a set of minimal criteria for the existing NPPs to fulfil. If these criteria are not met, the plant has to be taken out of service and backfitted.
There is a dynamic requirement and precautionary principle also for existing NPPs. Article 22, clause 2, letter g, of the NEA requires that the licence holder shall: «backfit the installation to the necessary extent that it is in keeping with operational experience and the current state of backfitting technology, and beyond insofar as further upgrading is appropriate and results in a further reduction of risk to humans and the environment».
The Inspectorate is currently developing guideline ENSI-G02 «Design principles for existing NPPs» to concretise the state of backfitting technology used in Article 22. Clause 2, letter g, of the NEA. In this guideline, all the relevant safety requirements set by the IAEA and WENRA will be put in concrete terms.
The Inspectorate reviews the backfitting projects and in doing so closely monitors the process. The projects and modifications are subject to a four-step procedure, consisting of the concept, the detailed design, the installation, and the commissioning of the systems. The Inspectorate grants permissions for every step of the procedure after thorough examination of the appropriateness and compliance with national and international safety requirements.

In conclusion it can be stated that the dynamic requirement and the precautionary principle for existing NPPs in the Swiss legal framework ensures that safety improvements according to international good practice are implemented in a timely manner.

There are plenty of examples for backfitting projects in Switzerland. Already in 1987, it was required by the Inspectorate that NPPs had to be protected against heavy external hazards such as an aircraft impact, explosion, and third party action (HSK-R-101). This requirement led to the construction of the bunkered special emergency heat removal systems, which are designed to operate autarkically for at least 10 hours after the initiating event.

The most important backfitting projects and the history of PSRs are outlined in Article 6 of this report. A list of backfittings and improvements ordered and performed after Fukushima, is given in Article 18. For more information on PSR and backfitting, see Articles 6, 14 and 18.

3. National requirements and regulations for addressing this objective throughout the lifetime of nuclear power plants are to take into account the relevant IAEA Safety Standards and, as appropriate, other good practices as identified inter alia in the Review Meetings of the CNS.

Article 5 of the NEA stipulates «When designing, constructing and operating nuclear installations, preventive and protective measures must be taken in accordance with internationally accepted principles.» Consequently, internationally accepted principles must be taken into account even by the minimal requirements for new NPPs. The relevant IAEA safety standards are being incorporated into the Swiss national requirements and regulations through the above-mentioned dynamic requirement, as the IAEA safety standards essentially are being used as definition for the latest state of the art of science and technology. Other good practices are taken into account through the precautionary principle.

Developments and Conclusion

The Nuclear Energy Act requires the Swiss licensees to perform periodic safety reviews at least every 10 years and to backfit the installation to the necessary extent such that it complies with operational experience and the current state of backfitting technology. Due to a government decision in 2011, no new nuclear power plants are planned in Switzerland.

Article 6 – Existing nuclear installations

Each Contracting Party shall take the appropriate steps to ensure that the safety of nuclear installations existing at the time the Convention enters into force for that Contracting Party is reviewed as soon as possible. When necessary in the context of this Convention, the Contracting Party shall ensure that all reasonably practicable improvements are made as a matter of urgency to upgrade the safety of the nuclear installation. If such upgrading cannot be achieved, plans should be implemented to shut down the nuclear installation as soon as practically possible. The timing of the shutdown may take into account the whole energy context and possible alternatives as well as the social, environmental and economic impact.

The general safety of Swiss NPPs was satisfactory at the time the Convention came into force. All NPPs are subject to PSRs at least every 10 years; the safety of all NPPs has been reliably established based on deterministic and probabilistic assessments, operational performance and aspects of safety culture.

PSRs are stipulated in Article 22, clause 2, letter e of the Nuclear Energy Act. The licence holder shall «in the case of nuclear power plants, carry out a comprehensive periodic safety review». The obligation of backfitting nuclear installations is stipulated in Article 22, clause 2, letter g of the Nuclear Energy Act. The licence holder shall «backfit the installation to the necessary extent that it is in keeping with operational experience and the current state of backfitting technology, and beyond insofar as further upgrading is appropriate and results in a further reduction of risk to humans and the environment». The Nuclear Energy Act came into force in 2005. Nevertheless, major backfitting projects have been implemented since the eighties. The most important are outlined below.

The **first generation of NPPs** in Switzerland (Beznau and Mühleberg) started operation between 1969 and 1972. At that time, the Swiss Federal Nuclear Safety Commission was responsible for the review and assessment of applications for site, construction and operating licences. It relied mainly on US regulations and guidance dating from the period as the two reactors came from the USA.

However, certain principles of nuclear safety were not universally acknowledged at that time and so no account was taken of them, e.g.:

- separation criteria for electro-technical and mechanical equipment as a way of protecting an NPP from common cause failures resulting from fire or internal flooding, for example;
- rigorous application of the single failure criterion, including those relating to supporting systems in the event of a loss of offsite power;.
- protection of residual heat removal (RHR) systems against external events (e.g. aircraft crashes, earthquakes, floods, lightning and sabotage);
- supplementary shutdown capability in a remote area if the main control room has been lost.

By 1980, the safety authorities had demanded two major backfitting projects in order to improve RHR systems in first generation plants. These projects, which extended over several years, were known as «NANO» for the PWR twin-unit at Beznau NPP and «SUSAN» for the BWR at Mühleberg NPP. In addition, a seismic requalification was carried out in the late 1980s. This back-fitting project consisted primarily of adding one or two fully separated shutdown and RHR systems, including support systems, which addressed the above four issues.

In addition to the NANO feed water system, an emergency feed water system was installed in both Beznau units in the years 1999 and 2000. This was done to improve the reliability and the capacity of the auxiliary feed water system. In both Beznau units, improvements were also made to the reactor protection system and the control systems for separation, redundancy, self-supervision, testability and reliability of power supply by replacing the original systems with a state-of-the-art computerised system in 2000 and 2001. In 2015, a seismically robust emergency diesel generator system was installed in both Beznau units.

Extensive reviews were conducted at both plants following these major backfitting projects. For the Mühleberg NPP, the review was completed in 1992 and for the Beznau NPP in 1994. Following this backfitting work, the two plants were granted new operating licences. Extensive review of these two NPPs was in the form of PSRs. For the Mühleberg NPP, the assessments of the PSRs were completed in 2002 and 2007, for the Beznau NPP in 2004.

The most recent PSR for the Mühleberg NPP was submitted towards the end of 2010 and the Inspectorate's review report was published in 2013. In December 2012, the Inspectorate published its review report on the long-term operation of the Mühleberg NPP. Following the decision to shut down the plant at the end of 2019 the strategy for the long term operation of the Mühleberg NPP has become obsolete.

The review report on the long-term operation of Beznau NPP was published in 2010. There are no fundamental reasons precluding long-term operation. Several requirements to be achieved in order to ensure safe long-term operation of the plant were defined. The most recent PSR for Beznau NPP was submitted towards the end of 2012 and the Inspectorate's review report will be published by the end of 2016.

Aerial view of Beznau NPP – Source Axpo Power AG

In 2013, the owner of the Mühleberg NPP, BKW Energie Ltd., decided to shut down the plant at the end of 2019. Provisions to increase the safety of the plant during the remaining time of operation have been decreed by ENSI (see Article 18). On 18 December 2015, BKW submitted a formal application for the decommissioning order according to Article 28 of the Nuclear Energy act (NEA) to DETEC.

The **second generation of NPPs** in Switzerland started operation in 1979 (Gösgen) and 1984 (Leibstadt). They had a higher degree of redundancy and their protection against external events was significantly better than that in the first generation plants. Some further improvements were introduced during licensing and construction (in particular, inclusion of a special emergency heat removal system at the Leibstadt NPP).

Currently the replacement of the analogue control technology of the Gösgen NPP by a modern digital system is in progress. With regard to a similar replacement of the control-technology of the Leibstadt NPP, a project was started in 2015. In 2015, it was decided to upgrade the bunkered emergency systems of the Gösgen NPP in order to cope with a broader spectrum of external hazards.
Table 1(see introduction) contains an overview of the main technical characteristics of the Swiss NPPs. Both second-generation plants have undergone PSRs. For the Leibstadt plant, the first review was performed in 1996 together with a review of the 14.7% power uprate request for the utility. The most recent PSR for Leibstadt NPP was submitted by the end of 2006 to ENSI, which published its review report in August 2009. The first PSR for the Gösgen plant was completed in 1999. The second PSR for the Gösgen NPP was submitted to ENSI by the end of 2008. ENSI published its corresponding review report in August 2012.
In 1993, all five plants were back-fitted with a filtered containment venting system to mitigate the consequences of severe accidents (e.g. failure of RHR systems).
After the Fukushima Accident, additional safety reviews were performed. All Swiss nuclear power plants were required to backfit two additional external feed options to resupply spent fuel pools with coolant. An external storage facility at Reitnau has been in place since June 2011, containing various operational resources for emergencies that can readily be called up. If transport by road is not possible, there is the option of air transportation by helicopters. Mobile accident management (AM) equipment stored on-site has been significantly upgraded. For further information on measures taken after the Fukushima Accident, see Articles 16–19.
For further information on backfitting works, see Articles 14 and 18.

Decommissioning of Mühleberg NPP

In late 2013, BKW Energy Ltd announced that Mühleberg will be decommissioned by the end of 2019. The single 373 MWe boiling water reactor began operating in 1972. It will be the first Swiss NPP to be decommissioned.
On 18 December 2015, BKW submitted the application documents (the final decommissioning plan) to decommission its NPP to DETEC. The application comprises the main report detailing the decommissioning project's conceptual framework and three sub-reports: accident analyses and emergency protection measures; the environmental impact report; and the security report.
During the preparation of the decommissioning of the Mühleberg NPP, the Swiss Confederation established a cross-institutional monitoring group. All stakeholders are member of this group: Swiss Federal Office of Energy (SFOE), the Federal Office for the Environment (FOEN), the Canton of Bern, ENSI and BKW. Three subgroups were formed with respect to technical aspects, legal procedure and communication. In March 2015, the subgroup of communication organised three public events near Mühleberg NPP. In total more than 800 people visited these events and showed much interest in the decommissioning plan, funding, costs, waste treatment and disposal. In April 2016, these public events were repeated.
The requirements for the final decommissioning plan are described in the Nuclear Energy Act, the Nuclear Energy Ordinance and in ENSI's technical guideline ENSI-G17. The decommissioning guideline ENSI-G17 is in accordance with the WENRA Safety Reference Levels and the respective IAEA Safety Standards on decommissioning.
The submitted documents will be reviewed by the authorities (SFOE, FOEN, The Swiss Accident Insurance Fund SUVA, and The State Secretariat for Economic Affairs SECO, ENSI, and the Cantons). Based on the authorities advisory opinions DETEC will issue the decommissioning order that regulates the decommissioning process. BKW expects the decommissioning order in mid-2018 – more than one year before final shutdown. This approach should ensure that any potential appeal procedures could be finalised before the plant's planned shutdown on 20 December 2019.

The decommissioning of Mühleberg NPP will be the first decommissioning of a commercial NPP in Switzerland. According to the plans of BKW, performing certain preparatory dismantling activities while spent fuel is still on site will reduce the time for decommissioning to about 11 years.
The decision to shut down the Mühleberg NPP in 2019 has not led to a fall in staff numbers at Mühleberg. The plant has developed a concept that ensures that the staff of Mühleberg NPP have a perspective for their work life after decommissioning.

Developments and Conclusion

Backfitting required in response to technical progress, or analysis of hazards in light of the Fukushima accident has been tracked continuously in all NPPs. Concerning the shutdown of NPPs, no safety compromises will be accepted by ENSI during the final years of operation.
Switzerland complies with the obligations of Article 6.

Article 7 – Legislative and regulatory framework

Clause 1: Each Contracting Party shall establish and maintain a legislative and regulatory framework to govern the safety of nuclear installations.

The legislative and regulatory framework in Switzerland for the peaceful use of nuclear energy, the safety of nuclear installations and radiological protection is based on a four-level system:

- Level 1: Federal Constitution of the Swiss Confederation;
- Level 2: Federal Acts;
- Level 3: Ordinances (issued by the Federal Council or a federal department);
- Level 4: Regulatory guidelines.

Federal Constitution of the Swiss Confederation (1st level)

Articles 90 and 118 of the Federal Constitution stipulate that legislation on the use of nuclear energy and on radiological protection is enacted exclusively at the federal (national) level. As a result, the authorities of the Confederation have exclusive authority to establish legislation in the field of radiation protection and the use of nuclear energy.

Federal Acts (2nd level)

The main legal provisions for authorisations and regulation, supervision and inspection are based on the following legislation:

- Nuclear Energy Act (2003);
- Radiological Protection Act (1991);
- Act on the Swiss Federal Nuclear Safety Inspectorate ENSI (ENSI Act, 2007).

Nuclear Energy Act[7]

The Nuclear Energy Act regulates the peaceful use of nuclear energy. It applies to nuclear goods, nuclear installations, and radioactive waste that is generated in nuclear installations or that is surrendered to the federal collection centre.

The most important provisions of the Nuclear Energy Act are:

- basic principles of nuclear safety, including the precautionary principle, the protection of people and the environment and measures to prevent sabotage or the proliferation of nuclear material;
- a licensing procedure describing authorisations (licences) for the siting, construction (including design), operation (including commissioning) and decommissioning of nuclear installations;
- the general responsibilities of the licensee, including the responsibility for the safety of the installation, the obligation on NPPs to conduct systematic and periodic safety reviews and to backfit installations to the necessary extent that is in keeping with operational experience and the current state of backfitting technology, and beyond insofar as further upgrading is appropriate and results in a further reduction of risk to humans and the environment;
- regulations on decommissioning and on the disposal of radioactive waste, including the licensee's obligation to decommission and dispose of waste at its own cost, and special provisions relating to deep geological repositories;
- the designation of ENSI as the supervisory authority for nuclear safety and security;
- provisions regarding the authority and powers of the supervisory authorities, including the right to (i) access all relevant information and documentation to perform comprehensive assessments and carry out effective controls, (ii) enter nuclear installations without prior notification, and (iii) order the application of any measure necessary and appropriate to maintain nuclear safety and security;
- the funding of the supervisory authorities by fees collected from the licence holders and applicants;
- criminal sanctions.

[7] The English translation of the Nuclear Energy Act is available on the website of the Swiss Confederation (www.admin.ch/ch/e/rs/c732_1.html).

Radiological Protection Act [8]

The Radiological Protection Act has a comprehensive scope: It applies to all activities, installations, events and situations that may involve an ionising radiation hazard. It includes the following:

- fundamental principles of radiation protection (justification and limitation of exposure, dose limits);
- licensing obligation for the handling (including use, storage, transport, disposal, import, export) of radioactive substances;
- protection for persons who are occupationally exposed to radiation and for the general population;
- permanent monitoring of the environment;
- protection of the population in the event of increased radioactivity (emergency response organisation and emergency measures).

ENSI Act

The Act on the Swiss Federal Nuclear Safety Inspectorate ENSI came into force on 1 January 2009, when the Inspectorate was separated from SFOE. The Inspectorate was founded as a new organisation, taking over the staff and responsibilities of its predecessor, which had been part of SFOE (see Article 8 (2)).

Ordinances (3rd level)

All significant provisions that establish binding legal rules must be enacted in the form of a federal act. Ordinances require a legal basis in a federal act, although this basis may be of a rather general nature. In the field of nuclear energy and radiation protection, there are a number of highly relevant federal ordinances issued by the Federal Council or a Department (Ministry). The most important ones are the following:

- Nuclear Energy Ordinance[9];
- Radiological Protection Ordinance[10] (currently under revision);
- Ordinance on Safety-Classified Vessels and Piping in Nuclear Installations;
- Ordinance on the Qualifications of Personnel in Nuclear Installations;
- Ordinance on Hazard Assumptions and Evaluation of Protection Measures against Accidents in Nuclear Installations;
- Ordinance on the Methodology and Boundary Conditions for the Evaluation of the Criteria for the Provisional Taking-out-of-Service of Nuclear Power Plants;
- Ordinance on the Federal Nuclear Safety Commission;
- Ordinance on the Swiss Federal Nuclear Safety Inspectorate;
- Several ordinances on emergency preparedness, emergency organisation, iodine prophylactics, alerts to the authorities and public etc. (see Article 16);
- Several ordinances on security issues that are not the subject of this report, e.g. security guards, trustworthiness checks for employees, protection of information or thread assumptions and security measures for nuclear installations and nuclear materials.

Regulatory guidelines (4th level)

The Inspectorate either issues guidelines in its capacity as a regulatory authority or based on an explicit delegation in an ordinance. Most of the delegations to issue guidelines can be found in the Nuclear Energy Ordinance and in the Radiological Protection Ordinance. Guidelines are support documents that formalise the implementation of legal requirements and facilitate uniformity of implementation practices. They also embody the state-of-the-art in science and technology. The content of the guidelines is

[8] The English translation of the Radiological Protection Act is available on the website of the Swiss Confederation (www.admin.ch/ch/e/rs/c814_50.html).

[9] The English translation of the Nuclear Energy Ordinance is available on the website of the Swiss Confederation (www.admin.ch/opc/en/classified-compilation/20042217/index.html)

[10] The English translation of the Radiological Protection Ordinance is available on the website of the Swiss Confederation (https://www.admin.ch/opc/en/classified-compilation/19940157/index.html)

«semi-mandatory». Whereas acts and ordinances have legal force, guidelines are semi-mandatory. The Inspectorate may allow deviations from the guidelines in individual cases provided that the suggested solution ensures at least an equivalent level of nuclear safety or security.

International Conventions

Switzerland has ratified various international conventions, in particular the following:

- Convention on Nuclear Safety;
- Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management;
- Convention on Early Notification of a Nuclear Accident;
- Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency.

In addition there are various bilateral agreements that Switzerland has agreed upon with different countries.

Clause 2(i): The legislative and regulatory framework shall provide for the establishment of applicable national safety requirements and regulations.

National requirements

Safety requirements and regulations are specified in acts, ordinances and regulatory guidelines. After the Nuclear Energy Act and the Nuclear Energy Ordinance entered into force in February 2005, ENSI started a special project to ensure that its guidelines were complete. The guidelines were divided into three categories based on the classification introduced by ENSI for its oversight activities, which distinguishes between assessments of facilities and monitoring of operations:

- Series A: Guidelines covering the assessment of facilities;
- Series B: Guidelines covering the surveillance of operations;
- Series G: Guidelines with general requirements (covering both the assessment of facilities and surveillance of operations).

In this process, ENSI was able to identify gaps in former regulations, especially in its own guidelines. The majority of the new guidelines are enacted as of March 2016. Consistency and comprehensiveness are characteristic features of the ENSI guideline system.

Appendix 2 contains a list of the regulatory guidelines currently in force. The status of the guidelines is available on the Inspectorate's website.[11]

With respect to regulatory guidelines, the Inspectorate has established a «Regulatory Basis» Committee which meets monthly, examines and surveys the guidelines, and reviews draft guidelines to ensure their consistency with the regulatory framework and the accuracy of the content. The specification of a guideline lists all relevant IAEA requirements and guides as well as the relevant WENRA Safety Reference Levels. Once the draft guideline including the explanatory report has undergone an internal hearing, it is subject to an external consultation round. All interested parties, to which belong in particular all existing nuclear facilities, the Federal Offices of Energy and of Public Health, Federal Commissions, and the Swiss cantons, as well as non-governmental organisations may submit comments. The comments are carefully evaluated, and the corresponding ENSI decisions are documented in a «public consultation report». Comments not considered in the final version of the guideline must be justified. The final draft is closely examined by the Committee for the Regulatory Basis. Finally, the guideline is put into effect by ENSI's Director.

When it becomes apparent that some aspects of a guideline no longer reflect the state of the art, ENSI initiates a revision of the guideline. Moreover, the Committee for Regulatory Basis systematically reviews the guidelines on a regular basis, at least every ten years. However, most guidelines are reviewed earlier.

[11] http://www.ensi.ch/de/category/dokumente/richtlinien/

International harmonisation

In addition to the IAEA and the OECD Nuclear Energy Agency, WENRA is a major driving force in efforts to harmonise nuclear safety requirements at the European level. Switzerland was one of the founding members and has held the chair of WENRA since 2011. WENRA provides regulatory authorities with a single forum at which they can share their years of experience in regulating a range of nuclear facilities as well as in elaborating and implementing standards. Based on this expertise so-called Safety Reference Levels (SRLs), which are based on the IAEA safety standards, are issued. The SRLs may be adopted and incorporated into national legislation. The implementation is monitored by the corresponding WENRA working group.

The Inspectorate participates in the following WENRA groups: «Reactor Harmonisation Working Group» and «Working Group on Waste and Decommissioning». The Swiss self-assessment in the area of «Reactor Harmonisation» identified a number of SRLs to be incorporated into the Swiss regulatory framework. All WENRA SRLs for spent fuel and waste storage as well as for decommissioning are implemented in the Swiss regulatory framework, the latter by the guideline ENSI-G17 «Decommissioning of Nuclear Installations», which was published in April 2014. Besides considering the WENRA SRLs, the guideline ENSI-G17 also respects the IAEA Safety Standards on decommissioning.

The Inspectorate participates in several IAEA committees to promote high international standards in nuclear safety. On the other hand, the Inspectorate harmonises its guidelines with IAEA Safety Standards. Therefore, when issuing a new guideline or revising an existing one, the Inspectorate analyses the IAEA Safety Fundamentals and Safety Requirements relevant to the topic of the guideline. Every guideline is accompanied by an explanatory report. This report shows also for each IAEA Safety Requirement where in the Swiss legislation or the Inspectorate's guidelines it is implemented.

In addition, the Inspectorate has committed itself to implementing all safety reference levels issued by WENRA. In the explanatory reports, it is shown for each guideline if and how each safety reference level is implemented.

The Inspectorate has published its Regulatory Framework Strategy consisting of five guiding principles:

1. ENSI's regulatory framework is harmonised with the relevant international requirements and is comprehensive.
2. ENSI's regulatory framework is based on existing, tried-and-tested regulations, insofar as they are suitable for application within its supervisory scope.
3. ENSI issues its own guidelines only when it is necessary to do so.
4. ENSI's guidelines are drawn up transparently, with the involvement of all stakeholders.
5. The level of detail of ENSI's regulatory framework is based on the hazard potential and the risk.

Clause (2)(ii): The legislative and regulatory framework shall provide for a system of licensing with regard to nuclear installations and the prohibition of the operation of a nuclear installation without a licence.

The system of licensing results from the Nuclear Energy Act and the Radiological Protection Act described above in Clause (1) of this Article. The complex licensing procedures affect the responsibilities of many authorities. An important instrument for coordination is the so-called «concentrated decision procedure»: the authority whose responsibility is primarily affected acts as a «lead authority» and decides on all relevant aspects. The other authorities that could claim jurisdiction refrain from taking their own decisions. Instead, their opinions are submitted for consideration to the lead authority.

In Switzerland, three main types of licences exist:

- general licence;
- construction licence;
- operating licence.

With the exception of the general licence, every licensing decision can be challenged in court. Constructing or operating a nuclear installation without a licence is a criminal offence according to the Nuclear Energy Act.

Licensing procedure

The **general licence** is required for the siting of a nuclear facility and defines the site, the purpose and the essential features of the planned facility, and the maximum permissible radiation dose to the public due to the facility. The licence also specifies a time delay within which the licence holder must submit an application for a construction licence.

The application must contain detailed information on the site characteristics, purpose and outline of the project, the expected radiation exposure in the plant's surroundings, important information on organisation and personnel, an environmental impact report, a report on compliance with spatial planning requirements and a concept for decommissioning or, in the case of deep geological repositories, for the monitoring period and closure.

The process of granting a general licence starts with the review and assessment of the application by ENSI. The result of the regulatory review and assessment is documented in a Safety Evaluation Report (SER). ENSI may suggest licence conditions. The SER may then be evaluated by the Federal Nuclear Safety Commission NSC.

As the licensing process affects the responsibilities of other federal authorities as well as cantons and neighbouring countries, the concentrated decision procedure set out above applies. The opinions of the other authorities must be included, especially of those responsible for environmental protection and land use, planning and construction. The application and the corresponding reviews by the federal and cantonal authorities are published as official documents and are subject to a three-month-consultation period during which everyone can raise objections. The process ends with a decision of the Federal Council, which must be ratified by Parliament. Eventually, the decision may be subject to a nationwide popular vote, a so-called (optional) referendum.

The **construction licence** specifies the licence holder, the location of the installation, the planned reactor thermal power output or the capacity of the installation, the main elements of technical implementation, a brief outline of emergency protection measures and most specially a list identifying all structures, systems and components of the installation that may only be constructed or installed after a permit has been issued by the relevant supervisory authority (namely ENSI). Further conditions may be attached to the licence as proposed by the competent authorities (e.g. by ENSI). The licence also specifies a time delay within which the licence holder must start with the construction works.

The application for a construction licence must contain a Safety Analysis Report (SAR), an environmental impact report, a report on compliance with spatial planning requirements, a quality management programme for the planning and construction phase, an emergency preparedness concept and a decommissioning plan or, in the case of deep geological repositories, a plan for the monitoring period and a plan for the closure of the installation. It must include a report on compliance of the project with the general licence conditions.

The concentrated decision procedure again applies. As with the review of the application for a general licence, the various Federal offices are involved in evaluating those issues related to their specific responsibilities. With the exception of the environmental impact and spatial planning, the ENSI Safety Evaluation Report for a construction licence application covers all areas mentioned above.

The licensing process also involves the canton where the facility is to be constructed and the public. The application and the assessment reports are made public and those entitled may file an objection. The construction licence is drafted by SFOE and eventually issued by DETEC.

The **operating licence** specifies the licence holder, the permitted reactor thermal power output or capacity of the facility, the limits for release of radioactive substances into the environment, the measures for environmental surveillance, the safety, security, and emergency measures to be taken by the licence holder during operation of the installation and most specifically the start-up levels that require a permit from the relevant supervisory authority (namely ENSI) prior to commencement of operation of the installation. Further conditions may be attached to the licence as proposed by the competent authorities (e.g. by ENSI).

The application for a construction licence must contain the Final Safety Analysis Report, technical documentation necessary for operation (as defined in Annex 3 of the Nuclear Energy Ordinance), and evidence of insurance cover. It must include a report on compliance of the project with the general and construction licence conditions.

With the exception of the insurance cover, the ENSI Safety Evaluation Report for an operating licence application addresses all areas mentioned above.

The procedure for granting an operating licence is essentially the same as for granting a construction licence.

The owner of a nuclear installation is obliged to decommission the installation if it has been definitively taken out of operation or if the operating licence has not been granted, withdrawn, or expired. The **decommissioning order** is based on the owner's decommissioning project, which must describe the various project phases and overall timetable, each step in the process of dismantling and demolition, protective measures, personnel requirements and organisation, the management of radioactive waste and the overall costs, measures taken by the operator to secure the necessary financing. It must also contain an environmental impact report.

DETEC issues the decommissioning order. The procedure is essentially the same as for granting a construction licence. After the decommissioning activities have been completed in accordance with the applicable regulations, the Department verifies that the installation no longer represents a radiological risk and is thus no longer subject to the provisions of nuclear energy legislation.

To control the conditions of the licence and the decommissioning order, a «permit procedure» has been instituted. The permits granted by the supervisory authorities as part of a valid licence and the decommissioning order are defined in the Nuclear Energy Ordinance or in the licence, and the decommissioning order respectively. They include selected elements of the construction work, the manufacture of important components, assembly and wiring on site, sets of commissioning tests as well as any safety-relevant changes to the installation during operation, and the decommissioning itself. Therefore, this permit procedure can be considered as an enforcement tool (see Clause 2(iv) of this Article).

Clause (2)(iii): The legislative and regulatory framework shall provide for a system of regulatory inspection and assessment of nuclear installations to ascertain compliance with applicable regulations and the terms of licences.

The legal basis for inspections by the Inspectorate is provided in the Nuclear Energy Act. It grants the Inspectorate a right of access to all relevant information and documentation, including documentation located in the offices of supplier companies, to perform comprehensive assessments and carry out effective controls, to enter nuclear installations without prior notification, and to order the application of any measure necessary and appropriate to maintain nuclear safety and security.

The aim of regulatory inspections is to ensure that the licensee complies with its primary responsibility for safety. The Inspectorate, with the help of experts working on its behalf, reviews the licensee's programmes and independently assesses the performance of the licensee by (i) observing specific activities, and by (ii) carrying out its own inspections and taking its own measurements.

Clause 2(iv): The legislative and regulatory framework shall provide for the enforcement of applicable regulations and of the terms of the licences, including suspension, modification or revocation.

The licensing and regulatory authorities have enforcement powers based on the Nuclear Energy Act. They can order any measure necessary to protect persons, property and other important rights, to

safeguard Switzerland's national security, to ensure compliance with its international commitments and check that measures have been implemented.
In terms of licences, the licensing authorities (Federal Council; DETEC) will not grant a licence (general licence, licence for construction, commissioning, operation, modification of NPPs) or a decommissioning order unless the legal requirements are met. The licensing authority shall withdraw a licence if the prerequisites for granting it are not or are no longer met or if the licence holder fails to comply with a condition or ordered measure despite having been reminded to do so. The withdrawal of a general licence also results in the withdrawal of the construction and operating licences. The Inspectorate has the authority to suspend or withdraw permits.
The supervisory authorities order necessary and reasonable measures to maintain nuclear safety and security. The Nuclear Energy Act provides provisions for the special case of an immediate threat. An immediate threat is defined as an objective situation that, if not hindered in its evolution, could with high probability lead to damage. In the event of an immediate threat, the Inspectorate may impose immediate measures that deviate from the issued licence or an order. In particular, ENSI may order an immediate plant shutdown and allow restart only when the licence holder has implemented the necessary corrective actions. If necessary, the supervisory authorities may seize nuclear goods or radioactive waste, eliminate potential threats, and charge the cost to the owner. They may seek intervention by cantonal and local police forces, including the investigating arm of the customs authorities. If the provisions of the Act are breached, the supervisory authorities may call in the relevant federal police authority. The Federal Council may order the precautionary shutdown of a nuclear power plant if an extraordinary situation exists.

Developments and Conclusion

The Nuclear Energy Act and the Nuclear Energy Ordinance came into force in 2005 and are well established. New ordinances and guidelines issued by the Inspectorate have been introduced. By involving the stakeholders in the procedure of issuing guidelines (especially hearings), the regulatory process is transparent. Furthermore, each new regulatory guideline includes the related international WENRA and IAEA requirements.
Switzerland complies with the obligations of Article 7.

Article 8 – Regulatory body

Clause 1: Each Contracting Party shall establish or designate a regulatory body entrusted with the implementation of the legislative and regulatory framework referred to in Article 7, and provided with adequate authority, competence and financial and human resources to fulfil its assigned responsibilities.

Organisation and competence of the regulatory body

Licensing

The **Federal Council** is the authority that grants general licences. The **Department of the Environment, Transport, Energy and Communications** grants construction licences and operating licences for nuclear facilities (see Article 7). For the three kinds of licences mentioned, SFOE is responsible for the co-ordination of the application procedure. In addition, SFOE issues licences for the handling of nuclear materials and radioactive waste.

Supervision

ENSI is the supervisory authority for nuclear safety including radiological protection and nuclear security. Its responsibilities and duties are as follows:

- to establish safety and security criteria and requirements that reflect operational experience and the state of the art of science and technology;
- to prepare safety and security review reports (SER) to support decisions by the licensing authority;
- to monitor compliance with regulations including inspections and reports and to request documentation on aspects of nuclear safety, nuclear security and radiological protection;
- to grant, suspend or withdraw permits;
- to order the application of measures necessary and appropriate to maintain nuclear safety and security, including the precautionary and active protection of personnel in NPPs, the public and the environment against radiation hazards;
- to ensure on-site and off-site emergency planning and the dissemination of appropriate information in an emergency according to Article 16.

Advisory committee

The federal **Nuclear Safety Commission NSC** is designated as an advisory committee to the Federal Council and DETEC. It is involved in the licensing process as it reviews and comments on the SER prepared by the supervisory authorities.

The NSC consists of five to seven part-time members, supported by a secretariat with three employees representing 2.5 full-time equivalents and, if necessary, temporarily supplemented by external experts in specific disciplines. NSC members are appointed by the Federal Council on a personal basis. Members have a broad range of expertise including most, if not all, of the disciplines relating to reactor safety, radiation protection, emergency preparedness, waste management, human and organisational factors and transport safety.

The NSC focuses on fundamental aspects of nuclear safety and suggests necessary measures. The responsibilities of the NSC are defined in the Ordinance on the Federal Nuclear Safety Commission. Among them are the following:

- The NSC comments on new legislation or amendments and the development of regulations relating to nuclear safety. The Commission may recommend additions or amendments to regulations.
- The NSC may recommend measures to improve the safety of nuclear installations.
- The NSC may issue statements of position on expert opinion regarding general licence, construction licence, operating licence and decommissioning order.
- The NSC may suggest research projects in the field of nuclear safety.

Others

The authorities listed below have responsibilities associated with the operation of NPPs. However, they are not involved in the licensing process and have no authority over the plants:

- the **National Emergency Operations Centre** (NEOC) – part of the Federal Office of Civil Protection (FOCP) in the Federal Department of Defence, Civil Protection and Sports – in charge of all emergency situations, including those arising from events at NPPs and relating to the protection of the public and the environment;
- the **Division of Radiological Protection** at the Federal Office of Public Health (FOPH) in the Federal Department of Home Affairs – in charge of the radiological monitoring of the environment (in the vicinity of nuclear installations);
- the **Supervision and Safety Division (ASI)** is responsible for the national accounting and control system for nuclear materials as well as further supervisory activity incumbent on Switzerland from bilateral and multilateral agreements relevant to the non-proliferation of nuclear weapons, control of exports of nuclear goods and the nuclear fuel cycle
- several advisory committees to the government or government departments covering aspects of radiological protection, emergency planning and waste disposal.

Financial and human resources

Costs incurred by the safety authorities (with exception of the regulatory framework and information to the public) totalling some 60 million Swiss Francs per year, are mainly covered by fees from licensees. Nuclear safety research promoted and endorsed by the regulatory body has a budget of about 6 million Swiss Francs: some 2 million Swiss Francs come from public funds and 3 million Swiss Francs come from NPPs.

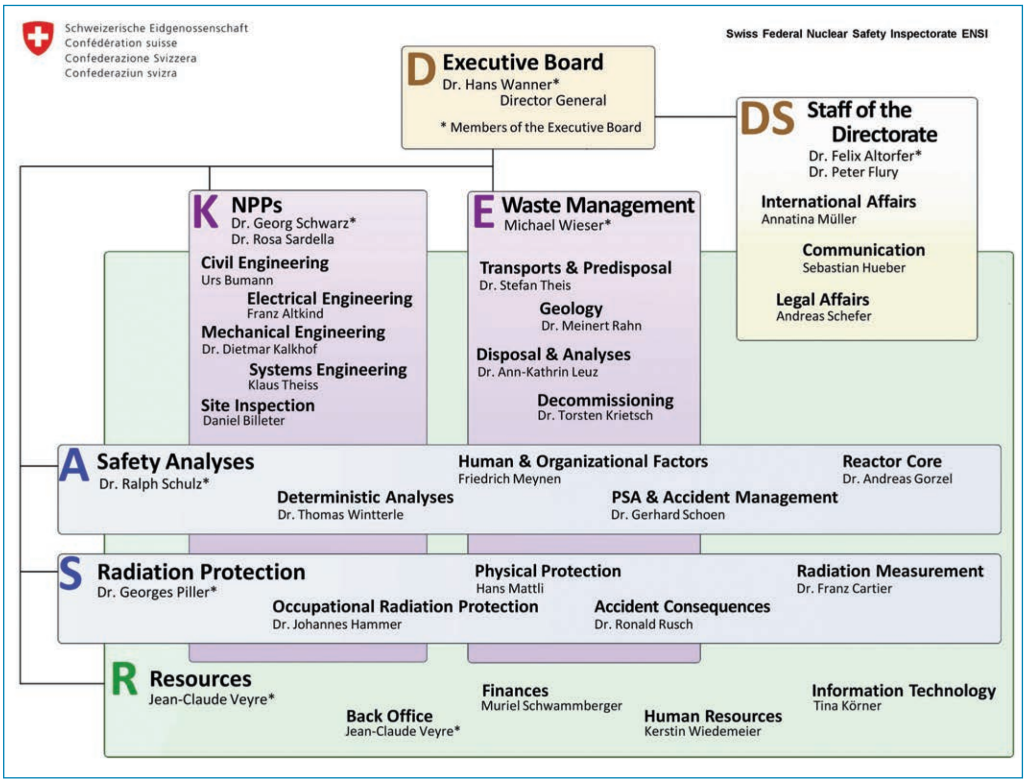
Supervisory authorities

ENSI is a stand-alone organisation (separated from the SFOE) controlled by its own management board (ENSI board) and with its own budget. This gives the Inspectorate complete flexibility over budget decisions and independence when recruiting personnel.

The Inspectorate currently has a staff of about 120 specialists covering the following fields:

- site inspection (5);
- reactor safety (60);
- radiation protection and emergency preparedness (20);
- waste management and transport safety (20);
- human and organisational factors (5);
- security (5);
- regulatory framework and international affairs (7)
- communication (5)

Some additional 20 staff are involved in administration and infrastructure tasks. The number of staff has not changed greatly over the past few years: In January 2012, the Inspectorate had 143 employees including 138 FTE. By January 2016, this number increased to 148 while the number of FTE remained at 138.



ENSI Organisational Chart June 2016 – Source ENSI

While the additional workload caused by the accident in Fukushima has decreased significantly, the public interest in the work of the ENSI has grown and the number of requests under the Federal Act on Freedom of Information increases year by year. Since 2011, legal affairs have become more and more important as several stakeholders appealed decisions of the Inspectorate.

In order to maintain the necessary amount of staff for the years to come, a human capital management concept was developed in 2012 and implemented by 2015. The concept deals with seven topics: recruiting, education, career planning, resource planning, succession planning, salary system and fringe benefits. Independent consultants are commissioned to advise the Inspectorate in special technical areas (e.g. civil engineering). The Swiss Association for Technical Inspections, an independent private company is responsible for monitoring the manufacture, repair, replacement, modification and in-service inspection of pressure-boundary components.

Quality management

The Inspectorate uses a process-oriented Management System, which was awarded ISO 9001 certification (quality management) in December 2001 and ISO 14001 certification (environmental management) in November 2007. The current certificates are valid until December 2016. In addition, it is planned to obtain ISO 45001 certification (health&safety management) as soon as the final standard is published. The laboratory for radiation measurement has been accredited in accordance with ISO 17025 since 2005, the Inspectorate was accredited as an inspection body according to ISO 17020 in 2015.

The Management System is applied to all relevant activities and includes the Inspectorate's safety, quality and environmental policies as well as the performance agreement between the ENSI board and the Inspectorate. The performance agreement includes strategic and operational goals as well as budget allowance for the Inspectorate for one year. All system documents can be accessed quickly by all staff members using user-friendly IT tools.

The Management System is subject to continuous improvement ranging from self-evaluation to internal audits, management reviews, evaluation of performance indicators and routine checks by the certification agency.

Internal audits: ISO 9001 requires that an institution conduct an audit of its activities at appropriate intervals to verify that operations still comply with the requirements of the quality system. A team of around 10 staff members, assigned to this function and trained as quality auditors, carries out the internal audits based on an annual audit plan. All processes are subject to an internal audit at least once every three to five years.

- Management review: this is carried out yearly by senior management at the Inspectorate in order to assess the quality of staff performance (e.g. by appraising performance indicators) and to reflect changes that have occurred (or are expected to occur) in the organisation, risks, staffing, procedures, activities and workload. Senior management is also responsible for ensuring the implementation within a specified period of actions identified by an internal audit, surveillance or reassessment visit by IRRS or the certification body together with complaints from customers and internal suggestions for improvements. This process is supported and managed by a sophisticated but user-friendly IT tool.
- Performance indicators: Performance indicators are defined for each process, including the indicators contained in the performance mandate. The results are evaluated by the owners of the process and reviewed in conjunction with the management review mentioned above.
- External audits: in 2015, an International Regulatory Review Team carried out an IRRS follow-up mission. In addition, the annual supervisory and renewal audits required for ISO 9001 and 14001 certification were held by the certification company SQS, the accreditation audits for ISO 17020 and 17025, and the annual financial audits were carried out by KPMG. Periodic external audits, including IAEA missions, are required by the ENSI act and the ENSI ordinance.

These mechanisms and measures provide the means for continuous assessment and opportunities for improvements to the Management System. They also facilitate the introduction of the New Public Management Elements and generally strengthen the Inspectorate's regulatory effectiveness.

Knowledge management and training

Knowledge management and training measures are an integral part of the Inspectorate's Management System. The process includes an annually updated systematic compilation of the skill and knowledge requirements for each organisational unit. Staff training is based on this compilation. The Inspectorate operates a career development programme in order to exploit staff potential. In addition, it tries to replace employees who are resigning at a very early stage so that there is a degree of overlap between the person leaving and his/her successor.

The Inspectorate has also increased its involvement and participation in nuclear safety assistance programmes at many levels. This includes participation in international working groups and IAEA services, such as the IRRS and OSART missions, staff exchanges with foreign regulators and inspection workshops in other countries. There is also close collaboration with the Swiss Federal Institute of Technology (ETH).

Co-operation with neighbouring countries

Switzerland has concluded agreements on the bilateral exchange of information on nuclear safety and radiation protection issues with its counterparts in many countries, in particular with its neighbours Germany and France. As a minimum, the agreements include early notification of nuclear accidents or extraordinary radiological situations. Collaboration with France, Germany, Italy and Austria also includes standing bi-national committees.

The German-Swiss and French-Swiss committees are the most comprehensive because both these countries have sizeable nuclear power programmes. They go well beyond early notification and include the exchange of information on all relevant aspects of nuclear safety and radiation protection. Each has a permanent technical working group that meets at least once a year. Collaboration with France includes inspections of nuclear installations in both countries conducted jointly by members of the French and Swiss safety authorities. Both German-Swiss and French-Swiss commissions have proved instrumental in harmonising and coordinating trans-border emergency management.

Openness and transparency of regulatory activities

Acting in the politically sensitive field of nuclear energy, ENSI is constantly under the scrutiny of the media, the public and non-governmental organisations (NGOs). Therefore, ENSI has a vital interest in maintaining its independent status (see clause 2) and in resisting any undue interference from third parties.
After the accident in Fukushima, ENSI created a section responsible for communication. The six staff members are responsible for the organisation of the information activities and work closely with the management.
Under the Nuclear Energy Act (Article 74), the Inspectorate «shall regularly inform the public of any special occurrences». In addition to that, the Inspectorate is obliged to respond to questions from parliament on nuclear safety and the work of the regulatory body. As a federal authority, ENSI is subject to the Federal Act on Freedom of Information in the administration. All ENSI documents generated after July 1 2006 are made public with a few exceptions relating to security, personal data or proprietary information.
The information services of the Inspectorate go well beyond these legal requirements. The Inspectorate's website www.ensi.ch is an important information tool covering all aspects of nuclear safety in Switzerland in the national languages German and French as well as Italian and English to a lesser degree. It is accompanied by activities on social media – e.g. Twitter, Facebook, YouTube etc. In addition to annual reporting (consisting of the Regulatory Oversight Report, the Research and Operational Experience Report, the Radiation Protection Report and the Business Report), it publishes reports on current topics – e.g. ENSI decisions on nuclear safety, disposal of radioactive waste etc. After the Fukushima accident, an interdisciplinary team of ENSI experts (the «Japan Analysis Team») reconstructed the events of the accident and subjected them to in-depth analysis. The results were presented to the public in four reports between August and December 2011. The final report including a summary on all measures taken based on the lessons learnt will be issued in summer 2016. In addition, the National EU Stress Test Report, the Peer Review Report and Action Plans following the analysis were made public. ENSI informed the public about the IRRS mission 2011 and the follow-up mission 2015 and its findings. As soon as the final report was finalised, it was published on the Inspectorate's website. ENSI also informed the public about the OSART mission to NPP Mühleberg and the implementation of the recommendations.
Other communication activities include responses to questions from NGOs and individuals as well as participation in public hearings, symposia and panel discussions on nuclear safety. ENSI regularly organises meetings with its stakeholders irrespective of their stance on nuclear energy. Media activities include press conferences and press releases as well as interviews on nuclear safety issues that are the subject of current media discussion and background discussions with journalists.
In 2009, in connection with the search for sites for deep geological repositories, SFOE set up the Technical Forum on Safety, which is led by ENSI. The Technical Forum on Safety discusses and answers technical and scientific questions asked by the public, municipalities, potential site regions, organisations, cantons and authorities in neighbouring states. The forum comprises experts from the body leading the process (SFOE), from other bodies with supervisory or supportive roles (ENSI, Swiss Federal Office of Topography (swisstopo)), from commissions (NSC), from the National Cooperative for the Disposal of Radioactive Waste (Nagra), from the cantons, and includes one representative from each of the potential site regions.
A similar panel was created by ENSI in 2012 for topics related to the safety of NPPs. The Technical Forum on NPPs is led by ENSI and discusses and answers technical and scientific questions posed by the population, communities, organisations, cantons and authorities in neighbouring states. The forum consists of representatives of the NPPs, NGOs, municipalities near NPP sites, cantons and authorities in neighbouring countries as well as experts.

Safety Culture

In 2012, an ENSI-wide project was initiated to assess the safety culture within ENSI, to identify shortcomings between the current and the target state and to define necessary corrective actions. The target state was developed within the framework of several workshops including all staff members. Finally, the project team submitted a list of 15 proposals for measures and about the same amount of recommendations to the management. While the implementation of the measures is still ongoing supervised by the Staff of the Directorate, one of the major outputs of the project was a new Mission Statement. In combination with the code of conduct, this document sets the guidelines for all kind of activities within the Inspectorate.

Clause 2: Each Contracting Party shall take the appropriate steps to ensure an effective separation between the functions of the regulatory body and those of any other body or organisation concerned with the promotion or utilisation of nuclear energy.

Swiss nuclear power plants

Swiss NPPs are operated by private companies, with cantons and municipalities as the most important shareholders. The federal administration does not hold shares in the nuclear industry. The regulatory body is therefore not directly linked to any person or organisation with a commercial interest in nuclear power.

Separation of the supervisory authority for nuclear safety from other governmental bodies concerned with the use and promotion of nuclear energy

The Nuclear Energy Act requires the supervisory authorities to be independent of technical directives and formally independent of the licensing authorities. It also clarifies and expands the position, duties and responsibilities of the Inspectorate as the supervisory authority for nuclear safety in terms of the development of safety criteria and the maintenance of nuclear safety. SFOE deals with questions of energy economics and politics and considers issues relating to the security of energy supply. The Nuclear Energy Act (Art. 70) stipulates that supervisors are not bound by instructions in technical matters and are formally separated from the licensing authorities.
The Act on the Swiss Federal Nuclear Safety Inspectorate ENSI grants the Inspectorate regulatory independence and ensures the separation between the Inspectorate and the licensing authorities. In passing this Act on 22 June 2007, the two parliamentary chambers in Switzerland resolved to convert the Inspectorate into a body constituted under public law to be formally, institutionally and financially independent. The ENSI-Act (Art. 18) stipulates that ENSI shall exercise its supervisory activity autonomously and independently.
The Act on the Swiss Federal Nuclear Safety Inspectorate ENSI came into force on 1 January 2009. The new Inspectorate is supervised by the ENSI Board whose members are elected by the Federal Council and report directly to it.

Developments and Conclusion

The Management System of the Inspectorate is well established and provides effective support for both management and daily operations. The entire system was considered a Good Practice in the IRRS mission of 2011. Some minor gaps to the IAEA requirements could be closed until the follow-up mission in 2015. The Management System is actively maintained and subject to regular minor modifications for further development and improvement. About one quarter to one third of the documentation is updated every year. However, the basic structure of the system remains the same and still covers the requirements set down in the related ISO and IAEA standards.
Since the beginning of 2009, the Inspectorate has been an independent body constituted under public law. It reports direct to the Government but is completely separate from SFOE. In other words, the regulatory body is now legally, institutionally, politically and financially independent. The remit

and the staff of the Inspectorate have not changed except that nuclear security has now been added to its responsibilities.

Switzerland complies with the obligations of Article 8.

Article 9 – Responsibility of the licence holder

Each Contracting Party shall ensure that prime responsibility for the safety of a nuclear installation rests with the holder of the relevant licence and shall take the appropriate steps to ensure that each such licence holder meets its responsibility.

Article 22 of the Nuclear Energy Act sets out the general obligations on the part of the licence holder. It expressly states that the licence holder is responsible for the safety of the installation and its operation. It further details the most important duties of licence holders as follows:

- to accord nuclear safety sufficient priority at all times when operating the nuclear installation and in particular to comply with prescribed limits and conditions;
- to establish a suitable organisation and employ an adequate number of appropriately qualified personnel;
- to take measures to ensure that the installation is kept in good condition;
- to carry out inspections and systematic safety and security evaluations throughout the entire life of the installation;
- to conduct a comprehensive periodic safety review in the NPPs;
- to report periodically to the regulatory authorities about the condition and operation of the installation and notify them without delay about any reportable events;
- to backfit the installation to the necessary extent on the basis of operational experience and the current state of backfitting technology, and beyond insofar as further upgrading is appropriate and results in a further reduction of risk to humans and the environment;
- to monitor scientific and technological developments, and compare operating experience and findings with those of other installations of a similar nature;
- to keep complete documentation on technical installation and on the operation of the installation, and amend the safety analysis report and security analysis report as necessary;
- to carry out appropriate measures to secure quality assurance for all activities conducted within the installation;
- to keep the decommissioning plan or the project for the monitoring period and the plan for the closure of the installation up to date.

During daily oversight activities (e.g. inspections, document reviews, safety reviews, regulatory meetings), reviews of modifications that require a permit, and safety expert reports, the Inspectorate verifies that decisions taken by the licensee meet the above stated general obligations on safety, i.e. that the licence holder retains responsibility for the safety of the installation and its operation.

The licence holder must designate the holder of the position for technical operation of the installation (as per Article 30 of the Nuclear Energy Ordinance). The holder of this position is responsible for decisions regarding safety. ENSI Guideline G07 (Organisation of NPPs) defines that neither the responsibility of the licence holder nor the responsibility of the holder of the position for technical operation of the installation can be transferred to third parties. In its nature, these legal statements about responsibility for safety are formulated in a very general manner. The Inspectorate therefore conducted a specialists' discussion in 2015 on safety culture with the senior management of all the Swiss NPPs to discuss and reflect on their understanding of responsibility and their arrangements made to fulfil their responsibility for safety. During these discussions, the participants reflected upon their understanding of responsibility and shared their views on the role of leadership and the management system in assuming responsibility for safety.

All NPPs have a well-established network of contractors and good contacts with their vendors. The responsibilities of contracted organisations that carry out safety relevant duties are laid down in contracts between the licensees and the corresponding external companies. The procedure for drawing up these contracts is part of the plants' management system and is inspected by the Inspectorate in accordance with the regulatory guidelines on the organisation of NPPs. Contracted personnel that carry out safety relevant tasks within a nuclear installation are required to comply with the policies and procedures of the NPP regarding safety. The regulatory guideline on organisation stipulates that the licence holder cannot transfer its responsibility for the safety of the installation and its operation to third parties or external organisations.

All Swiss NPPs are members of the World Association of Nuclear Operators WANO and benefit from an extensive information exchange on operational experience within this network. In addition, WANO serves as an adviser to the operators in several operational areas. In fact, many of the programmes to enhance human performance in nuclear installations recommended by WANO (e.g. managers in the field, operational decision-making, and pre-job-briefing) are implemented in the Swiss NPPs.

In Leibstadt and Beznau NPP, a safety controlling function is established. In each plant the safety controlling is conducted by a senior staff person (safety controller) who is critical and retains an open mind in respect of safety issues. The safety controller independently reviews a whole range of safety aspects, e.g. safety awareness and provision in daily work processes, safety provision in decision-making and in management system processes, and resource allocation in respect of safety. The safety controller notifies the plant manager of issues relating to safety and reports to the plant CEO. The safety controller's mandate lasts for about 3 years.

The licence holders also participate in two technical safety forums chaired by ENSI (see Article 8). Their main purposes are to receive, discuss and answer questions from the public about technical safety aspects of nuclear power plants and geological repositories.

The senior management of the Inspectorate meets periodically with the senior management of the licensees, addressing technical, financial and human aspects. The changed perception in society and the associated discussions about the use of nuclear energy in Switzerland did not noticeably affect the personnel turnover rate in the NPPs. However, the NPPs started adopting a more long-term approach to human resource planning as a means to preserving and further developing the necessary competences in nuclear technology and the NPPs report to the Inspectorate that personnel recruitment currently demands greater effort. The reasons for this greater effort, however, must also be seen as resulting from changes in the perception and reputation of the engineering professions, which is leading to a lack of skilled workers and problems in finding new recruits.

At the onset of the nuclear industry in Switzerland, the Swiss NPPs founded the «Group of Swiss NPP Managers» (Directors). The group itself and the subgroups in the areas of Operation, Training, Management Systems, Human System Interface, etc., meet regularly several times a year for exchange of experience and for the development of new concepts.

Developments and Conclusion

Switzerland complies with the obligations of Article 9.

Article 10 – Priority to safety

Each Contracting Party shall take the appropriate steps to ensure that all organisations engaged in activities directly related to nuclear installations shall establish policies that give due priority to nuclear safety.

The Nuclear Energy Act stipulates that each licence holder engaged in activities concerning nuclear facilities has a general obligation to give the necessary priority to safety. All licensees have implemented this obligation in their management system and have established an operating policy that gives due priority to nuclear safety. This operating policy is communicated to all staff in the NPP and submitted with other documents to the Inspectorate. Modifications to the operating policy of an NPP require a permit in accordance with the Nuclear Energy Ordinance.

The obligation to give the necessary priority to safety is also demonstrated by the commitment of these organisations to external comparison, peer review, and improvement. Every Swiss NPP is also a member of the WANO and, since 2005, all Swiss NPPs have been involved in the WANO peer review process. The scheduled cycle for WANO peer reviews and WANO follow-up missions is about six years. In 2013–2016, the following WANO peer reviews and WANO follow-up missions took place in Switzerland:

- 2013: WANO peer review in Gösgen NPP; WANO follow-up mission in Leibstadt NPP
- 2015: WANO peer review in Mühleberg NPP
- 2016: WANO peer review in Beznau NPP; WANO follow-up mission in Gösgen NPP and in Leibstadt NPP

All Swiss NPPs underwent OSART missions, including the follow-up missions. The last OSART mission took place in Mühleberg NPP in 2012 and the follow-up OSART mission in 2014. No further OSART mission is planned in Switzerland currently. This is also because the Swiss NPPs are regularly involved in the WANO peer review process. ENSI also demonstrated a commitment to peer review and improvement, by hosting an IRRS mission in 2011 and a follow-up IRRS mission in 2015, respectively (see Article 8).

In its supervisory functions, the regulatory body has a legal obligation to afford the highest priority to nuclear safety.

From a technical standpoint (i.e. design and construction), Swiss NPPs comply with the current state of the art of science and technology by virtue of the fact that their original design has been strengthened through backfitting. Personnel in all plants are well aware of the safety implications of their activities and safety-related training (see Article 11) continuously reinforces this level of awareness. The safety culture in all Swiss NPPs is an important means in fostering high levels of safety (see Article 12).

Occasionally the safety authority and the NPPs differ on the need for certain regulatory requirements. In the ensuing discussions, the Inspectorate uses the following graded approach in order to decide whether a safety measure is justified:

- safety measures required by legislation (this includes licence conditions);
- recommended safety measures based on the state of the art of science and technology;
- safety measures that appear desirable based on experience and current backfitting technology.

Developments and Conclusion

All Swiss organisations engaged in activities related to nuclear facilities comply with the obligation to give the highest priority to safety. All licensees have implemented this obligation in their management systems. It is also demonstrated by their commitment to external comparison, peer review, and improvement.

Switzerland complies with the obligations of Article 10.

Article 11 – Financial and human resources

Clause 1: Each Contracting Party shall take the appropriate steps to ensure that adequate financial resources are available to support the safety of each nuclear installation throughout its life.

Swiss nuclear legislation stipulates that nuclear installations must be kept in good condition and the licensee must provide persons with responsibility for the safe operation of a nuclear installation with the necessary resources.

The Swiss Licensees are in the majority owned by cantons (states) or municipalities. This public ownership ensures a solid financial situation of the licensees. To date, they have covered all costs associated with the construction, operation and maintenance (including replacement of obsolete or worn components) of their NPP. They have also paid fees to the regulatory body (see Article 8). They voluntarily implemented many modifications or backfitting measures shown to be necessary by virtue of developments in science and technology. These voluntary updates are in addition to those required by the safety authorities (see Articles 6 and 18). The licensees also cover the costs for radiological emergency protection.

If, for any reason (e.g. inadequate financial resources), the licensee could or would not implement any future backfitting measures considered necessary and required by the safety authorities, the licensing authority would suspend or revoke its operating licence. An NPP facing such a suspension or withdrawal of a licence would have an interest in ensuring that requirements are met if it wished to continue normal operations.

A decommissioning fund has been established as required by the Swiss Nuclear Energy Act. It covers the cost of decommissioning, including later dismantling. It is financed by regular contributions from the licence holder. In 2011, the licensees published a new set of decommissioning studies taking into consideration the latest experience from on-going decommissioning efforts internationally. The new study foresaw increased costs and lead immediately to increases in the fees paid into the funds. If after the final shutdown the resources paid into the fund during the operation of the plant are insufficient to cover the cost of decommissioning an NPP, the licensee is still required to pay the difference. If the licensee were financially not capable of doing so, the licensees of the other NPPs would be required to intervene and to cover the deficit. The decommissioning studies will be updated in 2016 according to the elevated requirements of the revised ordinance on the decommissioning and waste disposal funds.

Clause 2: Each Contracting Party shall take the appropriate steps to ensure that sufficient numbers of qualified staff with appropriate education, training and retraining are available for all safety-related activities in or for each nuclear installation, throughout its life.

Requirements regarding qualified staff

Under the Swiss Nuclear Energy Act, there must be a sufficient number of qualified staff with the expertise required to manage and control a nuclear installation during all phases of its life cycle. A minimum level of staffing with qualified personnel is stipulated for the plants on a 24-hour basis. This ensures that adequate staff is present in the plant at all times to operate under normal conditions, to initiate alarms and for the first measures required in case of an emergency. Moreover, all employees of Swiss NPPs are members of the respective Emergency Response Organisation ERO, so the plants can always draw on a sufficiently large pool of specialists for their ERO.

The specific minimum qualifications and training of specialised staff are laid down in the relevant ordinances (Nuclear Energy Ordinance, the Ordinance governing the requirements for personnel in nuclear installations, the Ordinance relating to checks on the trustworthiness of personnel and the Ordinance on security guards). In addition to technical qualification, the Ordinance governing the requirements for personnel in nuclear installations stipulates that NPP personnel must be medically and psychologically fit for their functions. In this context, NPPs conduct tests for psychotropic substances.

Staffing

The Nuclear Energy Ordinance and related guidelines issued by the Inspectorate stipulate the organisational arrangements required for the operation of nuclear installations. The Nuclear Energy Ordinance stipulates that the facility must be structured in a way that ensures internal responsibility for at least the following activities and areas:

- operation of the installation in all operating modes;
- maintenance, material technology and testing methods, technical support;
- design and monitoring of the reactor core;
- radiation protection and radioactive waste;
- water chemistry and use of chemicals additives;
- emergency planning and preparedness;
- supervision and assessment of nuclear safety;
- security;
- quality assurance for services provided by contractors;
- initial and continuing training of personnel;
- fostering of safety awareness.

There are no specific requirements with regard to staffing levels in NPPs. At the end of 2015, Mühleberg NPP had a workforce of 342, the twin-unit Beznau NPP had a workforce of 511, Gösgen NPP had a workforce of 535 and Leibstadt NPP had a workforce of 533. The slight decrease of staffing in Beznau NPP is due to backfitting projects concluded in 2015.

All Swiss plants have long been implementing programmes to ensure early replacement of retiring staff to guarantee that sufficient time is available for the transfer of know-how to new employees. In addition to these programmes, the NPPs have increasingly started to introduce personnel development measures, personnel retainment measures and personnel recruitment measures. These measures must be seen primarily as accompanying measures to compensate for the changes in the perception and reputation of the engineering professions, which is leading to a lack of skilled workers and problems in finding new recruits. At present, the changed perception in society and the associated discussions about the use of nuclear energy in Switzerland has not noticeably affected the personnel turnover rate in the NPPs.

In addition to employing their own personnel, licensees use contractors, particularly for maintenance during the annual refuelling outages and plant modifications. They include specialists from the manufacturer or supplier of major components or systems and other external experts for specific tasks. During these outages, the Inspectorate oversees the qualification and reliability of the contractors' personnel.

Workers in Gösgen NPP – Source Kernkraftwerk Gösgen-Däniken AG

Methods used for the analysis of competence, availability and sufficiency of additional staff required for severe accident management, including contracted personnel or personnel from other nuclear installations;

The requirements for knowledge, skills and competence of the staff in NPPs are established in the «Ordinance on the Requirements for the Personnel of Nuclear Installations», in the «Ordinance about Education and Training in Radiation Protection», in the Guideline B10 «Education, Qualification and Re-qualification of Personnel», in the Guideline B11 «Emergency Exercises» and in the Guideline B13 «Training and Continuing Education of the Radiation Protection Personnel», which cover actions in radiation protection in incidences and accidents. The Inspectorate examines the fulfilment of these requirements by recognition of education and training courses and/or the recognition of individual competences. Furthermore, the availability and competence of professionals for management of severe accidents are checked annually by means of inspections of emergency preparedness exercises at all NPPs. These inspections prove that, for example, the radiation protection personnel is able to act in accident situations in appropriate ways. Investigations on necessary improvements about the adequacy of staff have been started with expert discussion between the Inspectorate and NPPs in consideration of international experience exchange, e.g. in the ISOE Expert Group on «Occupational Radiation Protection in Severe Accident Management and post-accident Recovery» and in the WGHOF of NEA, CSNI on «Human Performance under Extreme Conditions». Finally, the last update of Guideline B11 now requires plant emergency exercises to be carried out with an emphasis on the involvement of the plant fire brigade. Such exercises are to be organised on a regular basis and the participation of plant external fire brigades is now foreseen as well. Such exercises primarily serve the purpose of training and verification of the operational readiness of the plant fire brigade.

Licensing of operators

The control room operators, shift supervisors, and stand-by safety engineers working in NPPs need a licence. Licences are granted by the NPP to specialists who satisfy the conditions in the Ordinance governing the requirements for personnel in nuclear installations. The licensee can only grant a licence to an operator if the candidate passes the examinations specified in the above-mentioned Ordinance. The examination board consists of representatives from the licensee and the Inspectorate. To pass an examination, the candidate must meet with the unanimous approval of both parties.

Education and training

The Ordinance governing the requirements for personnel in nuclear installations specifies the education, knowledge and experience required by the personnel that perform safety-relevant activities in nuclear installations (e.g. plant managers, licensed operators, personnel carrying out maintenance duties).

The personnel selected as potential candidates to obtain a licence, i.e. reactor operators, shift supervisors and radiation protection experts, must have successfully completed vocational training of 3–4 years in a technical profession and have a minimum of two years' experience in their profession (the latter is not compulsory for radiation protection experts) before starting their operator's and radiation protection expert training, respectively. Stand-by safety engineers must be in possession of a shift supervisor's licence as well as of an engineering school or university degree.

The Reactor School at the PSI provides specific training in nuclear fundamentals, the basics of electrical and mechanical engineering, water chemistry, safety concepts and radiation protection. The selection procedure for all licensed control room personnel includes aptitude tests. Under the Ordinance governing the requirements for personnel in nuclear installations, plant managers must have an engineering or science degree, basic knowledge of nuclear engineering and the specific knowledge required for the individual function together with management experience and experience in the relevant NPP.

The education and training required for control room personnel to obtain a licence is given in summary form below:

- **Field operators:** employees wishing to become licensed control room personnel must start as field operators. There is no licensing at this level. However, it is common for such operators to have passed an officially recognised examination. Courses and on-the-job training provide them with a good understanding of the NPP and a basic understanding of radiation protection, physics and nuclear engineering.
- **Reactor operators:** this function requires a formal licence. Candidates for positions as reactor operators must have worked for one or two years as a field operator. They must complete a detailed theory course at the Reactor School at the PSI or an equivalent institution. On completion of this basic education, candidates complete plant-specific training. This takes the form of various courses at the NPP, on-the-job training and simulator training.
- **Shift supervisors:** applicants for this function must be experienced reactor operators (one to three years of experience). They receive additional education and training in leadership, specific plant behaviour, procedures and undergo full-scope simulator training with their team.
- **Stand-by safety engineers:** shift supervisors with an engineering school or university degree can become stand-by safety engineers. In particular, they need further training in leadership under unfavourable conditions plus an extensive and detailed knowledge of emergency procedures.

Radiation protection specialists and radiation protection technicians are trained at the Radiation Protection School at the PSI or an equivalent institution abroad. The Inspectorate supervises the final examinations of candidates for both functions.

Adequate recurrent training exists for all of the above functions. It comprises simulator training (except for radiation protection experts), plant-specific courses and theoretical courses, usually at the Reactor School and the Radiation Protection School at the PSI. Members of the training section of the relevant operational department provide the training of licensed control room personnel. They are professionals and are trained in adult education.

All Swiss NPPs have full-scope replica simulators on site. Thus, each NPP has its own site-specific simulator training, which is also used for requalification purposes. The Inspectorate supervises training activities.

Non-licensed personnel in NPPs are also well educated and trained. Regular retraining is provided to ensure that personnel are up to date with advances in science and technology and plant modifications. The financial resources allocated to training are defined in the annual budget produced by the NPP. The annual management meeting between NPPs and the Inspectorate includes an overview of this budget. In order to maintain specific expertise in nuclear technology within Switzerland, Swiss NPPs sponsor a dedicated professorship at ETH Zurich.

Developments and Conclusion

The existing nuclear installations have adequate financial resources to support the safety of each nuclear installation. They also have sufficient qualified staff with appropriate education and training for all safety-related activities together with adequate retraining opportunities.
Switzerland complies with the obligations of Article 11

Article 12 – Human factors

Each Contracting Party shall take the appropriate steps to ensure that the capabilities and limitations of human performance are taken into account throughout the life of a nuclear installation.

In 2013–2015, the Inspectorate (i.e. its team of human factors specialists) worked on a common understanding of the term «human and organisational factors» as well as on a systemic approach to oversee these factors. This work as well as the oversight activities in this area are listed below.

Human and Organisational Factors Understanding and Oversight Approach

In nuclear facilities, in addition to technical aspects, human and organisational factors (HOF) also influence the plant safety. However, a common understanding of what is meant by the term, HOF, has not yet been agreed in the nuclear safety community.[12] Therefore, the Inspectorate (i.e. its team of HOF specialists) jointly worked on a common understanding of the term «human and organisational factors» as well as on an approach for overseeing human and organisational factors.

First, the HOF specialists reviewed the measures taken to implement Article 12 described in the national reports of the sixth Review Conference of the Convention on Nuclear Safety. This review revealed that regulatory authorities employ different understandings of the role individuals play in an organised and engineered environment. Four different paradigms of the role individuals play in such an environment can be identified:

- Isolation of Individuals from Technology: the individual is viewed in isolation from technology. Human factors are considered as human errors. In an effort to minimize these errors, e.g. traditional psychological measures for selection or training are performed almost exclusively on the individual himself.
- Relation of Individuals to Technology: human factors are understood as the immediate interplay at the man-machine interface. The questions focus on how human performance can be increased and how the impact of possible human failures can be mitigated. In this view, individuals and technology are adapted to each other.
- Separation of Individuals, Organisation and Technology: individuals, organisation and technology are considered separately from each other. Therefore, their effect is also studied separately from each other.
- Integration of Individuals, Organisation and Technology: This understanding distances itself from either isolating, separating or linking the three components and tries to understand individuals, organisation and technology as a whole in a systemic context.

Considering these paradigms, it is not surprising that they lead to different ways of examining the influence of HOF. However, it appears that especially after the Fukushima accidents, the fourth approach, i.e., the integrated or systemic view has been discussed more intensively, internationally. Hence, the HOF specialists started the process for a common understanding of the term HOF and of a systemic approach to oversee these factors by reflecting on the questions

- What is the understanding of an overall system?
- What are human and organisational factors and what is their role within an overall system?

The answers to these questions were found by focusing on an individual acting in his/her surrounding environment. Every individual exists in a surrounding environment with which he/she is constantly interacting. He/she behaves in this environment and he/she acts upon it and on him/herself. Hence, the individual is influenced by his/her environment (external influence). Under this premise, every action of an individual on his/her environment and on him/herself is called a human factor or human

[12] There is no definition of HF or HOF included in the IAEA Safety Glossary – Terminology used in Nuclear Safety and Radiation Protection. 2007 Edition

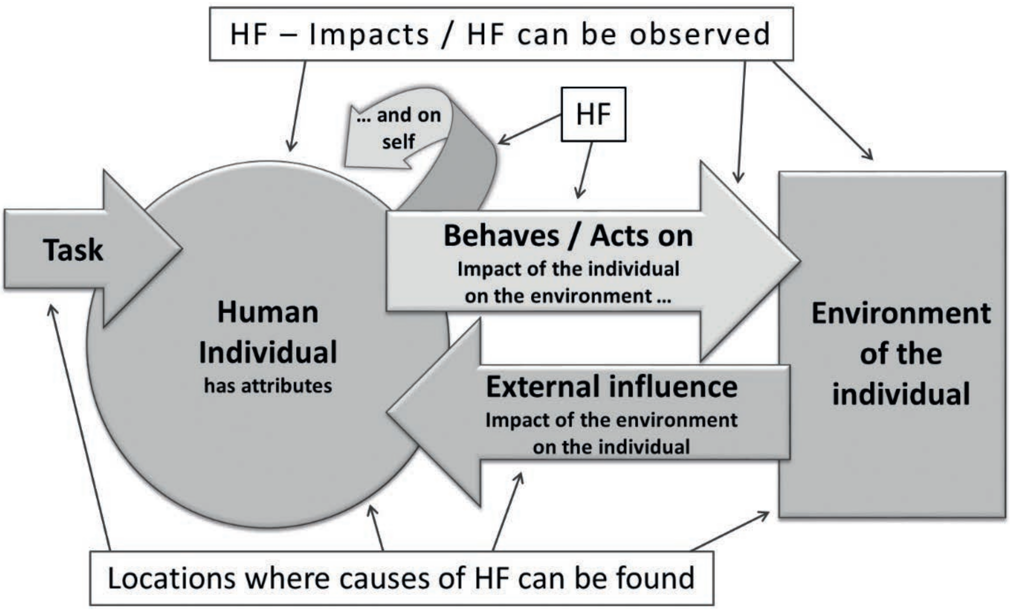
factors (HF). This ordinary observation in nature and society illustrates that a human factor is actually an old concept that represents the relation of an individual with his/her environment. This observation results, therefore, in the following summarizing definition of human factors:

- Human factors (HF) are the individual's actions on him/herself or his/her environment. HF are determined by the individual's attributes (i.e. inherent characteristics of each individual), the external influences that have an impact on him/her and the task at hand. HF can be observed in the action and the behaviour of the individuals as well as in the effects this action and behaviour cause on him/herself and on his/her environment.

The individual influences him/herself as well as his/her environment. His/her action and behaviour are the HF. HF can be detected directly by either the action and behaviour of the individual or indirectly by the impact of his/her action and behaviour in the environment or on him/herself. Causes of HF, however, can be found within the individual, but just as well in the environment, in the interaction and interference between individual and environment as well as in the task set. Anything that can influence human action or behaviour must be considered as a possible cause for HF and needs to be considered as well as its consequences. Thus, in the systemic understanding the HF are not the explanatory causes for their effects. They are merely human action and behaviour taking place under the conditions in which the individual is interfering and interacting with his/her environment.

Figure 2 represents a systems' view of the individual's interference and interaction with his/her environment as well as the causes and effects of human factors within this system.

Figure 2: *Causes and Effects of Human Factors in the Individual-Environment Interference/Interaction-Schema*



Therefore, the clarification of the causes of a particular human behaviour or its consequences always requires considering the overall system or interference/interaction-schema. Approaches that split this schema and consider its components in an independent way take into account a loss of knowledge with respect to the overall arrangement of cause and consequences.

Compared with the term HF, the term HOF stresses the organisational measures as a part of the environment of an individual in a distinct way. Analogous to the definition of HF, the term HOF can be defined as:

- Human and Organisational Factors (HOF) are the individual's action on him/herself or his/her environment together with the effect of the organisational measures on the individual, on other environmental aspects as well as on his/herself.

Consequently, addressing HF or HOF for oversight, requires the same systemic approach that can be understood with the help of individual-environment interference/interaction-schema (see Figure 2). Pursuant to guideline «Organisation of Nuclear Power Installations», the management system – understood as all the conditions and processes relevant to plant safety and operation – must map the nuclear installation as a system consisting of the ITO-elements, i.e. individuals, technology and organisation. Hence, oversight of HOF requires a systemic approach according to the understanding of the individual-environment interaction/interference-schema and the inclusion of the management system as a central organisational factor. In this context, oversight of HOF includes:

1. Organisation and management System:
   to ensure that the management system complies with the regulatory requirements (e.g., the management system reflects the ITO-elements in a systemic way) and that it is implemented in the nuclear installation
2. Human Factors Engineering:
   to assess (for design) how the management system in combination with the attributes of the individual and the task on hand is interacting and interfering with the individual in his environment (see Figure 2, view in arrow direction)
3. Event Analysis:
   to asses (for cause analysis) how the influences of the individual on the organisational factors (i.e. management system), on the task in hand and on the other environmental conditions can be traced back (see Figure 2, view in opposite arrow direction).

Organisation and Safety Culture

The obligation of the licensee to establish a suitable organisation (i.e. organisational structures and processes) is firmly embedded at several places in the Swiss legislative framework. The Nuclear Energy Ordinance sets out requirements concerning the organisation that are specified in detail in the guideline «Organisation of Nuclear Power Installations». The guideline describes the requirements of the Inspectorate in terms of organisational structure and work processes of the NPPs together with the requirements to be taken into account by the operating organisation to ensure the safe management of technical as well as organisational changes. The guideline also stipulates that the operating organisation must give top priority to safety in all plant activities.

In July 2013, the revised guideline on the Organisation of Nuclear Power Installations was implemented. The aim of the revision was to incorporate the IAEA requirement on management systems as well as the WENRA reference levels on organisational requirements into the regulatory framework by adapting them to the Swiss circumstances. The revised guideline covers the operation as well as the post-operation phase of a nuclear installation.

Attention is also given to the concept of safety culture. The guideline on organisation stipulates that the licensee must permanently incorporate measures in its management system to observe, to assess, and to strengthen its safety culture. Further, the licensee must also define the meaning of the term as well as the principles and prominent features of safety culture in a document that is considered binding for all employees.

The Inspectorate has conducted a series of oversight activities, e.g. inspections and technical discussions in the field of organisation as well as safety culture. In addition to these ordinary oversight instruments for organisational as well as plant engineering issues, the Inspectorate employs a specific method to oversee safety culture: specialist discussions on safety culture issues. The aim of these discussions is to establish a platform where the licensees can reflect on safety culture topics previously set by the Inspectorate. The Inspectorate facilitates the discussions in an open and constructive way. In 2015, the Inspectorate conducted such a discussion on the subject of responsibility for safety (see chapter 9).

In the aftermath of Fukushima, the Inspectorate formed an interdisciplinary analysis team to understand the scope and complexity of the accident in Fukushima. The analysis team also included experts in the field of human and organisational factors. In 2011, the Inspectorate published its analysis of the accident. One of these reports was dedicated to analysis in the field of human and organisational factors. Since this first and early publication on the human and organisational aspects of the Fukushima accident was based on the initially available and at that time still sparse information, a team of experts in the human and organisational factors area pursued and deepened its analysis on the basis of numerous accident reports published after the accident and still being published by several official and authoritative investigation committees. A first new report on the events and the organisations involved in the response to the accident has been published in 2015 in German (and will be published in English as well) (see: www.ensi.ch). Further reports are under preparation.

Human Factors Engineering

The Nuclear Energy Ordinance lays down a series of design principles for NPPs, including a principle relating to human factors engineering: «Work stations and processes for the operation and maintenance of the installation must be designed so that they take account human capabilities and their limits». The Inspectorate pays particular attention to this principle when it oversees modifications that affect human-machine interfaces. Since 2007, the Inspectorate has required a human factors engineering programme in conjunction with the initial concept of modernisation projects (see Article 18). Within the human factors engineering programme, the licensee must describe how human and organisational factors (e.g. a human-centred design process, integration of operating experience from predecessor or similar systems, multidisciplinary project management) are integrated continuously and systematically throughout the entire modification project.

The human factors engineering programme adopts a graded approach. This ensures that appropriate resources are allocated in accordance with the criteria in Paragraph 2.6 of the IAEA Safety Standard GS-R-3.

Event Analysis

All NPPs conduct thorough investigations of human and organisational factors whenever they are identified as the root cause or a contributing factor in events with a relevance to safety. If these investigations identify weaknesses in these areas, this triggers an assessment of similar situations in other NPPs. The Nuclear Energy Ordinance states that all NPPs must appoint a committee to analyse events and outcomes attributable to human and organisational factors. All NPPs have appointed such committees, who receive adequate education and training on a regular basis.

Developments and Conclusion

The Inspectorate has continued to develop its understanding of the term «Human and Organisational Factors HOF» as well as methods to oversee the organisation of NPPs. It has also pursued its effort to oversee human and organisational factors in plant modernisation projects and in event analysis.

Switzerland complies with the obligations of Article 12.

Article 13 – Quality assurance

Each Contracting Party shall take the appropriate steps to ensure that quality assurance programmes are established and implemented with a view to providing confidence that specified requirements for all activities important to nuclear safety are satisfied throughout the life of a nuclear installation.

All Swiss NPP have an integrated management system and are certified under the ISO 9001 (Quality Management), OHSAS 18001 (Occupational Health and Safety) and ISO 14001 (Environmental Management) standards. According to the certification roles the management systems are audited periodically by the certification institute and the certi-ficates are renewed on a regular basis. NPPs apply well-established methods for a self-assessment of their management system.

The Inspectorate concentrates its supervisory activities on the aspects of the licensee's management system that are relevant to nuclear safety. These safety-relevant processes need to ensure an appropriate quality assurance of the output. They are supervised within the framework of ENSI's event analysis, ENSI approvals for plant modifications and during outages, but also by series of inspections for the management system which are dedicated to actual topics.

Considering the licensees' challenges due to the changes in the nuclear supply industry and the difficult economic situation, ENSI decided to perform the management system inspections in all NPPs, ZZL and PSI based on the two following topics: Procurement/Customer Capability and Competency management. Both aspects contribute very much to a proper quality assurance especially when contractors are involved. According to the Swiss nuclear ordinance the licensees have to take full responsibility for the quality assurance of the products supplied by their contractors.

During the inspections, ENSI confirmed the fulfilment of the regulatory requirements for both topics. Best practices were identified and shared with all licensees.

The inspections included the issue of major changes in the management system which require notification to the Inspectorate.

All NPP activities other than normal operation, e.g. backfitting, replacement and modifications to systems and components, need a permit. In order to achieve the regulatory approval, the Inspectorate assesses the quality assurance program with special attention to the performance of an independent verification of all safety relevant information within the framework of the quality assurance process.

Developments and Conclusion

All Swiss NPPs have an integrated management system that is certified under ISO 9001. The management systems are audited periodically by the certification institute and the certificates are renewed on a regular basis.

The NPP apply internal and external audits as well as established methods for a self-assessment in order to advance on the continuous improvement of their management systems.

The Inspectorate regularly performs inspections to assess the effectiveness of quality assurance measures incorporated in the management system especially for processes with an involvement of contractors.

Switzerland complies with the obligations of Article 13.

Article 14 – Assessment and verification of safety

Clause 1: Each Contracting Party shall take the appropriate steps to ensure that comprehensive and systematic safety assessments are carried out before the construction and commissioning of a nuclear installation and throughout its life. Such assessments shall be well documented, subsequently updated in the light of operating experience and significant new safety information, and reviewed under the authority of the regulatory body.

Overview of the Contracting Party's arrangements and regulatory requirements to perform comprehensive and systematic safety assessments

For existing plants, a Periodic Safety Review (PSR) is required at least every ten years. Important elements of a PSR are an update of the Safety Analysis Report (SAR), an assessment of design basis accidents, an assessment of the ageing surveillance programme, an update of the Probabilistic Safety Analysis (PSA) and an evaluation of operating experience over the last 10 years. The details (scope and process) of a PSR are defined in the Inspectorate's Guideline ENSI-A03.

Changes in the organisation, modifications or backfitting of components and documents (e.g. Technical Specifications) related to safety must be approved by the Inspectorate. The Inspectorate's associated review may involve inspections (see Clause 2). Data from inspections, event assessments and safety indicators provide a foundation for ENSI's systematic assessment of operating safety, carried out annually (see Clause 2). In addition, the licensees must perform annual safety assessments according to the requirements given in the guideline ENSI-G08 and probabilistic evaluations of their operating experience according to the guideline ENSI-A06.

The above safety analyses are explicitly specified in the Nuclear Energy Ordinance as the requirements for the analysis and reports to be submitted for decommissioning projects. The following paragraphs provide further information on certain safety analyses.

Further reviews and assessments of the design basis are mandatory if events of INES 2 and higher occurred in a national or international NPP. As a direct consequence of the major accident in Japan, the Inspectorate issued three formal orders in which the operators of the Swiss nuclear power plants were required to implement immediate measures and to conduct additional reassessments. The Inspectorate ordered immediate measures comprising the establishment of an external emergency storage facility for the Swiss NPPs, including the necessary plant-specific connections, and backfitting measures to ensure the provision of external injection means into the spent fuel pools. The additional re-assessments, which were to be carried out immediately, focused on the design basis of Swiss NPPs against earthquakes, external flooding, extreme weather conditions and combinations thereof. Investigations were also requested regarding the coolant supply for the safety systems and the spent fuel pool cooling, taking into account the lessons learnt from the accident in Japan.

As a part of the Action Plan Fukushima, an additional safety margin analysis has been performed for the Swiss NPPs. The safety margin analysis is a follow up of the analysis done in the EU stress tests. The safety objective of the safety margin analysis was a systematic evaluation of the plant`s robustness concerning earthquakes and external flooding. Based on the results, possible improvements had to be identified.

Safety assessments within the licensing process and safety analysis reports for different stages in the lifetime of nuclear installations

Because of the accident at the Fukushima Daiichi NPP, the Swiss government has suspended plans for new-builds. On-going activities regarding safety assessment for the different stages in the lifetime of nuclear installations consist of

- periodic assessments included in the next topic and
- assessments of long-term operation.

Long-Term Operation

Around 2004 ENSI started to develop an approach for the evaluation of long-term operation (LTO) of nuclear power plants in Switzerland. ENSI's approach is based on international recommendations, IAEA-Safety Guides NS-G-2.6 and NS-G-2.12, and IAEA-SALTO Guidelines, WENRA Reactor Safety Reference Levels K and I, and on the Swiss legal basis, Nuclear Energy Act, SR 732.1, Nuclear Energy Ordinance, SR 732.11, DETEC Ordinance on the Methodology and the General Conditions for Checking the Criteria for the Provisional Taking out of Service of Nuclear Power Plants, SR 732.114.5, the ENSI-Guidelines ENSI-B01 and ENSI-B06 and the Guideline of the Swiss Association for Technical Inspections (SVTI) SVTI-N-14. The LTO safety case shall cover two main areas: material ageing and conceptual ageing. In the first area the focus is on the ageing management programs (e.g. maintenance, in-service inspection, in-service testing) and on the status of major plant components (e.g. RPV, containment, selected reactor coolant piping) with respect to the relevant ageing mechanisms including forecast analyses over the next reporting period. Within the area of conceptual ageing, the focus is on the plant safety concept (updated deterministic and probabilistic analyses) and on backfittings (considering the advancements in the state-of-the-art of backfitting technology). In particular, the licensee is required to demonstrate that the limits described in the DETEC Ordinance SR 732.114.5 are adhered to, an infringement implying that the NPP must be provisionally shut down.

The licensees submitted the required LTO safety concepts in 2008 for Beznau NPP and in 2010 for Mühleberg NPP. Results of the ENSI review are described in the LTO safety evaluation reports dated November 2010 for Beznau NPP and December 2012 for Mühleberg NPP. The results were summarised in the previous ENSI report for CNS. As a result of the LTO review, it was confirmed by ENSI that Beznau NPP and Mühleberg NPP meet the Swiss safety objectives at least for an additional period of 10 years of operation. There is no indication that the terms and conditions for a provisional shutdown (DETEC Ordinance SR 732.112.5) of Beznau NPP and Mühleberg NPP will be fulfilled. In 2013, the licence holder of Mühleberg NPP decided to phase out in 2019 for economic reasons and cancelled the planned backfitting program for LTO. ENSI issued a formal order to establish binding conditions for operation until 2019, requesting alternative measures be implemented. The alternative backfittings required by ENSI are listed in Article 18.

Periodic safety assessments of nuclear installations during operation using deterministic and probabilistic methods of analysis, as appropriate and, conducted according to appropriate standards and practices

In addition to the continuous review and evaluation of plant modifications, the PSR is an important control mechanism for both licensees and the Inspectorate. It enables them to identify and assess the actual state of safety in a plant in order to ensure the compliance with legal requirements, the provisions of the licenses and the official stipulations of the Inspectorate. The actual plant status and past operating experience are compared against the current state of the art of science and technology and operating experience from other plants. The licensee carries out the PSR and the Inspectorate evaluates the PSR report submitted by the licensee. The Inspectorate adds its own experience from previous inspections, assessments and reviews.

The concept of defence in depth as described in the IAEA Safety Standard NS-R-1 plays a central role in the PSR and its evaluation. In its report, the licensee is required:

- to explain the plant-specific implementation of safety policy;
- to assess the operating performance and management of the plant;
- to perform a deterministic safety status evaluation;
- to perform a probabilistic safety analysis.

Based on the evaluation mentioned above, the licensee must demonstrate that the fundamental safety functions specified in SSR-2/1 (Rev. 1) and the radiological protection measures are effective in both normal and abnormal plant operation. The licensee must also demonstrate how the evolving state of science and technology is taken into account in the plant's design and operation and how the experience gained from similar plants worldwide is integrated. In addition, in its assessment of operating experience over the last 10 years, the licensee must pay particular attention to human and organisational factors and their impact on safety. The Inspectorate's assessment also considers the licensee's safety culture. The PSR includes not only a review of the plant's current safety status but also an assessment of its future safety status.

Deterministic analysis

The Nuclear Energy Ordinance requires Swiss NPPs to implement a Deterministic Safety Status Analysis (DSSA). The Ordinance on Hazard Assumptions and Evaluation of Protection Measures against Accidents in Nuclear Installations assigns one of three categories to the design-basis accidents according to their frequency of occurrence and defines technical criteria of compliance and related safety objectives dependent on the assigned accident category. Design Basis Accidents (DBA) must be considered up to a frequency greater than 10^{-6} per year under the DETEC for NPPs.

The review of DSSA aims to verify the expected behaviour of the plant under assumed accident conditions as defined in the Inspectorate's Guideline ENSI-A01. Based on a set of accident scenarios, the licensee must demonstrate that the relevant plant and core-specific parameters remain within safe limits and comply with the technical criteria defined in DETEC Ordinance on the Hazard Assumptions and the Assessment of the Protection against Accidents in Nuclear Installations SR 732.112.2. In addition, the licensee must demonstrate that it complies with the individual dose limits for the public, as defined in the Radiological Protection Ordinance. The guideline ENSI-A01 focuses specifically on:

- suitability, validation and compliance with best estimate computer software; conservative initial and boundary conditions for the analysis are to be used.
- compatibility of analysis assumptions with system and component design;
- conservatism of simplifications and assumptions in the analysis; and
- adequacy of assumed single failures following initiating events.

The Inspectorate's review also includes evaluations of design basis analyses (e.g. loss of coolant accidents, etc.) using appropriate computer codes and its own plant models, which are being further developed, in keeping with the backfitting measures of the plant.

Furthermore selected Beyond-design-basis accidents (BDBA) or Design Extension Conditions (DEC) (e.g. Anticipated Transient Without Scram or Total Station Blackout) must be considered under the Inspectorate's Guideline ENSI-A01.The list of BDBA is derived from the WENRA Issue F.

According to the latest results of deterministic safety analyses, all Swiss nuclear power plants entirely fulfil the requirements of the current rules and standards.

Probabilistic analysis

The Nuclear Energy Ordinance requires the development and use of a Probabilistic Safety Analysis (PSA) for all relevant operating modes of the Swiss NPPs. These requirements are further specified in two regulatory guidelines aimed at harmonising the use and development of PSA:

- Guideline ENSI-A05 defines the quality and scope of requirements for the plant-specific Level 1 and Level 2 PSA for NPPs and other nuclear installations.
- Guideline ENSI-A06 formalises the requirements for applying PSA to NPPs. It defines general principles for all PSA applications and the scope of mandatory PSA applications.

All Swiss NPPs perform plant-specific Level 1 and Level 2 studies, including internal and external events such as fire, flooding, earthquakes, aircraft impacts and high winds. Full power as well as low power and shutdown modes are considered in both the Level 1 and Level 2 PSA.

The licensees update PSA studies at regular intervals. Every 10 years, as part of the Periodic Safety Review (PSR), PSA studies are revised as needed to reflect advances in methods and current operating experience. At least once every five years, PSA models are updated to reflect plant modifications and the availability of additional reliability data. Guideline ENSI-A06 also defines the conditions for updating the PSA models at other times for plant modifications not yet incorporated in the PSA models but which may have a significant impact on PSA results.

The requirements of Guideline ENSI-A05 is the main basis of the regulatory review of the PSA studies. The regulatory review aims to develop a thorough understanding of plant attributes, its vulnerability to potential severe accidents and plant-specific operating characteristics. The review focuses on a general evaluation of PSA models, assumptions, analytical methods, data and numerical results and on understanding the range of uncertainties in core-damage frequency, fuel-damage frequency, containment performance and radioactive releases. At the beginning of the review process, ENSI verifies whether the PSA documentation is complete and assesses the PSA approach and analytical methods, as well as the plant design features intended to prevent and mitigate potential severe accidents. Based on the results of this evaluation, the Inspectorate submits requests for additional information to the licensee and its responses are used in the review. In addition, site audits, including plant walk-downs, are conducted. In particular, a detailed regulatory review of the PSA is conducted within the scope of the PSR.

With the aim of identifying potential plant improvements, Guideline ENSI-A06 specifies the scope of mandatory PSA applications:

- probabilistic evaluation of the safety level;
- evaluation of the balance of risk contributions;
- probabilistic evaluation of the technical specifications;
- probabilistic evaluation of changes to structures and systems;
- risk significance of components;
- probabilistic evaluation of operational experience, including reportable events.

In addition, the following analyses are part of or related to the PSA:

- Probabilistic hazard assessment for external events. The hazard curves are used for the PSA itself and as an input for the specification of DBA in the deterministic safety analysis.
- Categorisation of accidents according to their frequency. Based on their frequency, accidents are defined as design-basis or beyond-design-basis. For design-basis accidents, different dose limits are set according to the frequencies.
- Analyses of seismic and extreme wind fragilities used for both the PSA and the deterministic safety proofs.
- Development of Severe Accident Management Guidelines (SAMGs). The Level 2 PSA is used as a technical basis for the development of SAMGs. In particular, the Level 2 PSA provides analyses of severe accident phenomena, indications of the completeness of the SAMGs and information that can lead to the prioritisation of measures. SAMGs have been developed for all Swiss nuclear power plants.

According to the latest results of probabilistic safety analyses, all Swiss nuclear power plants meet the safety objectives of the IAEA for existing nuclear power plants, which recommend a core damage frequency of less than 10^{-4} per year and a large early release frequency of less than 10^{-5} per year.

Clause 2: Each Contracting Party shall take the appropriate steps to ensure that verification by analysis, surveillance, testing and inspection is carried out to ensure that the physical state and the operation of a nuclear installation continue to be in accordance with its design, applicable national safety requirements, and operational limits and conditions.

As already mentioned in the response to Clause 1, appropriate safety analyses must be submitted to the Inspectorate in support of an application as required, before any modification or backfitting to safety-related systems or components. The following proofs are required before any such permit can be granted: evidence of the suitability of the manufacturing process and of the assembly and commissioning processes, evidence of compliance with safety limits, details of the dedicated start-up tests as required, procedure for periodic inspections and audits, and finally probabilistic evaluation in respect of the impact on the plant core damage frequency. These proofs are required to ensure that each modification or backfitting measure conforms to previously approved safety requirements and that the relevant safety margins and operational limits are maintained.

Overview of the Contracting Party's arrangements and regulatory requirements for the verification of safety

The Inspectorate's arrangements and regulatory requirements for the verification of safety address the outage activities and refuelling process, backfitting and replacement programmes, inspections, information meetings, and the review of extraordinary licensee's reports and derived plant modifications which are issued by the Inspectorate in terms of national or international events of INES 2 and higher.

Fukushima

In the scope of the EU stress test performed on the Inspectorate's orders after the Fukushima accident, the operators of the Swiss nuclear power plants submitted their reports. The results of the Inspectorate's review confirmed that the Swiss NPPs display a high level of protection against the impacts of earthquakes, flooding and other natural hazards, as well as loss of electrical power and ultimate heat sink. The complete summary of backfittings initiated after Fukushima is given in Article 18.

PSR

As part of the Periodic Safety Reviews (PSR) that are carried out every ten years, the condition of the NPPs and their operational management are reviewed to ensure compliance with legal requirements, the provisions of the licenses and the official stipulations of the Inspectorate. Finally, the compliance of the plant condition with the approval bases is examined in the course of ongoing supervision and during inspections by – and technical discussions with – the supervisory authority.

Main elements of programmes for continued verification of safety (in-service inspection, surveillance, functional testing of systems, etc.)

Outage activities and refuelling

During each refuelling outage, the plant is subjected to a review covering many aspects. Below are some examples:

- The Inspectorate monitors in-service inspections, preventive maintenance and repairs/modifications to safety-related mechanical equipment undertaken by licensees to maintain or enhance plant safety. Its mandated expert, the Swiss Association for Technical Inspections, supervises and verifies these activities using a combination of selective supervisory and random checks. In contrast, the Inspectorate focuses on specific issues.
- The licensee carries out a review of mandatory periodic functional testing of systems and components, including switchover tests for the electricity supply. These tests are performed in accordance with written procedures and all test results are documented. The Inspectorate inspects selected tests and reviews the results of the entire test programme.
- Cycle-specific fuel and core-related issues are reviewed as part of the «Reload Licensing Submittal» submitted by the licensee four weeks before the beginning of the plant-refuelling outage. The Inspectorate must approve fuel and core loading before refuelling. The Inspectorate also assesses the state of the fuel assemblies and control rods and attends selected fuel inspection campaigns as well as the start-up measurements.

The Inspectorate issues a letter granting permission to restart plant operation after the maintenance/refuelling outage. In this letter, the Inspectorate gives its assessment of the outage maintenance and refuelling activities, the radiological status of the plant and the cycle-specific safety analyses. The permit may also include conditions for plant operation or requirements and recommendations for maintaining and improving plant safety. The Inspectorate documents its own activities during the outage in a separate outage report.

Backfitting and replacement

Backfitting and replacement of safety-related equipment are necessary when existing equipment no longer satisfies current standards and the state of the art or when it becomes difficult to maintain. The Inspectorate may also require backfitting or replacement of equipment, e.g. following a PSR. New equipment is mainly installed and commissioned during plant outages. The Inspectorate reviews the process for such activities and thereby monitors the process closely. In most cases, the Inspectorate must approve the design, installation, modification and commissioning of the equipment. A list of backfittings and improvements is given in Article 18.

Inspection

Inspections in nuclear installations are primarily performed by the Inspectorate. In the field of mechanical engineering, some aspects of inspections are delegated to external experts who act exclusively on behalf of the Inspectorate.

The regulatory inspections by the Inspectorate serve to provide the basis for independent judgements on safety-related issues such as:

- quality measures during plant modifications and operation;
- availability of documentation (e.g. operating instructions, technical specifications, emergency instructions and emergency plans);
- adherence to operating instructions and technical specifications;
- plant operation and recording of safety performance;
- adequacy of PSA models in representing the current plant configuration and operational characteristics;
- housekeeping practices designed to prevent or mitigate fire and the effects of seismic hazards;
- availability and training of operating personnel;
- radiation protection;
- human factors engineering (e.g. human-system interface);
- organisation and safety culture;
- protection against sabotage and malicious acts.

The inspections cover all aspects of engineering relevant to safety (including fire protection), the relevant disciplines of natural sciences (e.g. reactor physics, water chemistry) and social sciences (e.g. work and occupational psychology).

In 2015, ENSI was accredited by the Swiss Accreditation Service (SAS). Inspections in the following fields are covered by the accreditation:

- operational radiation protection
- radiation measurements
- transportation of radioactive substances

For 2016, an extension of the accreditation is planned. Inspections concerning the following topics shall be included: Reactor core, fuel elements and control elements.

The Inspectorate plans inspections in accordance with its Basic Inspection Programme, which provides a systematic basis for **periodic inspections**. The inspection intervals are based on the safety-relevance of the items (components, systems, processes) to be inspected and on operating experience.

In addition to the above *periodic* inspections, the Inspectorate's management defines **issue-based inspections**. They focus on specific issues identified in the annual systematic safety assessment described below. If necessary, **reactive inspections** are carried out, e.g. in response to international experience, events or plant modifications proposed by the licensee.

Inspections are performed at any time and are more frequent during outages than during normal operation. In most cases, the licensee is given advance notice of inspections. This ensures that activities to be addressed by the inspection are compatible with the inspection, that components are accessible and that the relevant staff are available for discussions. Inspections by the site inspector are usually unannounced.

Most inspections are performed during the operation of nuclear installations, although a few inspections cover research reactors, which have been shut down.

A full-time site inspector is appointed for each NPP. Other less critical nuclear installations have been allotted to part-time installation inspectors. As the Inspectorate's offices in Brugg and the NPP sites are in relatively close proximity, regional offices are not required. For the same reason, there are no resident inspectors, although regular unannounced visits occur.

During normal operation, the site inspector is present at the site one day per week on average. During outages, the site inspector is present for four or five days. Inspections by specialists focus on specific issues, whereas site inspectors develop a more general view of the NPP. Findings of potential interest are reported by the site inspector to the specialists at the Inspectorate. The duties of site inspectors are not limited to inspections. They also act as a vital link between the licensee and the Inspectorate. Site inspectors take the lead role in the systematic safety assessments (see below), which are part of the process of integrated oversight. Site inspectors also contribute to the annual regulatory oversight report published by the Inspectorate on their particular site.

Information meetings

Each site inspector (see above) conducts monthly meetings with the respective licensee in order to obtain the latest information on plant status and performance.

Members of the management of the Inspectorate and the licensee meet annually for an information meeting at which the licensee reports on plant operation. The meetings also discuss special issues and on-going or planned projects. The Inspectorate then gives its view on the various topics and clarifies current or future requirements (safety-related requirements are normally presented to the licensee before any enforcement).

In addition, there is an annual meeting between senior managers from the Inspectorate and the licensee in order to discuss current safety issues. There are also annual management meetings between the Inspectorate's senior management and senior managers from all nuclear installations, including ZWILAG and PSI.

In addition to these regular information meetings, the Inspectorate may arrange meetings on specific issues at any time deemed appropriate.

Elements of ageing management programme(s)

Review of Ageing Surveillance Programme

The safety-relevant aspects of material ageing must be taken into account for all classified systems, structures and components (SSCs) in Switzerland, which was one of the first countries to introduce systematic ageing management programmes (AMPs). All licensees started their plant specific AMPs in 1992. The regulatory expectations for the AMP in Switzerland are provided within the current guideline ENSI-B01 (issued 2011), which superseded guideline HSK-R51 (issued in 2004). The guideline ENSI-B01 is based on the legal framework in Switzerland (Nuclear Energy Ordinance and Nuclear Energy Act) and in the guideline reference is made to requirements according to IAEA Safety Guide NS-G-2.12 related to material ageing issues.

Information from manufacturers, knowledge gained from maintenance, operational experience, root cause analysis of international reportable events and the current state of the art of science and technology must be considered when implementing and maintaining the ageing monitoring programme.

The AMP covers the areas of mechanical, electrical and civil engineering SSC. There are specific requirements for the individual implementation of AMP for electrical and I&C systems, mechanical systems and civil structures. This reflects the individual necessities based on the different physical ageing mechanism and the respective maintenance strategy, following also the approach according to IAEA TECDOC-1736. The documentation of the AMP in Switzerland comprises:

- Technology-specific assessment of the potential possible ageing mechanisms;
- Plant-specific or generic guidelines;
- Fact sheets on AM with structural-element specific/component-part-specific or component-specific categorisation of the relevant ageing mechanisms and their adherence with the respective maintenance programmes. The guideline requires updating of Fact Sheets to reflect any new safety-related results or at least once every ten years;
- Annual status reports which include a compilation of: updated fact-sheets and complementary measures; evaluation of ageing relevant internal and external operating experience and current state of science and technology; assessment of the effectiveness of the applied AMP and the complementary measures taken.

AMPs provide essential information for the qualification process of the respective in-service inspection programmes (ISIs) for mechanical components and are considered for a verification of maintenance programmes already in place. The maintaining (updating) process of the AMP ensures that the relevant ageing mechanisms for all safety-relevant components and structures are identified and that appropriate complementary measures are initiated if any divergences or gaps are discovered.

The complementary measures initiated are one key issue of the AMP. They cover for example the following topics:

- Studies for specific material degradation issues (e.g. material degradation susceptibility under specific conditions, root cause analysis of flaws);
- Modification/adjustment of in-service inspection programmes (temporarily or permanently);
- Mitigation techniques.

Arrangements for internal review by the licence holder of safety cases to be submitted to the regulatory body

Reporting

Article 37 and Annex 5 of the Nuclear Energy Ordinance specify the periodical reports to be submitted to the regulatory body in order to assess the status and operation of the facility. Article 38 and Annex 6 address the reporting of planned activities, events and findings of relevance to safety. Article 39 governs the reporting obligations in the area of security. The Nuclear Energy Ordinance delegates the detailed requirements in terms of the content of the report to the Inspectorate. These aspects are covered in Guidelines ENSI-B02 and ENSI-B03, both of which came into force in 2009. Guideline ENSI-B02 deals with periodic reporting, e.g. monthly reports, annual safety reports and outage reports. Guideline ENSI-B03 addresses the reporting of planned activities, events and findings of relevance to safety. Data relating to general plant performance, including radiological characteristics and plant modifications for which a permit is not required, must be reported periodically (monthly or yearly). However, events such as equipment failures, scrams and the failure of mandatory tests must be reported immediately or at the latest within 24 h where they relate to nuclear safety aspects (see Annex 6 of the Nuclear Energy Ordinance).

The licensee also must review information on international events available through various channels such as WANO, IAEA and supplier information letters. The insights gained from these reviews must be reported on a monthly basis. A set of safety indicators has been defined and the raw data for these indicators must be included in the monthly reports.

Reports by licensees may trigger regulatory requirements or recommendations for improvement. The Inspectorate also reviews information from international events as well as insights from safety research. Those reviews may also trigger regulatory action and, if appropriate, requirements or recommendations to the licensee.

Quality requirements concerning the internal review by the licence holder of safety cases to be submitted to the regulatory body (e.g. by means of independent verification) are defined in ENSI-G07.

Regulatory review and control activities

Integrated Oversight: ENSI's Annual Systematic Safety Assessment

Under the Inspectorate's integrated oversight approach, all aspects of relevance to nuclear safety are integrated into a single comprehensive oversight strategy. The aim is two-fold: firstly, the Inspectorate must ensure it has sufficient information on the design, state and effectiveness of all safety provisions so that it can provide a realistic assessment of the safety of each nuclear installation. Secondly, the Inspectorate must ensure it takes adequate and effective measures if it detects a weakness in a safety provision. Every assessment and action must be justified and traceable.

In order to obtain a realistic picture of the safety of each installation, the Inspectorate operates a systematic safety assessment system. Firstly, safety information is structured based on the following key issues:

- requirements subdivided into design and operational requirements;
- operating experience subdivided into state and behaviour of the plant and state and performance of human factors and organisation.

Secondly, information is structured based on the following safety goals:

- safety functions;
- levels of defence in depth and barrier integrity.

For each NPP, data is collected as shown in Table 2 and Table 3.

Inspection findings, operator licensing results, event analysis results, safety-indicator data and information in the periodic licensee reports are evaluated annually as part of the integrated oversight process.

Table 2: *Safety Assessment Table – Defence in Depth*

Goals	Subject	Requirements		Operational experience	
		Design requirements	Operational requirements	State and behaviour of the plant	State and behaviour of man and organisation
Levels of defence in depth	Level 1				
	Level 2				
	Level 3				
	Level 4				
	Level 5				
Barrier integrity	Fuel integrity				
	Integrity of the primary cooling system boundary				
	Containment integrity				
overall defence in depth aspects					

Table 3: *Safety Assessment Table – Safety Functions*

	Subject / Goals	Requirements		Operational experience	
		Design requirements	Operational requirements	State and behaviour of the plant	State and behaviour of man and organisation
Safety functions	Controlling reactivity				
	Cooling the fuel				
	Confining radioactive materials				
	Limiting exposure to radiation				
	overall aspects				

Each finding identified during an inspection is assigned to one or more cells in each table (defence in depth and fundamental safety function). The same process is used for the event analysis results, and each direct or indirect cause along with each safety-relevant effect is detailed. Finally, operator licensing results and the safety indicator assessments are given.

Findings are rated on a scale based on the International Nuclear Event Scale (INES). The scale is designed to assess all levels of safety performance ranging from good practice to a severe accident on an identical scale. The categories are defined as follows:

- Category G: Good practice – All requirements are fulfilled and the practice of other NPPs is clearly exceeded.
- Category N: Normality – All requirements are fulfilled
- Category V: Need for Improvement – Deviations from requirements in documents not requiring formal authorisation by the Inspectorate fall into this category
- Category A: Deviation – Deviations from normal operation within operational limits and conditions
- Categories 1 to 7 – Rating based on the INES Manual

Categories V and A correspond to INES 0. Findings from inspections rated INES 1 or higher are classified as events. Findings rated A are checked to see whether they must be classified as events. Any finding in category V or higher requires action.

Inspection data, operator licensing data, event-analysis data, safety-indicator data and the periodic licensee report data are entered in a database. A software tool allows the display of safety assessment data and it is possible to display the ratings in a table for any period and any installation. Each rating is linked to a source document. The ratings for each NPP are evaluated annually. The result of this evaluation influences the focus of future inspections. Insights gained from the annual safety assessment of each plant are included in the annual regulatory oversight report published by the Inspectorate.

Developments and Conclusions

Switzerland complies with the obligations of Article 14.

Article 15 – Radiation protection

Each Contracting Party shall take the appropriate steps to ensure that in all operational states the radiation exposure to the workers and the public caused by a nuclear installation shall be kept as low as reasonably achievable and that no individual shall be exposed to radiation doses which exceed prescribed national dose limits.

Based on the recommendations of the International Commission on Radiological Protection (ICRP) (mainly Publication No. 60), both the Radiological Protection Act and the Radiological Protection Ordinance were revised and entered into force in 1994. The Inspectorate has subsequently issued revised and adapted versions of most of its guidelines relevant for radiation protection:

- R-07: Guideline for radiation protection zones in nuclear installations and in the PSI;
- B04: Clearance of materials and zones from controlled areas;
- B09: Determining and reporting of doses of occupationally radiation exposed personnel;
- G13: Radiation protection measuring instruments in nuclear facilities, basic concepts, standards and testing;
- G14: Calculation of the radiation exposure in the vicinity of nuclear installations due to emissions of radioactive materials;
- G15: Radiation protection objectives of nuclear installations.

The Radiological Protection Act was partly revised in October 2007. The latest review of the Radiological Protection Ordinance was carried out in January 2014. Relevant changes, among others, were the distinction of the dose factors for infants (1 a), children (10 a) and adults as well as the dose factors of irradiation for plume and soil. The Ordinance is currently under revision to obtain compatibility with the new European Safety Directive, Version 24th February 2010 (final) and the IAEA Basic Safety Standard, Version July 2014.

In January 2013, a new ordinance concerning the official gauging of radiation protection measuring instruments came into force.

Dose limits

The Radiological Protection Ordinance limits the general maximum individual total dose for NPP personnel (plant personnel and contractors) as a rule to 20 mSv per year. Exceptionally, a limit of 50 mSv per year, but not exceeding 100 mSv in five years, can be authorised by the Inspectorate. Since 1994, there has been no request to the regulatory body to extend the dose up to 50 mSv per year.

The total number of occupationally radiation-exposed plant personnel and contractors in all Swiss nuclear facilities is around 7000. Since 1996, all annual collective doses have remained around two man-Sv or well below per unit. The annual collective doses of the last 20 years are illustrated in Figure 3 (note: Beznau NPP consists of two units, both located on the same site).

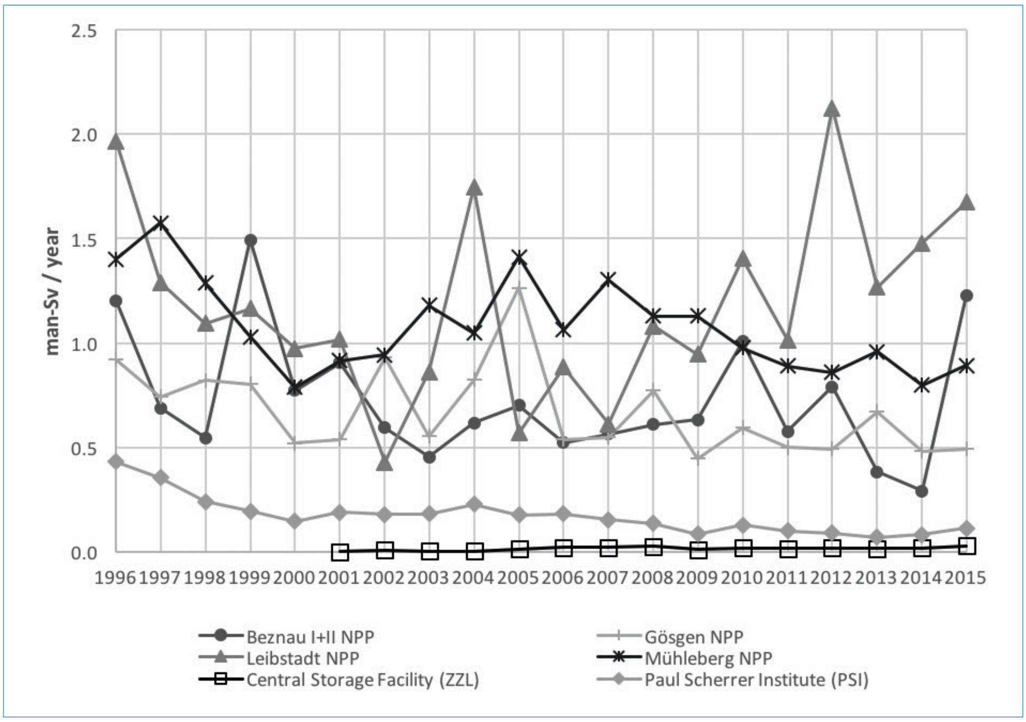


Figure 3:
Annual collective doses for the personnel in Swiss NPPs, the Central Interim Storage Facility (ZZL) and the research institute PSI. All peaks are related to extraordinary work performed: in 1999, the steam generators of Beznau NPP II were exchanged with a collective dose of 0.64 man-Sv. The low dose for this work can be largely attributed to «lessons learned» from earlier similar operations and to the optimisation of radiation protection. For your information: in 1993 for the same work in Beznau NPP I a collective dose of 1.2 man-Sv was generated. Extensive structural alteration works related to the planned power upgrade resulted in higher collective doses in 1994 and 1996 at Leibstadt NPP. In 2004, additional inspections carried out at Leibstadt NPP resulted in a higher collective dose. The exchange of the primary safety valve in 2005 occurred within project PISA at Gösgen NPP and led to an increase of the collective dose. The unplanned repair of a crack in a weld of a reactor pressure vessel nozzle in Leibstadt NPP resulted in an increase of the accumulated dose in 2012. The increasing amount of maintenance work and periodic testing are responsible for the increase in the annual collective doses in Leibstadt NPP since 2013. Long outage periods in Beznau NPP I and II led to a high collective dose in 2015. Within these periods major projects were completed, among others, installing new reactor vessel heads which required opening of the containment.

The dose due to non-natural sources, for members of the public, is limited to 1 mSv per year by the Radiological Protection Ordinance. The Inspectorate's guideline G15 defines a source-related dose constraint of 0.3 mSv per year representing the maximum allowed dose for persons living nearby nuclear installations resulting from emission and direct radiation from each site (independent of the number of reactors). Direct radiation may not cause a corresponding dose of more than 0.1 mSv per year.
A nuclear facility must be designed in such a way that the source-related dose constraints are not exceeded because of incidents with an occurrence greater than 0.01 per year and the dose limit for members of the public is not exceeded by incidents with an occurrence greater than 0.0001 per year. The Inspectorate's guideline G14 defines the rules for the calculation of doses due to emissions and discharges. The maximum allowed emissions are defined in the licences, based on the characteristics of the NPP and on the results of the dose calculations, taking into consideration the ALARA principle. Calculated doses based on annual emissions for a virtual most exposed group of the population, including the exposure due to deposition from former years, have always been well below 0.2 mSv per year. Since 1994, calculated values due to annual releases have been below 0.01 mSv per year for all Swiss NPPs. These facts are illustrated in figure 4. For all Swiss NPPs, doses due to direct radiation have always been below 0.1 mSv per year. Thus, it is shown that the sum of the annual dose caused by direct radiation and emission has always been below the source-related dose constraint.

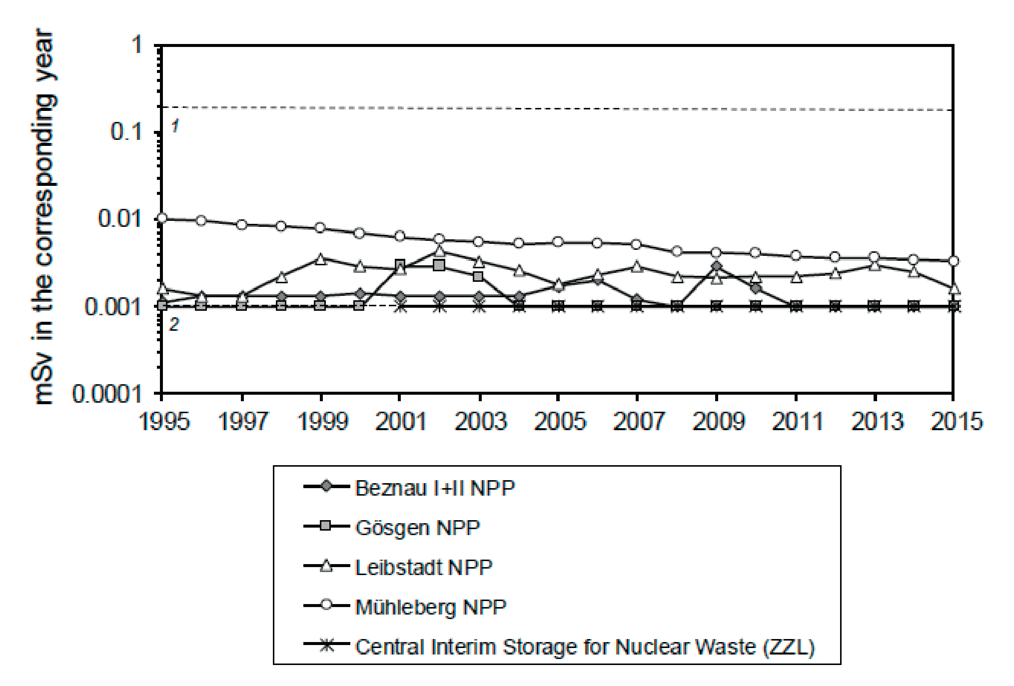


Figure 4:
Doses calculated on the base of annual emissions from the Swiss NPPs and the Central Interim Storage Facility (ZZL) excluding the contribution of direct radiation. The annual doses are calculated for a virtual most exposed group of the population, including the exposure due to deposition from former years. The higher value for the Mühleberg NPP is related to an emission of radioactive particles in 1986 due to a malfunction of the dry resin waste treatment system.

1. 0.2 mSv per year value (source-related dose constraint minus direct radiation constraint).
2. Values below 0.001 mSv per year are shown as 0.001 mSv per year.
3. Virtual person, permanently located in the main plume area, only consuming locally produced food and only drinking water from the river downstream of the NPP in question

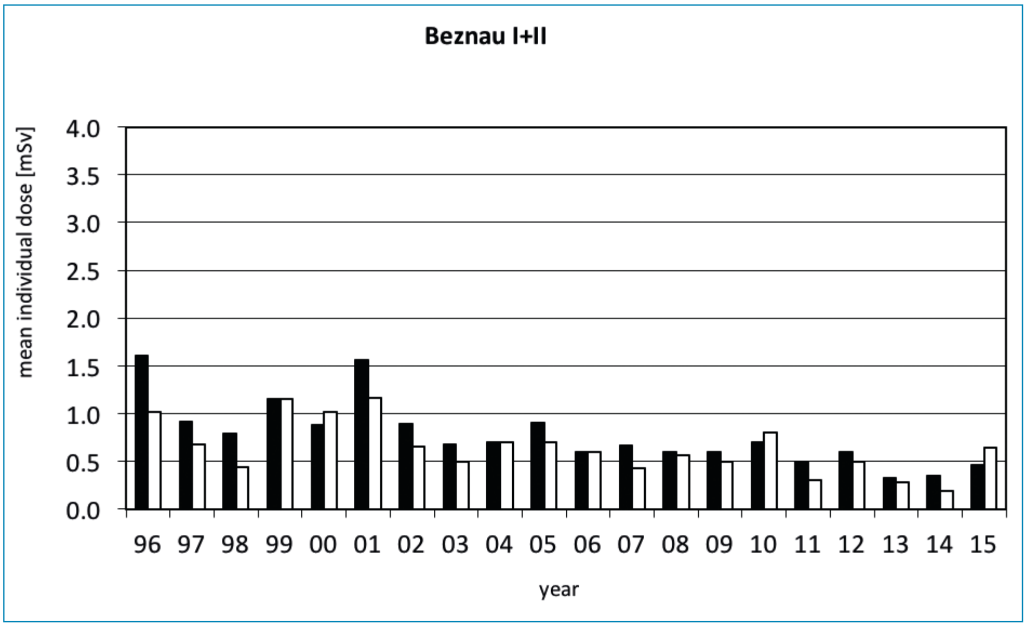
Steps taken to ensure that radiation exposure is kept as low as reasonably achievable

Over the years, NPP-specific methods have been progressively used to keep radiation exposure arising from the operation and maintenance work of NPPs as low as reasonably achievable. Since the year 1994, when the new dose limit of 20 mSv came into force, this limit was exceeded during two incidents: in Beznau NPP unit I in 2009 and in Leibstadt NPP in 2010. In both cases, the individual doses did not exceed 50 mSv. The mean individual doses for plant personnel and contractors (see Figure 3) remain largely unchanged over the last few years at all Swiss NPPs, reflecting the significant efforts made particularly since 1988. Since 2013 a slight increase of the mean individual doses is evident at Leibstadt NPP, which is in agreement with the results of the annual collective doses. The increase of the mean individual doses in Beznau NPP in 2015 is explained by the extended outage periods of both units to perform the various projects supported by numerous on-site contractors.

The most significant dose reduction measures undertaken at the Swiss NPPs over the last few years are compiled in Table 4.

In order to maintain low doses in a reasonable way under consideration of optimisation, the ICRP recommends, in its publication 75, the use of operational dose constraints based on estimated levels achievable through the application of best practice. In this sense, the Inspectorate's guideline G15 requires the NPP to define dose-planning objectives (e.g. maximum individual doses or collective job doses) for the respective activities based on:

- empirical values for comparable activities in its own or a comparable installation;
- current radiological situation;
- international experience;
- optimisation processes.



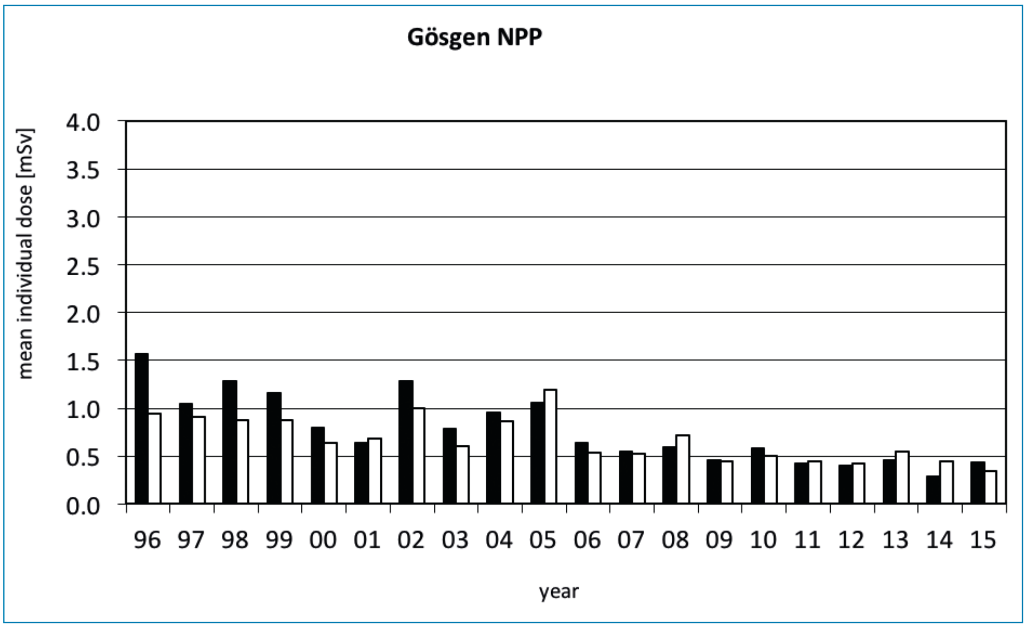
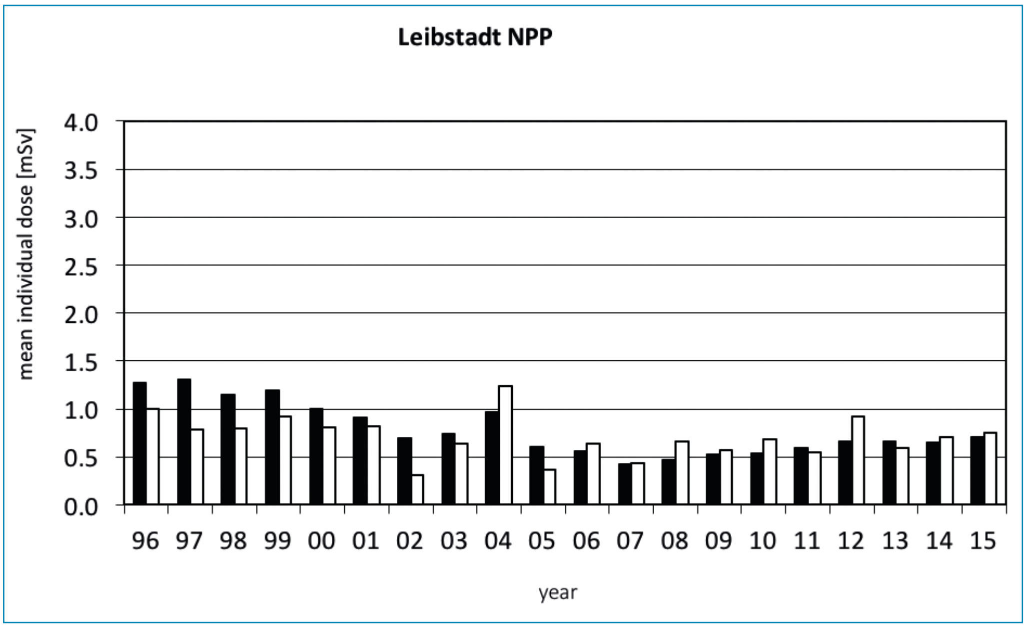


Figure 5:
Mean individual dose of plant personnel (dark bars) and contractors (white bars) at Swiss NPPs.


Leibstadt NPP
mean individual dose [mSv]
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
96 97 98 99 00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15
year

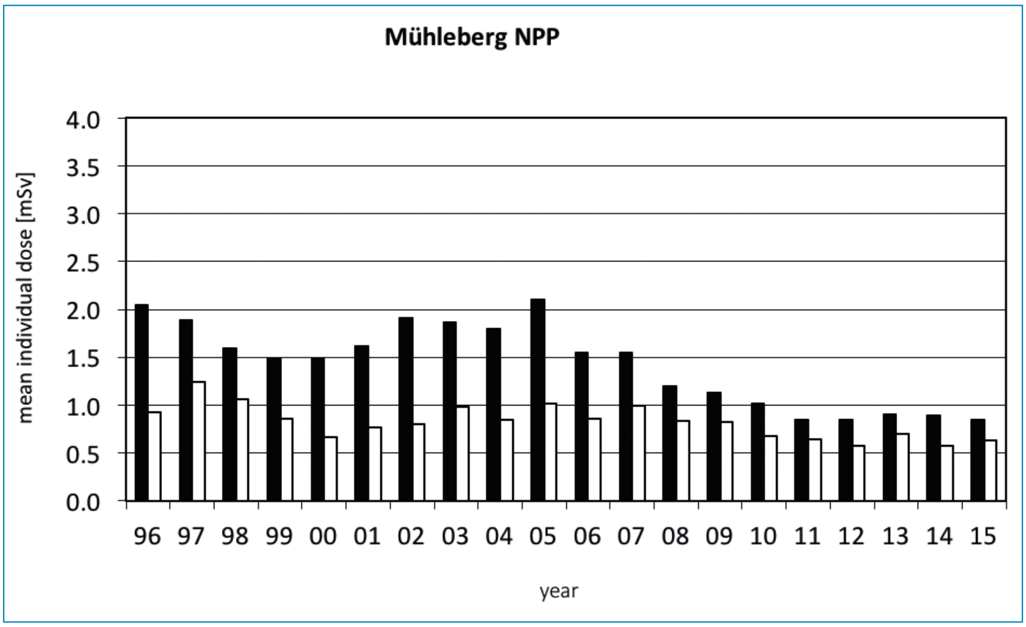

Mühleberg NPP
mean individual dose [mSv]
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
96 97 98 99 00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15
year

Table 4:
Main dose reduction measures in Swiss NPPs

Plant	Average of collective dose during outages over the last five years [man-mSv]	Main dose reduction measures
Beznau I and Beznau II NPPs	581	Temporary lead shielding (70 tons). Low dose rate areas for personnel (< 0.005 mSv/h). Personal acoustic dose and dose rate warning. Strong emphasis on training and motivation. Daily job-specific follow up of doses vs. planning including interventions if necessary to remain within the NPP-internal dose constraint of 10-mSv p.a. for workers. Remote tools for primary system inspection. Improved water chemistry, reducing fixation of colloids on primary system surfaces. Radiological risk analyses and improvement of infrequent or high dose tasks/works.
Mühleberg NPP	606	Temporary lead shielding (85 tons). Permanent racks for supporting removable lead sheets. Use of a conveyor belt to transport the temporary lead shielding into the drywell. Replacement of components with «Stellite» parts by components made from a cobalt-free alloy. Daily follow up of job specific actual doses vs. planning doses. Zn-64-depleted zinc feed in primary water. Online noble chemistry (OLNC) primary water operation mode induced a reduction of the dose rates of the recirculation pipes. Stopping the addition of hydrogen to the primary water system some hours before the reactor is shut down for the outage. Application of wireless dosimeters for special kind of works in order to control the dose and dose rate on-line.
Gösgen NPP	444	Temporary lead shielding (up to 40 tons). Highly compartmentalised containment with compartments made out of concrete. Replacement of the old isolation system with new isolation cassettes on the primary coolant pipes. Daily monitoring of total and selected job specific actual doses vs. planning doses. Extensive mock-up training. Zn-64-depleted zinc feed in primary water. Shutdown procedure individually adjusted to the current activity of the primary coolant water. Chemical decontamination of all three-reactor coolant pumps. Wireless telephone set with sound suppression used for work in noisy areas to improve communication. Intensive surveillance of high dose or high risk works on site. Planning of work includes reasonable system conditions (filled pipes or compounds, closed systems etc.).

Plant	Average of collective dose during outages over the last five years [man-mSv]	Main dose reduction measures
Leibstadt NPP	1121	Temporary lead shielding (32 tons). Temporary shielding with water bags. Job dosimetry (bar code) with online monitoring. Very detailed job planning for jobs implying collective radiation exposure > 50 man-mSv. Job planning for jobs implying collective radiation exposure > 10 man-mSv. Replacement of components with «Stellite» parts by components made from a cobalt-free alloy. Zn-64-depleted zinc injection in feed water. Extensive mock-up training. Stopping the addition of hydrogen to the primary water system some hours before the reactor is shut down for the outage. Extensive camera system in the turbine building to reduce the number of operator walk-downs in steam affected areas. Chemical decontamination of components and systems as required. Application of teledosimetry for specific jobs in order to control the dose and dose rate on-line. Soft Shutdown and optimised RHR operation during refuelling outage.

According to the Radiological Protection Ordinance, radiation protection is deemed to be optimised if the following conditions are met:

- Different possible solutions have been individually assessed and compared.
- The sequence of decisions that led to the particular solution is traceable.
- Due consideration has been given to the possible occurrence of incidents and the safe storage of radioactive sources which are no longer in use.
- In detail, the Inspectorate requires:
- Special quality management (QM) rules for the radiation protection department as a part of an NPP's QM system, (see Article 13) including procedures which define the determination of dose planning objectives, the optimisation process, the documentation as well as the relevant regulations regarding competencies.
- A radiation protection planning (including determination of dose planning objectives) in accordance with the internal procedure if the anticipated collective dose of a planned activity in a nuclear installation leads to higher collective doses than the internally determined planning thresholds (typically 5, 10 or 20 man-mSv).
- A report addressed to the authority on radiation protection planning in the case of a planned shutdown, and if the planning of an activity results in an anticipated collective dose higher than 50 man-mSv.

The Inspectorate must examine the dose planning objectives in detail if the expected annual collective dose exceeds 1.5 man-Sv per NPP. In this case, the Inspectorate will require optimisation measures if appropriate. The NPP must compare the monitored doses with the dose planning objectives. If relevant deviations become obvious, the activity must be stopped, the planning must be revised and improvements must be implemented.

In all Swiss NPPs, the wastewater is collected and treated in batches. However, for the treatment of wastewater in every power plant a different abatement technique is used. In Beznau NPP, the radioactivity in the wastewater is reduced by centrifugation, chemical precipitation and nanofiltration. In Gösgen NPP the evaporation and in Leibstadt the centrifugation and evaporation technique are used, while in Mühleberg the centrifugation, ion exchange and evaporation technique is applied.

Three of the Swiss NPPs – Gösgen, Leibstadt and Mühleberg – have conventional offgas treatment systems, which consist of catalytic recombiners, offgas-condensers, hold-up-lines, activated carbon filter columns, HEPA-filters and offgas pumps. Beznau NPP has a different system that works with four pressurised hold-up-tanks. The NPPs have formulated site-specific targets for liquid and gaseous discharges with the intention of keeping the dose to members of the public low in a reasonable way under consideration of optimisation. To reduce the iodine gaseous discharges KKL has backfitted the turbine building gland seal system with a filter system. The filter system cleans the feed water used for producing the gland seal steam.

At least every ten years the licensee of each Swiss NPP must perform a periodic safety review. Within the framework of this review, the licensee must assess the liquid and gaseous discharges of its plant and benchmark it against the corresponding discharges of similar European reactors. The outcome of this process, was that Beznau NPP improved the abatement system for liquid discharges by nanofiltration. Since 2007, the liquid discharges of Beznau NPP are less than one GBq per year.

The licensee of Mühleberg performed a periodic safety review in 2005. The Inspectorate has assessed this review in depth. As a result, the licensee is reducing the activity without tritium in the liquid discharges to a target setting of one GBq per year until 2010. To reach this aim, the licensee studied possibilities for reducing the quantity of wastewater as well as separating different qualities of wastewater for specific treatment. This work has resulted in a decrease of the activity released from seven GBq (2007) to 1.1 GBq (2015) per year. Additionally in September 2015, the licensee placed a small evaporator in operation. With this addition, the licensee plans to reduce the annual liquid discharges below the target setting of one GBq.

RCA boundary review in the Swiss NPPs

In 2004 ENSI required that all Swiss NPPs investigated their entire radiological controlled area (RCA) (as a whole) in order to find possible uncontrolled pathways between radioactive media and materials inside the RCA and the environment. The integrity of barriers and the outside boundaries of the RCA (walls, ceilings, floors, windows, doors, feedthroughs, locks, joints etc.) as well as interfaces between systems with potential radioactive media and systems open to the environment (tubes, tanks, valves, return valves, filters etc.) were examined in each NPP. The results of investigations performed along with suitable countermeasures were presented annually to ENSI. Since then the last corrective actions have been performed to inhibit unlicensed pathways. Summary reports have been submitted to ENSI by each NPP. In addition, the integrity of outside boundaries of the RCA are also relevant checkpoints in the approval procedure for facility modifications.

Operating radiation protection organisation

To ensure the independence of the radiation protection organisation from the production department of the facility, the licensee must carry out three requirements based on regulations in the radiation protection act.

- The licensee must provide a direct communication link between the authorised radiation protection expert and the management representative of the licensee.
- The licensee must delegate competences to the radiation protection experts to intervene in the operation of the NPP if radiation protection rules are violated.
- The licensee must provide adequate personal resources in the radiation protection organisation. His staff must be comprised of professionals with approved education and training. Radiation protection relevant tasks are reserved for these professionals.

Detailed descriptions of these rules are part of each NPP's documentation necessary for the granting of an operating licence. Modifications of the radiation protection rules of the NPP must be authorised by the Inspectorate.

Regulatory control activities

As mentioned above, the Inspectorate reviews the radiation protection planning process of the NPPs as a part of its supervisory duties. Typically, these reviews are performed in conjunction with the radiation protection planning for upcoming outages.

Inspections concerning radiation protection matters are focused on the outage phases. Normally, these inspections are planned based on the radiation protection planning of the plant several weeks in advance and are centred on activities with an anticipated collective dose greater than 50 man-mSv. Other routine inspections are performed in every NPP during operation in addition to specific inspections focused on special topics, like radiation instrumentation, contamination control, etc.

Additionally the Inspectorate reviews all periodical reports of the NPPs related to radiation protection measures. The Inspectorate maintains a computerised database of radiological and chemical plant data provided monthly by the licensees.

Environmental radiological surveillance

The Radiological Protection Act establishes the legal basis for the radiological surveillance of the environment. More detailed requirements are laid down in the Radiological Protection Ordinance and in the legislation for foodstuffs. On this basis, the Inspectorate has issued discharge and environment monitoring regulations. These regulations contain requirements on the control of discharges and a complete programme on environmental monitoring of radioactivity and direct radiation in the vicinity of the facility. The programme is drawn up by FOPH in co-operation with the Inspectorate, NEOC and the cantons. The programme is reviewed annually and modified as necessary.

The Inspectorate defines requirements for the measuring devices as well as how the measurements must be carried out. It monitors the correct maintenance of the devices and audits the measurement bookkeeping during annual inspections. In addition, it performs its own quarterly benchmark tests within each plant.

The environmental surveillance programme has three main aspects:

- Measurement of the emissions from the plant and comparison of the actual emissions with the limits set in the licence for the operation of the NPP. The limits are chosen in such a way that the dose for persons living in the vicinity of the plant remains well below the source-related dose constraint (see section «dose limits» above).
- Calculation of the dose from the measured emissions for the most exposed persons living in the vicinity of the NPP. The calculated values are compared directly with the source-related dose constraint. The models and parameters used for the calculation are defined in the Inspectorate's guideline G14.
- Programme for the radiological surveillance of immission. The environment is monitored nationwide by the FOPH. The vicinity of the NPPs is additionally monitored by the NPP and the Inspectorate independently. The programme includes online measurements of the dose rate near the plants (MADUK, see Article 16), as well as regular sampling and measurements of air, aerosol fallout, water, soil, plants and foodstuff.

The results are published in annual reports of the Inspectorate. A summary of the results of the entire environmental radiological surveillance is also published in the annual report of FOPH.

Developments and Conclusion

The figures with the annual collective doses for the personnel in Swiss NPPs, the mean individual dose of plant personnel and contractors, and the annual doses for a virtual most exposed group of the population were actualised with the data up to the year 2015.

Furthermore, the text of the sixth CNS report was updated with the results of the licensees' activities to keep the discharges as low as reasonably achievable.

Switzerland complies with the obligations of Article 15.

Article 16 – Emergency Preparedness

Clause 1: Each Contracting Party shall take the appropriate steps to ensure that there are on-site and off-site emergency plans that are routinely tested for nuclear installations and cover the activities to be carried out in the event of an emergency. For any new nuclear installation, such plans shall be prepared and tested before it commences operation above a low power level agreed by the regulatory body.

Prior to the start-up of a new NPP, on-site and off-site emergency plans must be established and approved by the Inspectorate. The general requirements for emergency preparedness are based on the following acts, ordinances, Inspectorate's guidelines and concepts:

Acts:

- Nuclear Energy Act;
- Radiological Protection Act.

Ordinances:

- Nuclear Energy Ordinance;
- Radiological Protection Ordinance;
- Ordinance on Emergency Preparedness in the Vicinity of Nuclear Installations (Emergency Preparedness Ordinance);
- Ordinance on the Organisation of Operations in Connection with NBC and Natural Events;
- Ordinance on Iodine Prophylactics in the Case of a Nuclear Accident;
- Ordinance on Alerting the Authorities and the Public;
- Ordinance on Foreign Substances and Food Contaminants.

Guidelines:

- Emergency exercises (Guideline B11);
- Emergency preparedness in nuclear installations (Guideline B12)
- Organisation of nuclear installations (Guideline G07)
- Source term analysis (Guideline A08).

Concepts

- Concept for the emergency protection in the vicinity of nuclear power plants, Federal Office for Civil Protection FOCP (2015).

A working group was set up by the Federal Council (IDA NOMEX)[13] in May 2011 to review emergency preparedness measures in case of extreme events in Switzerland. The group's report «Review of Emergency Preparedness Measures in Switzerland», which is available on the Inspectorate's website (www.ensi.ch), was adopted by the Federal Council in July 2012 and describes a series of organisational and legislative measures which have proven to be necessary as a result of the review conducted. These include, for example, measures in the field of equipment and material, emergency planning zones, scenarios for emergency planning and large-scale evacuations. As a consequence of IDA NOMEX, the legal basis as well as concepts pertinent to emergency preparedness and response were revised or are in the process of being updated. The scenario used for emergency planning purposes is now characterised by an unfiltered, substantially higher source term than previously assumed. Consequently, awareness for emergency preparedness and response beyond the outer radius of Zone 2 (i.e. 20 km) have been raised, which is reflected in the revised concept for the emergency protection in case of an accident at a nuclear power plant.

The Inspectorate has further set up an action plan for the follow-up of emergency preparedness and response issues identified in its analysis of the event in Fukushima.

Following a recommendation from the IRRS mission in November 2011, the Inspectorate has introduced an IAEA-compatible emergency classification system, extended the scope of inspections with

[13] The Interdepartmental Working Group to Review Emergency Preparedness Measures in case of Extreme Events in Switzerland. In German «Interdepartementalen Arbeitsgruppe zur Überprüfung der Notfallschutzmassnahmen bei Extremereignissen in der Schweiz»

regard to emergency preparedness and response at the NPP sites and improved the redundancy of emergency communication means. A national nuclear and radiation emergency plan is also being developed under the lead of the FOCP.

On-site emergency organisation

Each NPP has plant-specific documents on emergency preparedness, which include the following:

- operating procedures for abnormal situations;
- emergency operating procedures;
- severe accident management guidance (SAMG);
- procedures for reporting to the Inspectorate and to the National Emergency Operations Centre;
- procedure for reporting to cantonal police for fast-evolving accidents.

The emergency preparedness documentation of the NPPs is reviewed regularly.

SAMG programmes have been implemented at all Swiss NPPs: all plants have appropriate validated guidance for the mitigation of severe accidents during full-power operation. Validation is the result of emergency exercises to which the Inspectorate participates in its function as safety oversight authority and as observer. In addition to the full-power SAMG, all plants have developed special guidance for low power/shutdown conditions. The existing strategies to cope with Station Blackout (SBO) scenarios have been extended. As a result, additional equipment has been installed or stored on the plant sites and the existing accident management procedures have been adapted.

Since June 2011, extra equipment has been stored at the Reitnau centralised storage facility. Adequate resources such as diesel motor driven pumps, diesel generators, hoses, cables, borating agents, tools and personal protective equipment should be available from Reitnau within eight hours of request. For situations where transport to the power plant by road is impossible, an option exists for transport by air via military helicopter. The operators test the severe accident equipment stored at Reitnau once a month during their regular emergency exercises.

To ensure communication in an emergency, dedicated telephone and fax lines between the NPPs, the Inspectorate and the National Emergency Operations Centre are available. These communication systems are tested once a month. In the case of unavailability of the above-mentioned communication equipment, there is the possibility of using a digital radio system. As the IDA NOMEX report emphasised, the importance of redundant and failsafe communication systems, the requirements on redundancy and safety against failure of such systems have been reviewed and defined by the FOCP. Such requirements were also defined for monitoring (plant parameters and environment dose rate measurement data) and forecasting systems by the Inspectorate in 2012.

Aspects of short-term operability and habitability of emergency control centres during nuclear accidents were assessed during inspections in 2012. Further inspections to ensure that nuclear power plants have suitable emergency rooms and substitute emergency rooms have been carried out since.

Off-site emergency organisation

Off-site emergency organisation is based on resources built up as part of the general protection concept developed for the Swiss population as a whole. They consist of a well-developed shelter infrastructure and well-trained troops for fire and disaster intervention. The emergency preparedness for events in Swiss nuclear installations in which a considerable release of radioactivity cannot be excluded is regulated under the Emergency Preparedness Ordinance. In the event of a radiological emergency, the Federal NBCN Crisis Management Board (FMB NBCN) co-ordinates the response of all involved federal offices (ministries) including the civil and military support at federal and regional levels.

The Ordinance on the Organisation of Operations in Connection with NBCN is the legal basis for the FMB NBCN. FMB NBCN is responsible for suggesting appropriate measures to the Federal Council (government), which then issues the associated instructions to cantonal authorities and the general population. FMB NBCN runs a stand-by emergency service, NEOC, which is responsible for alerting and informing the public and for initiating protective actions during the initial phase of an emergency.

The major organisations involved in emergency preparedness have the following responsibilities:

- NPPs are responsible for detecting and assessing an accident, for implementing on-site countermeasures to control it and for disseminating information immediately and continuously to the relevant off-site authorities. According to the Emergency Preparedness Ordinance, the NPPs are further responsible for the timely determination of the source term and its communication to the Inspectorate.
- The Inspectorate is responsible for judging the adequacy of on-site countermeasures implemented by NPP staff. It makes predictions about the possible dispersion of the radioactivity in the environment and about the consequences of such dispersion. The Inspectorate also advises the National Emergency Operations Centre in ordering protective measures for the population. In addition, an automatic dose rate monitoring and emergency response data system (MADUK) has been installed around all NPPs in Switzerland. The system monitors dose rates continuously at 12 to 17 locations in the vicinity of each NPP. The data are transmitted online to the Inspectorate and the National Emergency Operations Centre. The Ministry of the Environment of Baden-Württemberg (Germany) receives online data from the dose rate monitors in the vicinity of the Beznau NPP and Leibstadt NPP. All data is also available on the Inspectorate's website (www.ensi.ch). For further information, please refer to Article 15. A second automatic network (NADAM) monitors the external dose rate on national territory. The data is available on the NEOC's website. Switzerland transmits every hour the mean value of the last hour of all stations to EURDEP which are then transmitted to IRMIS.
- The ANPA system also provides the Inspectorate with online access to measurement data for about 25 important plant parameters. The Inspectorate uses special software – the Accident Diagnostics, Analysis and Management system ADAM – to visualise these measurements, to diagnose the state of the plant and to simulate how an accident may develop. Furthermore, ADAM includes a module called STEP (Source Term Estimation Program), which allows a source term estimation considering actual plant parameters. The Inspectorate has set up a new automated system for radiological forecasting in 2015. Calculations are performed hourly using JRODOS (Java-based real-time online decision support system) in combination with LASAT (Lagrangian Simulation of Aerosol-Transport) as the dispersion engine, along with forecast meteorological data. The same system is operated in parallel at the National Emergency Operations Centre, thus ensuring a full redundancy.
- NEOC is responsible for the preparedness of the Federal NBCN Crisis Management Board, which has the task of preparing the decisions to be taken by the Federal Council on countermeasures after the initial phase of an emergency during an accident. The NEOC is also responsible for the overall assessment of an emergency situation and for the transmission of warnings to the cantonal and federal authorities. It must decide on initial protective actions to protect the population and to transmit the alarms (sirens) together with the behavioural instructions disseminated by radio broadcast. The NEOC is responsible for coordinating measurement teams, data processing and evaluation, assessing the radiological situation and sharing these results with other emergency related information with all the relevant response organisations on a secured electronic platform. It is also responsible for informing and communicating with international partners (neighbouring countries and international organisations).
- The Federal NBCN Crisis Management Board is responsible for the cooperation in connection with NBCN events and the coordination of operations. The Board has a committee and a permanent staff unit. The members of the Board are the directors and chiefs of all major federal offices, amongst others the Director of the FOPH, the Director of the FOCP, the Chief of the Swiss Army Command Staff, the Director of ENSI and representatives of cantonal government conferences. Within their area of responsibility, they take the necessary precautions for coping with radiological emergency events.
- The cantonal and communal authorities are responsible for executing protective actions for the public.
- The medical service of the Swiss army procures iodine tablets for the whole population in Switzerland. It will ensure that the required number of iodine tablets is made available to the authorities

who are responsible for the pre-distribution. It also ensures additional storage in drugstores and pharmacies.

- The canton where the NPP is located is responsible for informing its citizens of the potential consequences of an accident in a facility and providing advice on how to respond in an emergency.

In the event of an accident, information is disseminated to the media by the above authorities in line with their individual responsibilities.

Emergency planning zones

Under the updated concept for the emergency protection in the event of an accident at a nuclear power plant, released in 2015, each NPP in Switzerland has two distinct emergency planning zones:

- Zone 1 is the area around an NPP in which there could be acute danger to the public in the event of an accident and for which immediate protective measures are required. Depending on the NPP's power rating and the exhaust height of its stack, Zone 1 covers a radius of about 3–5 km.
- Zone 2 adjoins Zone 1 and encloses an area with an outer radius of about 20 km. The public can be alerted in individual sectors as appropriate.
- The area outside the zones 1 and 2 is the rest of Switzerland (former zone 3). As a basis for planning and preparation of specific measures, so-called planning areas have been defined (these areas correspond to the planning distances).

The outer borders of Zones 1 and 2 generally follow the boundaries of the relevant municipal authorities.

Emergency protective measures

The primary objective of emergency protective measures in the vicinity of NPPs is the prevention of acute radiation sickness resulting from the accidental release of radioactive materials. In addition to this primary objective, emergency protective measures are designed to minimise the prevalence of long-term, genetic radiation damage.

Protective measures designated for the public are based on the Dose-Measures Concept quoted in the Ordinance on the Organisation of Operations in Connection with NBC and Natural Events. This Concept describes the protective measures to be considered (see Table 5).

Table 5:
Intervention levels

Protective measures	Dose acquired in the first year after the accident	Dose intervention level (mSv)
Remain indoors for children, adolescents and pregnant women	Effective dose from external radiation and inhalation	1
Remain indoors, inside cellars or shelters	Effective dose from external radiation and inhalation	10
Evacuation	Effective dose from external radiation and inhalation	100
Take iodine tablets	Thyroidal dose from inhalation of radioactive iodine	50
Harvesting and grazing ban	Ordered as a precaution where any of the above measures is ordered as well as for areas in the downwind direction	-

In addition, the Ordinance on Foreign Substances and Food Contaminants contains limits and tolerance levels for foodstuffs. The limits correspond to the maximum permitted levels of radioactive food contamination under EURATOM regulations.

The protective measures applied during the cloud phase must be planned so that they can be implemented as a preventive measure in the initial phase of an accident. During the cloud phase, the primary measures include sheltering, taking of iodine tablets and possibly evacuation before any release. They reflect the following:

- The solid construction of houses in Switzerland and the high availability of private and public fallout shelters mean that in most cases sufficient protection is provided against the radioactive cloud shine in the cloud phase of an accident by shelter in houses, cellars or fallout-shelters. Therefore, this is considered as the most important protective measure. In order to prevent infiltration of radioactive material, windows and outside doors should be closed and air-conditioning systems turned off.
- Iodine tablets are distributed to all houses, schools and companies within a radius of about 50 km around the NPP's. The recent extension of the radius from 20 to 50 km for iodine pre-distribution is one of the results of the IDA NOMEX work. Outside of this 50 km radius, tablets are stored by the cantons so that they are available to the public within 12 hours.
- Under the Concept for emergency protection in the vicinity of nuclear power plants, a precautionary evacuation of zone 1 and affected sectors of zone 2 is to be prepared. Such precautionary evacuations in zone 2 or in sectors of zone 2 will be ordered by the Federal Council. A basic document containing standard requirements for the planning of large-scale precautionary evacuations was issued by the FOCP. An evacuation during the initial phase of an accident will be considered provided that no release of radioactive materials is expected during the evacuation period.

Protective measures during the ground phase are based on the actual radiological situation in the environment as indicated by measurement data. Important protective measures are staying indoors, evacuation after the cloud passage, restricted access to certain areas, restrictions on certain foodstuffs, countermeasures for agriculture, decontamination and medical support. Some protective measures outside of the zones 1 and 2 are still under discussion.

Alert procedures

If an accident occurs, the NPP is required to inform the Inspectorate and the National Emergency Operations Centre immediately. If the accident poses a threat to the public and the environment, this triggers a three-stage warning and alert procedure. To be effective, measures to protect the public should be taken before any radioactivity is released from the plant. Therefore, the warning and alert criteria are based primarily on the situation in the NPP.

- A **warning** is issued at the latest when a high dose-rate is detected by monitoring inside the containment. The warning (by a dedicated electronic system) puts federal, cantonal and municipal organisations (within Switzerland) on stand-by for a possible alert. The National Emergency Operations Centre informs the IAEA and authorities in neighbouring countries. It also activates the hotline operated by a professional medical call centre.
- The first **alert** is by siren (coupled with radio broadcast messages to the population) if an accident develops in such a way that it might lead to a dangerously high release of radioactive materials into the environment. This alert ensures that the population at risk is aware of the emergency, so that it can prepare to take protective actions. Instructions are given over the radio.
- Further **alerts** by sirens are issued if necessary in order to give advice to the population on taking iodine tablets, staying indoors, using shelters, etc.

Special regulations exist for the initiation of countermeasures in the event of an accident involving auxiliary systems such as off-gas systems. They are required because releases may occur rapidly with such accidents. In this case, the NPP assesses the dose to the public. The decision to alert the public depends on the time available and the amount of any release. If the annual limit for the release of noble gases is likely to be released in less than 1 hour, which would result in a dose in the immediate vicinity of a plant of about 1 mSv, sirens will alert the public located in Emergency Planning Zone 1. The public will be advised to stay indoors for the next few hours. The NPP initiates the action and the cantonal police (responsible for countermeasures in Emergency Planning Zone 1) initiate the alert without waiting for an order from the National Emergency Operations Centre.

Emergency exercises

Each Swiss NPP conducts an emergency exercise every year. The outcomes of an exercise may lead to new measures to improve the functioning of the emergency organisation. Such measures are implemented into the training programmes of the members of the emergency organisation. According to the Inspectorate's Guideline B11, the annual emergency exercise of each plant takes place in the presence of several representatives of the Inspectorate. This guideline allows the Inspectorate also to require staff emergency exercises lasting up to 24 hours in order to check the adequacy of Severe Accident Management procedures and organisational measures especially for long-duration events. This requirement was implemented following a suggestion from the IAEA IRRS mission, which took place in November 2011.

Clause 2: Each Contracting Party shall take the appropriate steps to ensure that, insofar as they are likely to be affected by a radiological emergency, its own population and the competent authorities of the States in the vicinity of the nuclear installation are provided with appropriate information for emergency planning and response.

All people living in the vicinity of Swiss NPPs have been sent a leaflet from the cantonal authorities describing the potential dangers associated with a nuclear accident. The leaflet also explains existing protective actions to cope with the consequences. The procedure for warning and alerting the population in case of accidents is described in Clause 1 of this Article.

Switzerland is party to the Convention on Early Notification and the Convention on Assistance. Switzerland has bilateral agreements covering notification and information exchange in case of a nuclear accident with its neighbours. Although Switzerland is not a member of the European Union, it is part of the European Community Urgent Radiological Information Exchange Network ECURIE. The National Emergency Operations Centre is responsible for the notification process and for providing the necessary information. Switzerland also participates in the INES reporting network and has undertaken to report all events rated as Level 2 or higher. If an incident occurs in an NPP, reporting is the responsibility of the Inspectorate. For other radiological incidents, it is FOPH.

Because the Leibstadt and Beznau NPPs are close to the national border, special plans have been agreed upon with Germany. These plans are designed to ensure the same level of protection on both sides of the border for the public and the environment. They also seek to harmonise procedures. Dedicated telephone lines exist for communication between authorities. Plans and procedures are updated regularly by bilateral working groups as part of the German-Swiss Commission for the Safety of Nuclear Installations (see Article 17, Clause 4).

In the event of an accident in a NPP, long-term consequences may extend beyond planning zones and so Switzerland has intensified its collaboration with France and Austria. For France, an expert group on nuclear emergency matters has been set up. Furthermore, the canton of Geneva is since spring 2016 represented within the «Commission locale d'information du Bugey». For Austria, there is a yearly exchange of information. In November 2012, the «Commissione italiana-svizzera CIS», a bilateral committee between Italy and Switzerland, met for the first time in Rome. An exchange of information with Italy also takes place on an annual basis.

Emergency plans are not only tested at the national level. German authorities at both the local and federal level take part in exercises at the Leibstadt and Beznau NPPs. Switzerland participates in exercises at the French NPPs of Fessenheim and Bugey, which are located some 30 km and 70 km from the Swiss border respectively. The last exercise of the Fessenheim NPP took place in November 2013.

The preparedness of Switzerland and its response at the international level is regularly verified by its participation in international exercises conducted by the IAEA or ECURIE. The OECD/NEA INEX exercises are another opportunity to verify certain aspects of emergency management. Switzerland usually participates in these exercises.

Emergency plans and procedures must be regularly improved and adapted to reflect new challenges and changing situations. Experts from several Swiss authorities take an active part in these activities. Switzerland also participates in working groups of HERCA and WENRA on emergency preparedness. Finally, in order to improve the emergency response system at the national and international level, members of the Inspectorate and the National Emergency Operations Centre actively support the activities of the OECD/NEA working party on Nuclear Emergency Matters.

Clause 3: Contracting Parties which do not have a nuclear installation on their territory, insofar as they are likely to be affected in the event of a radiological emergency at a nuclear installation in the vicinity, shall take the appropriate steps for the preparation and testing of emergency plans for their territory that cover the activities to be carried out in the event of such an emergency.

This Clause does not apply to Switzerland.

Developments and Conclusions

Since the sixth Swiss report and following the work of IDA NOMEX, several ordinances relating to emergency preparedness are in the process of being revised or have already been revised. The same applies to different concepts pertinent to emergency preparedness and response in Switzerland. The Emergency Preparedness Ordinance, the Ordinance on the Organisation of Operations in Connection with NBC and Natural Events and the Radiological Protection Ordinance have still to be updated, whereas the new ordinance on Iodine Prophylactics in the Case of a Nuclear Accident came into force by the 1st of January 2014. The lessons learned from the accident of Fukushima have led to the initiation of numerous activities with the aim of improving preparedness and response capabilities both on and off site. The follow-up to and completion of these activities are still ongoing.
Switzerland complies with the obligations of Article 16.

Emergency exercise with helicopter - Source ENSI

Article 17 – Siting

Clause 1: Each Contracting Party shall take the appropriate steps to ensure that appropriate procedures are established and implemented for evaluating all relevant site-related factors likely to affect the safety of a nuclear installation for its projected lifetime.

Under the Nuclear Energy Act and the Nuclear Energy Ordinance, a general licence for a nuclear installation can only be granted if the site is suitable. The procedures for granting a general licence and the associated requirements are discussed in the section on Article 7.

The Nuclear Energy Act contains a list of conditions governing the issue of a general licence. The first two are that humans and the environment shall be protected and that the granting of a licence does not conflict with other provisions of federal legislation, in particular legislation on environmental protection, preservation of the local natural and cultural heritage and the area development plan.

The Nuclear Energy Ordinance contains requirements relating to measures designed to prevent accidents initiated either within or outside the facility. For the purposes of the deterministic safety analysis, the Radiation Protection Ordinance gives dose constraints for the public during normal operation and for design-basis accidents. Based on this, the Inspectorate defines actual dose limits in Guideline G15 for normal operation, transients, and accidents. Dose constraints are ranked as a function of incident frequency. The Inspectorate's Guideline G14 specifies the methodology and boundary conditions for dose assessments for the public for doses arising from radionuclide transfer under normal operation and for accident analysis.

Under the Nuclear Energy Ordinance, the following reports shall be submitted with the application for a general licence:

- a safety analysis report (SAR);
- a security report;
- an environmental impact report;
- a report on compliance with area planning requirements;
- a concept for decommissioning;
- a report on the management of the resultant radioactive waste.

An integral part of the site evaluation is the assessment of external hazards. Specific requirements are provided in the Ordinance on Hazard Assumptions and Evaluation of Protection Measures against Accidents in Nuclear Installations and include earthquakes, flooding, aircraft crashes, extreme weather conditions (winds, tornados, etc.), lightning, shock waves, and fire. The hazard analysis shall follow comprehensive hazard impacts analysis. Consequentially, the SAR shall incorporate all relevant factors relating to the site (natural characteristics and human activities), in particular:

- geology, seismology, hydrology (including flooding and ground water) and meteorology;
- population distribution, neighbouring industrial plants and installations;
- anticipated exposure to radiation in the vicinity of the facility;
- traffic infrastructure (road, rail, air, water) and transport.

For the purposes of the PSA, the Nuclear Energy Ordinance demands that the mean core damage frequency (CDF) for any newly constructed NPP shall not exceed 10^{-5} per year. For existing NPPs, the licensee must prove a CDF of less than 10^{-4} per year (including external hazards), as required by the Ordinance on Hazard Assumptions and Evaluation of Protection Measures against Accidents in Nuclear Installations.

During the licensing procedure, the Inspectorate evaluates the site-related factors likely to affect the safety of a nuclear installation and produces an SER in which it defines additional requirements for plant design, if necessary.

Before the construction of an NPP, FOPH and the Inspectorate establish a programme for radiological surveillance in the vicinity of the NPP. The programme includes sampling and the measurement of air, water, soil and foodstuffs. The first set of data is collected before an NPP is commissioned and this is then used as a baseline when investigating the effects of an NPP after commissioning.

The relevant safety factors shall be evaluated whenever there are plans to build a relevant new feature (e.g. gas pipeline or industrial building) in the vicinity of an NPP.
Safety assessments shall be updated whenever relevant new findings or experience is available.
Following the Fukushima accident, the Inspectorate initiated a re-evaluation of several hazards (see Clause 3).

Construction of Gösgen NPP - Source Kernkraftwerk Gösgen-Däniken AG

Clause 2: Each Contracting Party shall take the appropriate steps to ensure that appropriate procedures are established and implemented for evaluating the likely safety impact of a proposed nuclear installation on individuals, society and the environment.
As outlined under Clause 1 appropriate steps are implemented in the regulations to ensure appropriate procedures. Switzerland is a small and densely populated country. The number and size of suitable sites for NPPs are limited. The concept of safety by distance encounters natural limitations in Switzerland. New NPPs were planned in the vicinity of existing sites. However, following the accident in Fukushima Daiichi, the Federal Council decided to abandon nuclear energy in an orderly manner. Consequently, there are now no activities to build new NPPs.

Clause 3: Each Contracting Party shall take the appropriate steps to ensure that appropriate procedures are established and implemented for re-evaluating as necessary all relevant factors referred to in subparagraphs (1) and (2) so as to ensure the continued safety acceptability of the nuclear installation.
When re-evaluating the relevant factors, the procedure is largely the same as that applied to the initial review and assessment (see Clause 1 above). Because the reporting procedures applicable to power plants include the relevant site factors, any modifications to these factors are known (e.g. construction of a new industrial plant in the vicinity of the NPP). The notification by the licensee of such modifications normally includes an assessment of their possible consequences. Site-related factors are re-evaluated as part of the periodic safety review (PSR). In particular, the SAR (including the deterministic safety analysis) and the PSA are updated by the licensee and reviewed by the Inspectorate.

In essence, the re-evaluation processes help to ensure the continued safety acceptability of the NPP as it confirms the validity of earlier assessments or indicates the impact of changes to site-specific safety factors. The applicability and effectiveness of the Inspectorate's re-evaluation process are illustrated by the probabilistic reassessments of the hazards posed by earthquakes, external flooding and extreme weather conditions.

Earthquake

The large-scale project PEGASOS – a German acronym for «Probabilistic Seismic Hazard Analysis for Swiss Nuclear Power Plant Sites» – was carried out by the Swiss licensees in response to a requirement that came out of the Inspectorate's PSA review process. In order to achieve a thorough quantification of the uncertainty of seismic-hazard estimates, an extensive elicitation process was conducted involving technical experts, scientific institutions and engineering organisations from Europe and the USA. The complete project report was released in 2006 at an OECD specialists' meeting in Korea and is available from the website of swissnuclear, a section of the Swiss electricity grid operators. A summary report in German can be downloaded from the Inspectorate's website.

In 2008, the Swiss licensees initiated a follow-up project, the PEGASOS Refinement Project (PRP). The project took advantage of the most recent findings in earth sciences and new geological and geophysical investigations at the Swiss NPP sites. A particular objective was to reduce the uncertainty range of the PEGASOS results. As with the PEGASOS project, the PRP sought primarily to characterise seismic sources, ground motion attenuation on rock and the local soil response at the NPP sites. In the course of the PRP, the project duration was extended to allow the inclusion of both of the then newly proposed Swiss nuclear power plant sites and research activities that were targeted at the local application of internationally obtained strong motion insights. The PRP summary report was submitted to the Inspectorate at the end of 2013.

The projects PEGASOS and PRP were designed according to the Senior Seismic Hazard Analysis Committee (SSHAC) level 4 methodology. Considering the same methodology, the Inspectorate followed the studies closely through a system of continuous peer reviews. At the end of 2015, after examination of the PRP summary documentation, the Inspectorate forwarded to the licensees the PRP review findings in the form of an order for a legal hearing. The order specifies both the now valid seismic hazard results and the seismic safety proofs that are required by Swiss regulation in the case of a change in hazard results.

The Inspectorate places particular emphasis on seismic safety measures. After conclusion of the PEGASOS project, the Inspectorate had increased the level of seismic hazard to be used for the PSA studies and for the design of new safety-related structures and components. Later, as a consequence of the Fukushima accident, the Inspectorate required the licensees to re-evaluate the seismic design with reference to hazard results that had to be derived from the available interim results of PRP (see Articles 14 and 18). In the context of the continuous backfitting process undertaken by the Swiss NPPs, significant seismic improvements had already been achieved in the past e.g., through the installation of bunkered emergency systems. Enhancements realised more recently include the backfitting of electrical cabinets, motor control centres, cable trays, diesel-oil day tanks, pipe runs, control room bracing and masonry walls as well as the upgrading of accident management measures by the utilisation of mobile pumps and additional diesel generators stored both on-site and in an external storage common to all Swiss NPPs (Reitnau).

External Flood

For the design of the nuclear power plants, protection against flooding was originally determined based on dam and/or weir breach scenarios or on a 1,000-year flood. In 2008, the flooding hazards for three sites were reassessed within the framework of the general licence applications for new nuclear power plants, which were intended to be built at already existing sites. The new flooding hazards were derived either by considering a 10,000-year flood or, in one case, an extreme flood scenario that actually gives rise to a higher discharge than the 10,000-year flood. The discharge values for the 10,000-year floods were calculated through extrapolation of river level data considering historical flood records, where appropriate. The flood levels were computed using a 2D-model for the flooding scenarios, including a detailed orographic representation. After the severe accidents in Fukushima, ENSI ordered the new results to be applied for the safety assessment of the existing nuclear power plants. Additionally, to evaluate the flooding risk comprehensively, ENSI asked the licensees to perform analyses regarding the effects of a total debris blockage of bridges or hydraulic installations near the sites. The analyses of the licensees, based on two dimensional flooding simulations and incorporating sediment transport and appropriate particle size distribution, indicate that total debris blockage does not cause cliff-edge effects for the plants.

Extreme weather conditions

For the purpose of the design of the plants, the hazard assumptions were defined based on rules and standards valid at the time of construction.

In the course of the EU stress test, the Inspectorate identified the need for a re-evaluation of the existing hazard assumptions concerning extreme weather conditions and the associated proof of adequate protection in order to determine whether these elements were up to date.

The requirements for the re-evaluation of the probabilistic hazard analyses concerning extreme weather conditions were specified in 2012. The probabilistic hazard analyses and the proof of adequate protection of the plant against extreme weather conditions were submitted to ENSI in 2014. The hazard analyses were reviewed by ENSI in 2015. As a result of ENSI's review, the Swiss NPPs were required to update their hazard analyses. Some provisional hazard values were defined to be used for the proof of adequate protection.

Clause 4: Each Contracting Party shall take the appropriate steps to ensure that appropriate procedures are established and implemented for consulting Contracting Parties in the vicinity of a proposed nuclear installation, insofar as they are likely to be affected by that installation and, upon request providing the necessary information to such Contracting Parties, in order to enable them to evaluate and make their own assessment of the likely safety impact on their own territory of the nuclear installation.

Switzerland has signed agreements on the exchange of information with Austria, France, Germany and Italy. The German-Swiss Commission for the Safety of Nuclear Installations, including its working groups, the Franco-Swiss Nuclear Safety Commission and the Italian-Swiss Commission for cooperation in Nuclear Safety meet annually to consult and exchange information and experience. They also define the terms of reference for individual working groups, e.g. exchange of operational experience, emergency protection planning and exercises, radiation protection, surveillance of ageing and waste disposal. In addition, representatives from Austria and Switzerland meet annually to share information on nuclear programmes, operational experience in nuclear installations and the legislative framework for nuclear safety and radiation protection. In 2011, the government decided to phase out the use of nuclear power in Switzerland. As a result, no new NPPs will be built.

Developments and Conclusion

Changes and developments: The comments on Clause 3 provide an update on the reassessment of the hazards posed by earthquakes, external flooding and extreme weather conditions.

Switzerland complies with the obligations of Article 17.

Article 18 – Design and construction

Clause 1: Each Contracting Party shall take the appropriate steps to ensure that the design and construction of a nuclear installation provides for several reliable levels and methods of protection (defence in depth) against the release of radioactive materials, with a view to preventing the occurrence of accidents and to mitigating their radiological consequences should they occur.

The design and construction of Swiss NPPs are based on US standards (Beznau I and II, Mühleberg, Leibstadt) and German standards (Gösgen) that applied at the time of construction. The standards used are still international and incorporate the principle of defence in depth. The various levels of defence ensure that the NPPs remain within safety limits in the event of a design-basis accident and that individual dose limits for the public are not exceeded. In addition, systems, equipment and procedures exist to prevent or mitigate the release of radioactive materials into the environment in the event of a severe accident. Severe Accident Management Guidance (regarded as an element of defence in depth) exists in all Swiss NPPs (see Article 16).

The design and construction of Swiss NPPs were thoroughly assessed as part of the **licensing procedure**. The results of this assessment are part of the SER and play an important role in licensing decisions (see Articles 7 and 14). In compliance with the IAEA Safety Standard NS-R-1, Switzerland included design requirements regarding redundancy, diversity, physical and functional separation, automation, and other fundamental design principles in Article 10 of the Nuclear Energy Ordinance and the Inspectorate's Guideline R-101.

After a licence has been granted, the design and construction of existing NPPs are periodically reassessed. An in-depth review comparing the actual design and the current state of science and technology is performed at least every 10 years (PSR, see Article 14).

It is also important to note that the Swiss Nuclear Energy Act Art. 22 requires that the licence holder of a nuclear power plant is obliged to backfit the plant according to the «state of the art of the backfitting technology», and beyond it, under consideration of the appropriateness to implement further measures if these measures allow for further risk reduction.

The **first generation** of Swiss NPPs (**Beznau I and II, Mühleberg**) were constructed using designs from the late 1960s. Beznau NPP consists of two identical units of a Westinghouse 2-loop PWR type with a net electrical output of 365 MW each. Mühleberg NPP is a General Electric BWR/4 type with a net electrical output of 373 MW. They were constructed before the establishment of the general design criteria (GDC) in 1972 by the former US Atomic Energy Commission. A comparison between the design of first-generation NPPs and the requirements of the GDC revealed that the main design criteria had been recognised and incorporated in the design. These NPPs included several unique design features that were not standard at the time of construction:

- Double containment (free-standing leak-tight steel plus concrete outer shell);
- Load rejection and turbine trip without scram;
- Continuous emergency power supply from a nearby hydroelectric plant;
- Ground water as emergency feed water system (Beznau NPP);
- Doubled containment size in relation to reactor power (Mühleberg NPP);
- Hilltop reservoir to flood the core (Mühleberg NPP);
- Outer torus (Mühleberg NPP).

However, a review of the design by the Inspectorate concluded that the protection against external events of natural origin, especially earthquakes and flooding, and against man-made external events, e.g. aircraft crash, explosion or intrusion, was not sufficient. Furthermore, a lack of separation of safety-relevant systems was revealed.

The Inspectorate therefore demanded the backfitting of bunkered special emergency shutdown and residual heat removal systems. The systems had to be redundant and independent from the «normal» or conventional safety systems, including a diverse ultimate heat sink and an independent special emergency power supply, and protected against external events and against third party intervention (SUSAN, NANO, see Article 6). The special emergency buildings include a bunkered emergency control room from where the safe shutdown of the plant and the residual heat removal can be monitored and operated. The systems are designed to operate automatically in a special emergency case, without any operator action needed during the first 10 hours after initiation. The backfitting of bunkered special emergency systems was an important measure to strengthen the safety provisions against design basis accidents, as well as beyond design basis accidents.

In this context, another important safety improvement at Beznau NPP was the seismic requalification programme REQUA conducted until 1992 in order to strengthen the seismic resistance of the vital equipment of the plant. Furthermore, in 1989, the existing pressuriser relief valves at Beznau NPP were replaced by pilot-operated pressuriser safety/relief and isolation valves of the SEBIM type. These valves allow a primary pressure relief and a feed and bleed operation to be conducted.

In the early nineties, within the framework of the «Measures against Severe Accidents» developed by the Inspectorate after Chernobyl, hardened filtered containment venting systems were backfitted at Beznau (SIDRENT, 1992) and Mühleberg NPPs (CDS, 1992), allowing an active or passive venting of the containment in case of severe accidents. Also, the containment atmosphere of the Mühleberg NPP was inertised with nitrogen in order to prevent the formation of ignitable gas mixtures as already in 1988. Furthermore, in both NPPs, different means for alternative core cooling and alternative containment cooling were backfitted. For example, at Mühleberg NPP, a drywell spray system was installed in 1992 allowing flooding of the containment. In 1999, the backfitting of an emergency feed water system, in addition to the existing auxiliary feed water system, was completed at Beznau NPP unit 2. The system is located in a bunkered building protected against external hazards. The emergency feed water system for unit 1, located in the same building, has been operational since 2000. The feed water supply to the steam generators is backed up by a third system – the special emergency feed water system, which is integrated in the bunkered NANO system. Taken as a whole, the feed water supply at Beznau NPP is very reliable because of the high degree of redundancy und diversity.

Further measures for improving the safety were completed in 2015. At Beznau NPP unit 2, the hydroelectric emergency power supply was replaced by an additional state-of-the-art, seismically robust emergency diesel generator system. The new emergency diesel generators are air cooled so that they are independent from any cooling water supply. This backfitting project, which had already been initiated before the Fukushima events, is scheduled to be completed in 2016 (unit 1). Within this project, an additional, bunkered seal water injection pump and a secured long term water supply for the emergency feed water system are also being backfitted. The Inspectorate also reviewed Beznau NPP in the light of long-term operation (LTO), as unit 1 and unit 2 have been in operation for more than 43 years and 41 years, respectively. No further major backfitting measures were identified.

After Fukushima, the protection of the Swiss NPPs and their spent fuel pools (SFP) against external events had to be reassessed by the licence holders (see Article 14). Furthermore, the Inspectorate ordered all licence holders to immediately implement two physically separate lines/connections for feeding the SFPs from outside the buildings as an accident management measure, and to backfit the SFPs with qualified accident-proof level and temperature instrumentation with indication of these parameters in the main control room as well as in the bunkered emergency control rooms. At Beznau and Mühleberg NPP, the Inspectorate ordered the backfitting of new redundant SFP cooling systems because the existing systems were not qualified as safety systems. The implementation of two physically separate lines for feeding the SFP was completed at Mühleberg NPP in 2012 and at Beznau NPP in 2014.

As a result of the reviews regarding earthquake resistance, Beznau NPP is furthermore required to improve the earthquake resistance of the SFP storage building, and must implement a venting duct to remove heat and pressure generated by boiling SFP water in order to protect the building structure in case of beyond design basis accidents. The licence holder has initiated a backfitting project to implement the above-mentioned improvements by 2017. The earthquake analyses for the Mühleberg NPP confirmed that the seismic protection measures are adequate, and no additional measures were required.

As a consequence of the flooding analyses, the intake structure of the special emergency system SUSAN at Mühleberg NPP was enhanced to prevent blocking by bedload, sediment, and debris transport by the Aare River. This was performed already in 2011, together with the provision of mobile floodwalls. Nevertheless, the cooling water supply of safety and special emergency systems at Mühleberg NPP still relied solely on the Aare River, using diversified intake structures. The Inspectorate ordered that a diverse cooling water supply, independent of the Aare River, be implemented. The flooding analyses for Beznau NPP confirmed that the flood protection measures are adequate, and no additional measures are required.

The Mühleberg NPP has been operating for more than 40 years. In order to assess the requirements for a potential long-term operation (LTO), in 2012 the Inspectorate conducted a thorough safety review of the documents provided by the licence holder within the framework of the 2010 PSR. Besides the required backfittings identified in the Fukushima reassessment process as mentioned above, the Inspectorate addressed deficiencies in the spatial separation of safety systems in the lower floor of the reactor building and improvements for stabilizing the core shroud which is affected by cracks. In 2012, the licence holder planned a backfitting project for LTO that contains a cooling water supply from a protected well, a qualified redundant SFP cooling system, and an additional independent safety injection and residual heat removal system installed in a new building. In 2013, the licence holder decided to phase out operation in 2019 for entrepreneurial reasons and cancelled the planned LTO backfitting program. The Inspectorate issued a formal order to establish binding conditions for operation until 2019, requesting alternative measures to be implemented. On this basis in 2014 the licence holder submitted an alternative backfitting program, which was evaluated by the Inspectorate. The following main backfitting measures are planned or are already installed:

- In 2015 licence holder finished the installation of the new emergency system to feed cooling water from the hilltop reservoir into the special emergency cooling water system. The backfitting measure also included hose connectors inside the bunkered SUSAN-building to ensure an additional accident management-cooling water supply with mobile pumps.
- A new emergency cooling system for the spent fuel pool has to be installed by the end of 2016. Water supply is ensured from the bunkered cooling water system and from the hilltop reservoir. In 2020, the emergency cooling system for the spent fuel pool will be converted into a safety system.
- In 2015, Mühleberg NPP completed backfitting measures to reduce the internal flooding hazard by installing bypass lines with flow limiter, check valves and orifices into the piping of the RCIC system, the CRD system, the auxiliary condensate system, and the firewater system.
- By the end of its 2016 outage, Mühleberg NPP will have backfitted an additional, earthquake and flood resistant single line emergency water injection into the reactor pressure vessel. The system is located in a new building separated from other safety systems.

In October 2012, an IAEA OSART mission to Mühleberg NPP took place. The review team acknowledged the fast and thorough response to recent significant external operating experience events, including important plant modifications (see Article 19).

In conclusion, all first-generation NPPs have completed or are completing a comprehensive analysis and backfitting programme, and substantial improvements have been made. The results of the EU stress tests on these NPPs confirm this statement.

Where the realisation of backfitting measures and plant modifications is concerned, the Inspectorate monitors these activities very closely. The projects and modifications are subject to a four-step procedure, consisting of the concept, the detailed design, the installation, and the commissioning of the systems. The Inspectorate grants permissions for every step of the procedure after thorough examination of the appropriateness and compliance with national and international safety requirements.

The **second-generation** NPPs in Switzerland, Gösgen NPP, 1979, and Leibstadt NPP, 1984, were based on German and US design criteria respectively. The bunkered special emergency shutdown and heat removal systems, which provide a very high degree of protection against external events and diversity to the conventional safety systems, including a diversified ultimate heat sink, were integrated in the design from the beginning, requiring the US design of the Leibstadt NPP to be adapted to the specific Swiss demands regarding special emergency systems.

The safety status of the **Gösgen NPP**, a Siemens/KWU PWR with a gross electrical output of 1035 MW, has been continuously enhanced since its commissioning. In 1993, a filtered containment venting system was installed, allowing a passive or active venting of the containment in case of beyond design basis accidents.

In 1999, the reliability of the SFP cooling was enhanced by installing an additional independent train to the existing redundant trains for SFP cooling.

Beginning in 2001, the structures of several buildings were reinforced in order to improve the seismic resistance.

The provisions for conducting a primary pressure relief, the installation of three pilot-operated pressuriser safety/relief valves, were implemented in 2005. These valves make it possible to conduct a primary pressure relief and a feed and bleed operation in beyond design accident conditions.

During outages in 2006 and 2007, the existing containment sump suction strainers were replaced by new strainers of a filter cartridge type, enlarging the suction area from 10 m^2 to about 110 m^2.

In 2008, an aircraft crash and flood proof, earthquake-resistant building for the wet storage of spent fuel was commissioned. Cooling of the fuel elements is provided by a completely passive system, i.e. no electrical power or cooling water supply is required to maintain the fuel in a safe state.

The original design of the **Leibstadt NPP**, GE BWR/6-238 Mark III, was supplemented by the special emergency heat removal system SEHR in order to provide increased protection against external hazards, using groundwater from a protected well as an ultimate heat sink.

In the course of time, several backfitting measures have been realised. The alternate rod insertion system ARI was introduced in 1988, which provides redundancy and diversity to the existing SCRAM system, reducing the risk of anticipated transients without SCRAM significantly. In the same year, a redundant safety parameter display system was introduced.

After the Barsebäck event in 1992, the existing suction strainers of the emergency cooling systems with a size of two m^2 were replaced with strainers of 15 m^2. This took place in 1993, as well as the backfitting of the hardened filtered containment venting system allowing active venting by opening a valve or passive venting by a rupture disc.

The ventilation of the main control room (MCR) was improved in 1996 in order to ensure the habitability of the MCR in the event of accidents with a release of radioactive material. The special emergency control room displays were extended by adding neutron flux, important containment data, and stack release parameters to the existing displays. Further enhancements were carried out regarding operational safety and availability.

After Fukushima, the reviews of the seismic and flood resistance of the Gösgen and Leibstadt NPPs for the case of a 10,000-year earthquake showed compliance with the current licensing basis, and the fundamental safety functions are ensured (see Article 14). Nevertheless, the safety of Gösgen NPP was further enhanced by several improvements regarding the protection against flooding and earthquake. The seismic robustness of specific equipment important for safety is continuously improved (especially cable trays and control cabinets). Furthermore, the license holder of the Gösgen NPP decided in 2015 to enhance the existing bunkered special emergency shutdown and heat removal system. The aim of the project is to assure core cooling even in the case of very high peak ground accelerations up to 0.6 g. In addition to the existing protected low-pressure residual heat removal system, new redundant high-pressure coolant injection pumps are foreseen to cover a potential loss of primary cooling water triggered by a very strong earthquake. Other measures within this project ensure residual heat removal from core and spent fuel pool for at least 72 h, including extended DC power supply.

The assumption of a 10,000 year flood as new design specification led to several improvements at Gösgen NPP, including the introduction of an automatic advance flood warning system, the specification of organisational and administrative measures in emergency procedures, an additional sealing of building shells, air inlets and doors, as well as the provision of mobile flood walls to ensure access to important buildings. In 2015, the measures against external floods were further enhanced by installing a flood protection wall. For Leibstadt NPP, whose site is flood proof, no additional enhancements were required.
The seismic robustness of the filtered containment venting system (FCVS) was also assessed and revealed an adequate robustness of the systems in all NPPs. Nevertheless, Leibstadt NPP decided to enhance the existing FCVS in order to increase the existing margins. Gösgen NPP will enhance the existing FCVS with an additional filter device, aiming at reducing the release of organic iodine after severe accidents. In 2014, all plants conducted a re-evaluation of the hydrogen hazard. For two plants, it was decided to install passive autocatalytic recombiners (PAR) such that all Swiss NPPs will have passive measures (inertisation or PAR) against hydrogen combustion.
The measures regarding SFP cooling and SFP instrumentation – the provision of two physically separate lines/connections for feeding the SFPs from outside the buildings as an accident management measure, and backfitting of the SFPs with qualified accident-proof level and temperature instrumentation with indication of these parameters in the main control room as well as in the bunkered emergency control rooms – have been implemented in Gösgen NPP (2012) and in Leibstadt NPP (2014).
After Fukushima, the Inspectorate conducted several inspections to assess the situation in the Swiss NPPs regarding issues that resulted from the accident management actions performed at Fukushima. The Inspectorate verified the design, operability, and suitability of the filtered containment venting systems, taking into account possible adverse conditions, e.g. the loss of motive power of the valves to be opened, or radiological challenging conditions. It was verified that the venting valves can be opened in case of loss of power by provision of nitrogen accumulators that are stored on the spot, or by passive actuation by a rupture disk with defined opening pressure. The condition of the venting filters was also inspected. In another inspection, the suitability and habitability of the emergency operations centres was checked.
Furthermore, the Inspectorate conducted inspections to review the provisions of Swiss NPPs to cope with a long-lasting SBO. Despite the fact that five redundant and diversified safety layers regarding electric power supply exist, further measures against a potential SBO were taken. Each plant developed an SBO strategy and is prepared to cope with an extended SBO of seven days by means of accident management measures, including the provision of, for example, nozzles for feeding steam generators with mobile pumps or fire trucks, mobile diesel generators, means for opening valves by manual action, the provision of sufficient fuel and lubricants for extended operation, and the revision of severe accident management guidelines for SBO.
While the safety assessments after Fukushima demonstrated that the existing safety margins are adequate, the Inspectorate decided in 2013 to further strengthen the safety of the Swiss NPPs by increasing the safety margins in case of beyond design basis accidents. Based on the results of probabilistic and deterministic analyses, the objective was to identify areas where backfits could contribute the most towards a further reduction of the hazard, taking account of the principle of adequacy. Accordingly, the licensees conducted the required analyses in 2014. As a result of these investigations flood protection of the special emergency buildings in Beznau NPP and Mühleberg NPP and the seismic robustness of sensitive components in Gösgen NPP and Mühleberg NPP has been or will be improved.
In 2013, the Inspectorate ordered the licensees to conduct studies related to extreme weather conditions. The Inspectorate defined the requirements for the probabilistic hazard analyses and the safety cases to be applied to demonstrate adequate protection of the plants against extreme weather conditions. A return period of 10,000 years for extreme weather conditions had to be considered. More information about this item is given in Article 14.

Electrical systems

The design of electrical systems and components of the Swiss NPPs is mainly based on the standards set by the Institute of Electrical and Electronics Engineers (IEEE) and by the requirements of IAEA NS-R-1. These standards and requirements were also taken as a basis for the relevant guidelines of the Inspectorate. Depending on the safety significance of such equipment, safety class 1E or 0E is applied. Classification 1E is generally applied to all electrical systems in the emergency power supply within the NPP and to the special emergency electrical supply, as well as to the electrical components of the safety systems. For equipment classified as 1E, proof of qualification must be available for all the components involved in safety functions. This means that the design basis range of the components for ambient conditions are proven for normal operation as well as under adverse conditions regarding pressure, humidity, and radiation in case of an accident. Additionally, the components have to withstand the earthquake loads in case of a safe shutdown earthquake (SSE) at the location where they are installed, and the installation locations of such components must be above or protected against the design basis flood levels. Electrical equipment classified as 0E is of lower safety significance. Such equipment is not subject to the qualification criteria applied for 1E equipment, and its seismic resistance is limited to the operating basis earthquake (OBE).

The criteria for independence of class 1E equipment and circuits, as well as the criteria for independence of electrical safety systems, which are defined by IEEE and Reg. Guide 1.75, are also part of the design. KTA 3503, which sets the standards for type testing of electrical modules of the safety instrumentation and control system, is also an accepted and applied standard.

Regarding the safety importance of a reliable and diversified electrical power supply for NPPs in respect of the prevention of an SBO, it is to be pointed out that the Swiss NPPs display an enhanced protection against the loss of electrical power. In addition to the emergency power supply, which is usually provided by diesel generators, an independent special emergency power supply by dedicated special emergency power diesel generators that are protected against external events is in place. These supplies, which ensure operation of the systems required for safety purposes, can be operated autonomously for several days (with the exclusive use of equipment stored at the NPP site).

The special emergency diesel generators constitute an important «safety layer» of the electrical power supply, but they are only part of the provisions in place. The design of the electrical power supply installation complies with the «defence in depth» principle and displays several levels of protection, which are designated in this section as safety layers of the electrical energy supply.

The following safety layers are in place:

First Safety Layer: external main grid the generator feeds into

Second Safety Layer: auxiliary power supply in island mode in case of failure of the main grid

Third Safety Layer: external reserve grid in case of failure of the external main grid and of the auxiliary power supply

Fourth Safety Layer: emergency electrical power supply from an emergency diesel generator or hydroelectric power plants (HPP) in case of failure of the first three safety layers for the supply of conventional safety systems

Fifth Safety Layer: special emergency electrical power supply from special emergency diesel generators for the supply of the special emergency systems

Sixth Safety Layer: local accident management (AM) equipment, such as mobile emergency power units and possible connections to nearby hydroelectric power plants

Seventh Safety Layer: accident management equipment stored at the central storage facility in Reitnau and other off-site locations (mobile emergency power units)

In order to cope with an SBO, battery-powered DC power supplies and mobile accident management diesel generators are available at all Swiss nuclear power plants. In addition, there is access to further accident management equipment in the central emergency storage facility at Reitnau. The preparedness of the operators to handle a SBO scenario was inspected by ENSI in 2012.

Instrumentation and control

Where instrumentation and control are concerned, the standards set by the International Electrotechnical Commission (IEC) are applied in addition to the classification criteria defined by IEEE documents. The safety relevance of instrumentation and control functions is assigned to categories according to IEC 61226, and the assignment to instrumentation and control systems is performed according to IEC 61513. The Periodic Safety Reviews carried out for the Swiss NPPs have demonstrated that the instrumentation for operational and safety systems as well as the independent accident monitoring instrumentation are designed according to international standards and national requirements, and consider the defence in depth principle. After the accidents at Fukushima, all Swiss NPPs were inspected and it was confirmed that the accident monitoring instrumentation is continuously supplied by batteries and AM diesel generators in the event of an SBO, thus providing the operators with a means of surveying the most important plant parameters.

Seismic design of nuclear buildings

The nuclear buildings of the Swiss NPPs are divided into structural classes I and II, according to the seismic classes I and II of the equipment placed in the buildings. Equipment and buildings of class I are designed to resist a Safe Shutdown Earthquake (SSE), equipment and buildings of class II are able to resist an Operating Basis Earthquake (OBE). According to current practice, half of the SSE spectral accelerations are used for the OBE.

Originally the class I structures of the first generation of Swiss NPPs (Beznau I and II, Mühleberg) were designed by assuming a horizontal peak ground acceleration (PGA) of 0.12 g at rock surface. In the seventies, it was established that for the SSE an earthquake with an exceedance frequency of 10^{-4}/year respectively with an exceedance probability of 0.4% in 40 years must be considered. This led to seismic requalification of the first generation NPPs Mühleberg and Beznau in the eighties under the assumption of a higher PGA of 0.15 g at the rock surface. The second generation NPPs Gösgen and Leibstadt were originally designed for a PGA of 0.15 at the bedrock level.

Since the construction, the buildings of the Swiss NPPs have been backfitted continually. In all NPPs, the masonry walls, which can endanger safety relevant equipment, were secured with steel constructions. In addition, the reinforced concrete structures of different buildings were strengthened. Examples are the building of the emergency feed water system of NPP Gösgen in 2008 and both stages of strengthening of the SFP storage building of NPP Beznau in 2009 and then 2015. In both cases additional, heavily reinforced concrete walls were constructed to resist earthquake excitation.

Since 2002, increased earthquake accelerations have been considered for new buildings and for strengthening measures applied to existing buildings. As a rule, the spectral accelerations of the SSE are increased by factors between 1.5 and 2.0. Examples of new buildings where higher seismic accelerations were applied are the new SFP storage building of NPP Gösgen and the diesel buildings of the new emergency power supply in NPP Beznau.

After the Fukushima event, the Inspectorate ordered that the seismic safety of the Swiss NPPs must be verified. In their analyses, the operators had to consider the seismic hazard derived from available interim results from the PEGASOS Refinement Project (PRP). The seismic safety of the buildings was verified using different extensive linear and non-linear calculation methods. The analyses as well as the review of the Inspectorate confirmed that the nuclear buildings can withstand the massively increased earthquake impact implied by PRP compared to the present SSE. The calculations have also shown that in spite of the higher seismic excitation nuclear buildings still behave in a linear elastic manner. This means that for NPP buildings, high seismic margins exist and only low damage level is to be expected.

The PRP was completed and submitted to ENSI by the end of 2013. At the end of 2015, ENSI defined a new hazard, based on PRP, called ENSI-2015. The following table compares the earthquake accelerations of the present SSE to the accelerations of the new hazard.

Table 6: *Comparison of earthquake hazards (5% damping)*

	Beznau NPP	Mühleberg NPP	Gösgen NPP	Leibstadt NPP
Horizontal PGA, bedrock level (SSE)	0.15 g	0.15 g	0.15 g	0.15 g
Horizontal PGA, basement reactor building (SSE)	0.15 g	0.15 g	0.15 g	0.21 g
Horizontal PGA, reference rock level ENSI 2015 (10^{-4}, mean)	0.18 g	0.29 g	0.17 g	0.17 g
Horizontal PGA basement reactor building ENSI 2015 (10^{-4}, mean)	0.30 g	0.36 g	0.39 g	0.36 g

According to the Swiss regulations, the operators are obliged to verify the nuclear safety of NPPs in the event of significant changes to the hazard definition. The corresponding order was issued by the Inspectorate in 2016. The methodology of the seismic safety assessment of the existing NPPs has also been discussed in depth.

Summary

It can be confirmed that the Swiss NPPs were designed and constructed in full accordance with IAEA requirements regarding «defence in depth». The basic principles regarding redundancy, diversity, physical and functional separation, and automation were integrated in the Nuclear Energy Act, in the Nuclear Energy Ordinance, and in the guidelines issued by the Inspectorate, ensuring that those principles are implemented in the plants. The systems and components are classified in safety classes, designed, and manufactured according to proven codes like ASME and KTA.

The Swiss NPPs are capable of withstanding hazards of natural origin with a return period of 10,000 years. It is worth mentioning that safety margins exist for events beyond this level. The seismic accelerations considered in the analyses are amongst the highest values currently used in Europe. Furthermore, the plants are equipped with a highly reliable power supply, significantly reducing the risk of an SBO.

After commissioning, the Swiss NPPs have been backfitted systematically, taking into account the lessons learned from national and international safety relevant events. They have undergone several periodic safety reviews. The Swiss NPPs were also subject to the ENSREG stress tests that were performed in Europe following the accident in Fukushima. The peer review, which took place in 2012, confirmed that the degree of protection of Swiss NPPs is very high. Nevertheless, further backfitting measures will be implemented in order to ensure a continual improvement in nuclear safety.

Clause 2: Each Contracting Party shall take the appropriate steps to ensure that the technologies incorporated in the design and construction of a nuclear installation are proven by experience or qualified by testing or analysis.

Systems, structures and components (SSC) are subject to continuous refinement and regular testing to verify nuclear safety and fitness for service. Swiss NPPs are legally obliged to comply with the current state of science and technology. Therefore, the applied technologies for design and construction modifications as well as backfitting measures are proven by experience or qualified by testing or analysis, which is reviewed by the Inspectorate.

In Switzerland, the US ASME-Code is applied for the original design and construction of safety-relevant SCC as well for backfitting projects. Recognised non-nuclear codes and standards are used for some

SCC of safety classes 3 and 4. ENSI has implemented guidelines for the approval of design specifications that are applied in case of design modifications or backfitting measures.

The EC compatible Swiss SIA-Code based on the partial safety factors concept was used for civil engineering purposes. For fault events, e.g. loss of coolant accidents, earthquakes, and aircraft crashes, the design incorporated special load combinations with appropriate safety factors.

The various SSC are classified in accordance with internationally recognised Nuclear Safety Classes. These classifications reflect their relevance to safety. Safety-classified components must fulfil stringent requirements in terms of design, materials, fabrication processes, maintenance and inspection. Nevertheless, some material and design deficiencies have appeared over time. The following paragraphs describe major examples of deficiencies, together with the steps taken by the Swiss NPPs to control, eliminate or mitigate them:

- In the late 1960s, the nickel-based material Alloy 600 was used extensively in the primary circuits of NPPs. Its manufacturing, corrosion and mechanical properties appeared favourable for the then operating conditions and service requirements. However, despite earlier experience, this material suffered from stress corrosion cracking in the LWR coolant environment. The steam generators of Beznau NPP I and II were replaced in 1993 and 1999 for that reason.
- In consideration of international operating experience, Beznau NPP decided to replace the reactor pressure heads of units 1 and 2. It is known that Alloy 600 welding material at the penetration tubes of control rod drive mechanisms is susceptible to stress corrosion cracking in case of specific material and operational conditions. In 2015, the reactor vessel heads were successfully replaced at Beznau I and Beznau II. To improve the resistivity against stress corrosion cracking in Gösgen NPP, the Alloy 182/82 welding material at some pressurizer nozzles was replaced by stainless steel in 2013.
- Stainless steel components may suffer from stress corrosion cracking in the event of unfavourable manufacturing conditions such as sensitised material or local cold work. For this reason, the recirculation piping of the Mühleberg NPP was replaced in 1986. A project to replace the recirculation system at Leibstadt NPP is in progress.
- In 1990, the Mühleberg NPP was the first BWR worldwide to report horizontal cracks in the stainless steel core shroud welds. These were discovered during the annual in-service inspection. The design of the core shroud does not allow for a simple replacement. As a precautionary measure, tie rods have been put in place. Even if there were full circumferential separation of the core shroud welds, these tie rods would hold the core shroud together and in place. In 2000, NPP Mühleberg introduced hydrogen water chemistry and noble metal chemical addition to protect the reactor internals against stress corrosion cracking. In 2005, the injection method was modified to OnLine NobleChem™. Measurements of crack lengths have confirmed a considerable reduction in the rate of crack growth for most cracks since then. The newly qualified ultrasonic testing method confirmed that the circumferential cracks have not penetrated through the wall of the core shroud, but have stopped in the middle of the wall in most places. Since 2015, ENSI has required Mühleberg NPP to perform non-destructive inspections at the core shroud welds every year using qualified inspection systems. For the residual lifetime of Mühleberg NPP, ENSI has defined thresholds for the stress intensity factor and crack length in general for all core shroud cracks. Mühleberg must check compliance with the ENSI instructions every year using the results of non-destructive inspection.
- After ultrasonic inspections in the Belgian nuclear power plants Doel-3 and Tihange-2 in 2012 revealed a series of indications in the base material of the reactor pressure vessels, ENSI requested multiple investigations from the Swiss licensees. Following the corresponding WENRA recommendation, ENSI demanded a reassessment of the quality of the forged base material of the vessel. As a first part of the reassessment, a technical report was requested on the material quality, the fabrication process, and the performed inspections of the RPV base material. Beznau and Gösgen NPP (PWR) submitted this document in October 2013 to ENSI. As a second part of the reassessment, ENSI requested a supplementary ultrasonic inspection of the base material validated for the detection of

hydrogen-induced flaws. In Beznau and Gösgen NPP, the ultrasonic inspection of the base material of the reactor pressure vessel was performed in 2015. In Beznau Unit 1 a set of indications were found which require justification and a detailed assessment of the safety case of the RPV of Beznau I is ongoing.

Article 14 describes the strategies for managing ageing problems as an integral part of a comprehensive ageing surveillance programme.

Clause 3: Each Contracting Party shall take the appropriate steps to ensure that the design of a nuclear installation allows for reliable, stable and easily manageable operation, with specific consideration of human factors and the man-machine interface.

As mentioned in the comments on Clause 1 of this Article, Swiss NPPs were constructed using US or German designs and therefore met the requirements of these countries for reliable, stable and easily manageable operation, as well as the requirements in terms of human factors and the human-machine interface. However, in NPP control rooms – the most important element of the human-machine interface – all Swiss NPPs have made improvements compared with the original design. They have introduced computerised process visualisation techniques to facilitate operational control in normal as well as abnormal conditions. The degree of automation has been increased to reduce the need for manual action for 30 minutes in the event of a design basis accident and for 10 hours in the case of an external event.

The Inspectorate pays particular attention to the consideration of human factors in the design of modifications of existing nuclear installations. Since 2007, the Inspectorate demands a human factors engineering programme from the licensees together with the initial concept of a modernisation project that affects human-machine interfaces (see Article 12). This ensures systematic and continuous consideration of human factors throughout the modernisation project. Below are some recent examples of modernisation that have had an impact on the human-machine interfaces and where the Inspectorate is closely monitoring the human factors engineering process applied by the licensees:

- In the 1990s, the Beznau NPP installed two computerised systems to improve the human-system interface. The first is a computerised alarm system with a prioritisation scheme for displaying important messages with a safety function. The second is a computerised system for emergency operating procedures (EOPs) based on the printed EOPs. This system guides the shift supervisor step-by-step through the EOPs. Printed EOPs are available in case of computer failures. These computerised systems were modernised. In 2015, they were validated using the full-scope simulator of the Beznau NPP.
- In 2015, the Beznau NPP completed a large plant-modernisation project to replace the existing hydroelectric power station that is part of the emergency power supply systems with seismically qualified diesel generators.
- In 2009, the Gösgen NPP announced that it planned to replace all instrumentation and control systems. This modification had a major impact on the working conditions of the control room operators and in particular on the maintenance personnel. The project is being carried out in several steps. For each step, a human factors engineering programme is defined and implemented in order to address the specific human factors related aspects of the project.
- In 2011, the Leibstadt NPP started the stepwise modernisation of the operational instrumentation and control systems. With the modernisation of the systems, a new computerised human-machine interface was created. The oversight of the Inspectorate included close monitoring of the human factors engineering process and consideration of the new interfaces on the work of the operators applied by the licensees.

Developments and Conclusion

Further backfitting measures to be taken depend on the assessments and analysis that are still to be performed as a consequence of the Fukushima events (see Article 14). Further improvements will also be made by implementing the requirements from the Inspectorate regarding long-term operation. The safety requirements for equipment used in design basis and extended design conditions will be implemented in a new guideline in which updated design rules for existing NPPs will be laid down.

Switzerland complies with the obligations of Article 18.

Aerial view of Leibstadt NPP - Source Kernkraftwerk Leibstadt AG

Article 19 – Operation

Clause 1: Each Contracting Party shall take the appropriate steps to ensure that the initial authorisation to operate a nuclear installation is based upon an appropriate safety analysis and a commissioning programme demonstrating that the installation, as constructed, is consistent with design and safety requirements.

All five Swiss NPPs have valid operating licences granted in accordance with the law. The initial operating licence includes the commissioning licence. Essentially, the granting of an operating licence is based on the following elements:

- an extensive set of technical and organisational documents as specified in Appendices 3 and 4 of the Nuclear Energy Ordinance and submitted by the applicant with the formal application;
- a safety evaluation report by the Inspectorate;
- proof of insurance;
- report that the plant conforms with the general licence and construction licence.

The NSC may comment on the Inspectorate's SER. The licensing procedure is described in the section on Article 7.

The operating licence includes authorisation for commissioning. The commissioning programme must be approved by the Inspectorate and consists of pre-operating and start-up tests as well as procedures for testing all equipment important for safety. The licensee conducts a design review to verify that the «as built state» properly reflects the proposed design in terms of safety requirements (safety criteria and licence conditions). Commissioning itself and all stages of start-up tests are under regulatory control as permits are required from the Inspectorate.

As part of the operating licence, the Inspectorate issues a specialist report for each new operating cycle after outage for maintenance and refuelling. This report is also a substantiated opinion from the regulator that the NPP is safe for the next operating cycle in accordance with specified requirements. It is based on the Inspectorate's assessment of operating performance, including radiation protection, events during the last cycle, the results of maintenance and refuelling activities during the outage period, and approval of the reload licensing documentation (see Article 14).

Clause 2: Each Contracting Party shall take the appropriate steps to ensure that operational limits and conditions derived from the safety analysis, tests and operational experience are defined and revised as necessary for identifying safe boundaries for operation.

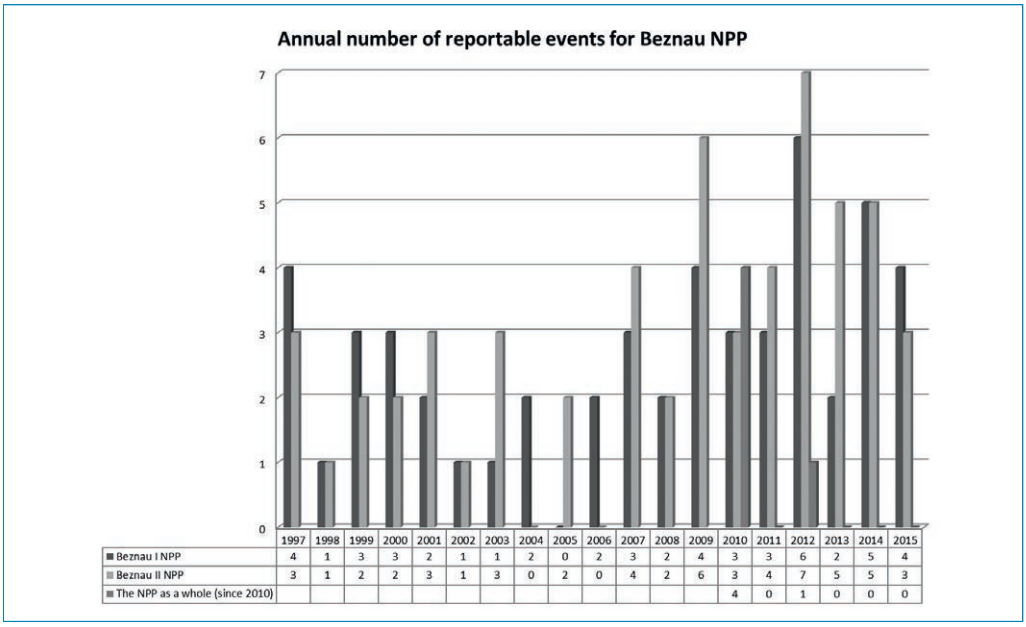
see Clause 3 below

Clause 3: Each Contracting Party shall take the appropriate steps to ensure that operation, maintenance, inspection and testing of a nuclear installation are conducted in accordance with approved procedures.

This Clause is closely linked to Clause 2 and so they are covered together in the following paragraphs. The operation of each NPP must comply with an appropriate set of limiting conditions for operation (LCO) approved by the Inspectorate. The LCO constitute boundary conditions for procedures and the instructions for normal operation. They are derived from safety analyses, test results, and are included in the Technical Specifications for the plant. The Technical Specifications also contain the plant-specific surveillance requirements. Technical Specifications are based upon the Standard Technical Specifications issued by the reactor supplier. The initial Technical Specifications and later modifications require a permit from the Inspectorate. Modifications are required as a result of plant modifications, operational experience and new knowledge. The Technical Specifications must accord with Chapter 6.3 of the Inspectorate's Guideline G09. Additional procedures implemented by licensees ensure the safe operation of NPPs. They are based on the regular verification of the operability of safety-related equipment.

These procedures are used in the extensive surveillance programmes for maintenance, inspection and testing. They encompass in-service inspections using a non-destructive examination of components, periodic examinations of electronic, electro-technical and mechanical equipment, periodic functional testing of systems and components, as well as an ageing surveillance programme (see Article 14). Non-destructive testing must accord with the Inspectorate's Guideline B07.

The regulatory surveillance of plant operation relies on information obtained from the reports submitted by operating organisations (in accordance with the Inspectorate's Guidelines B02 and B03), on information collected during the Inspectorate's inspections and on its own measurements. Since the INES classification was introduced into Switzerland in 1992, there have been 14 events in Swiss NPPs rated at Level 1 on INES and 2 events at Level 2. The annual number of reportable events as specified in the Inspectorate's Guideline B03 (until 2008 Guideline R-15) is shown in Figure 5 below. Due to changes in the criteria for event reporting, the figures for 2009 to 2015 are not comparable with those for 2000 to 2008.



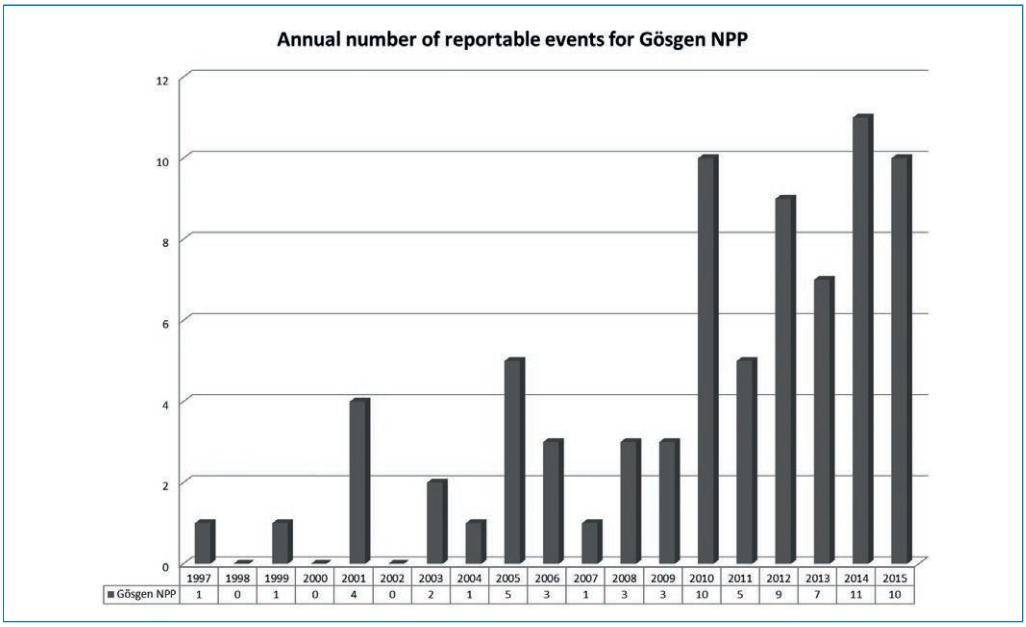
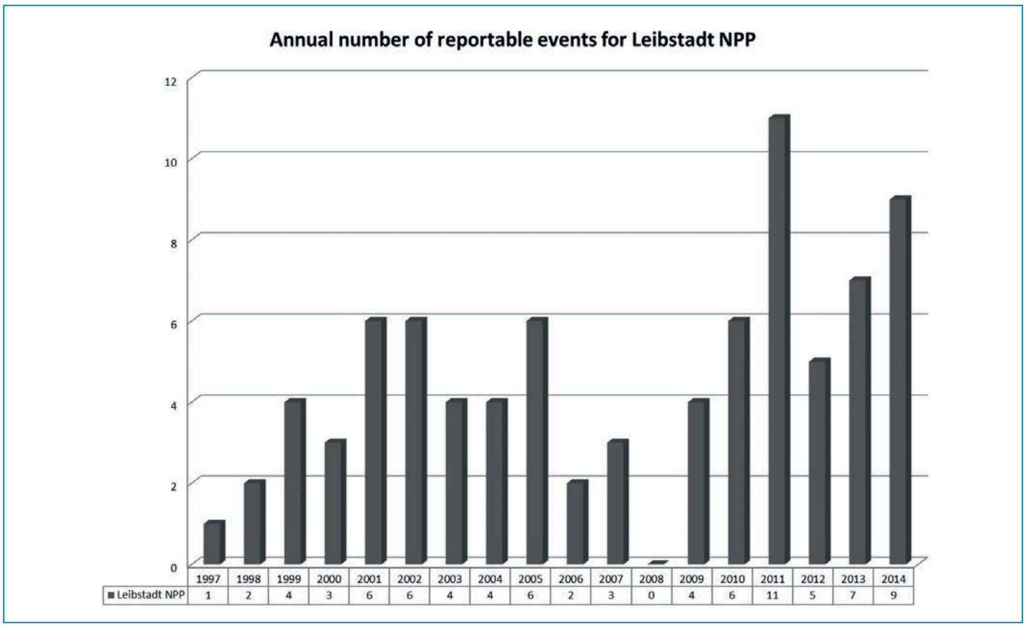
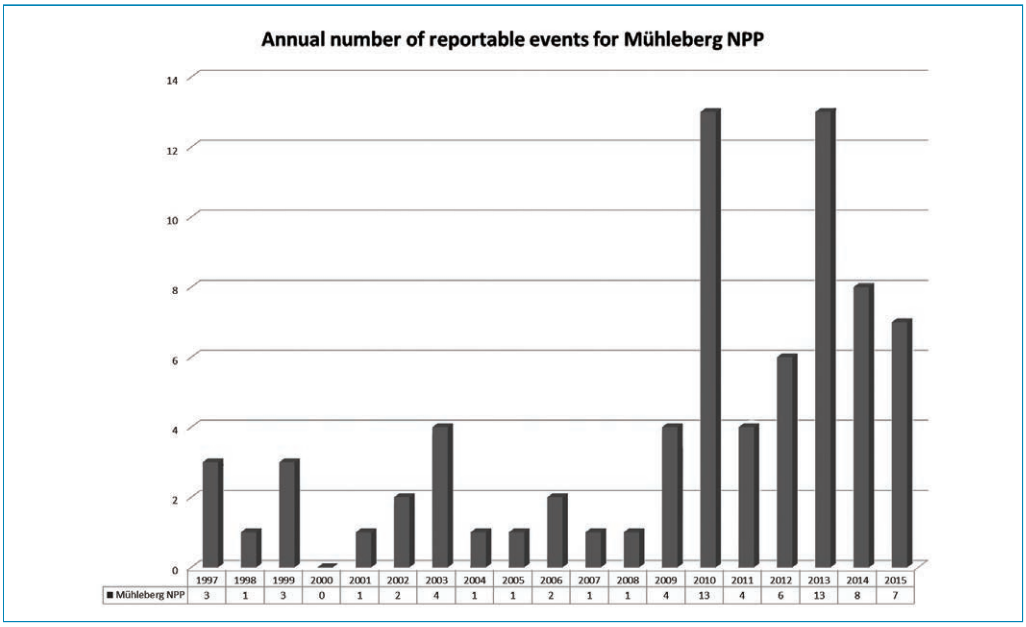


Figure 6:
Annual number of reportable events in Swiss NPPs.





The reporting system requires operating organisations to report periodically (monthly, annually, after refuelling outage) on operational performance and activities relating to safety. The most important of these are modifications to plant equipment, procedures and organisation and doses to personnel and the public. There is particular emphasis on event reporting and investigation. Lessons learned and event feedback are essential elements of operational experience. In addition, the threshold for event reporting in Switzerland is low and so the Inspectorate receives comprehensive reports on even minor events of relevance to safety. The analysis of incidents by both the utility and the Inspectorate is an important tool in efforts to increase nuclear safety (see also Clause 4).

Clause 4: Each Contracting Party shall take the appropriate steps to ensure that procedures are established for responding to anticipated operational occurrences and to accidents.

In addition to the operating procedures for all modes of normal operation, each NPP has dedicated procedures for operational anomalies and emergency conditions. As means for supporting the response to emergencies, emergency operation procedures (EOPs) are designed to bring the plant into a safe operational state, while the Severe Accident Management Guidance (SAMG) is designed to mitigate the consequences of accidents leading to fuel damage.

EOPs are a requirement of the Nuclear Energy Ordinance and they specify the measures required to manage incidents and accidents prior to core damage. In addition, the Nuclear Energy Ordinance requires the implementation of SAMG in order to mitigate severe accidents. The Nuclear Energy Ordinance concerning regulation of the content of EOPs and SAMG is embodied in guidelines published by the Inspectorate. Changes in the content of EOPs and SAMG shall be reported to the Inspectorate. Plants develop and implement EOPs and SAMG as part of the top-level organisational documents required by the Nuclear Energy Ordinance. They reflect the policy of the operating organisation. Plant modifications, operating and training experience, scientific and technological developments and lessons from events in NPPs trigger modifications to EOPs and SAMG if necessary.

The emergency procedures for NPPs include the steps for alerting the NPP stand-by safety engineer. They specify the duties of the stand-by safety engineer, in particular, the requirement to determine whether an emergency actually exists, to alert the plant's emergency staff and inform the Inspectorate if an event requires immediate reporting. The procedures also define the on-site criteria for alerts and alarms (see Article 16). Modifications to EOPs are verified and validated in the form in which they will be used in the plant, to ensure that they are compatible with the environment in which they will be used. The effectiveness of incorporation of human factors engineering principles is judged when validating them. The validation of EOPs is based on representative simulations, using the plant-specific simulator. Furthermore, spot checks of the adequacy of the EOPs are carried out within the review of selected cases of the human reliability analysis of the plant-specific PSA or during inspections.

The implementation of SAMG is required by the Nuclear Energy Ordinance. Detailed requirements on SAMG are presented in the guideline on the emergency preparedness in nuclear installations (ENSI-B12). In all plants, SAMG is implemented covering all relevant operational states. Two NPPs closely followed (Beznau) or adapted (Leibstadt) the SAMG concept of the owners' group, Westinghouse PWR or WOG/BWROG, respectively. The Mühleberg NPP (GE BWR) and the Gösgen NPP (Siemens KWU PWR) developed plant-specific concepts. The SAMG for each Swiss plant is symptom-oriented. The technical basis of the strategies developed within the framework of SAMG comprises thermal hydraulic calculations and the full-scope, plant specific level 2 PSAs. The developed decision-making support tools were checked for their applicability (validation) by the participants in the emergency response organisation. Furthermore, the validation was performed by means of exercise scenarios, for which SAMG plays the major role in managing the accident (see Article 16). SAMG is updated by the licensee according to the state of the art. ENSI reviews the SAMG by inspections and as part of emergency exercises and as part of the periodic safety review (PSR).

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. ENSI therefore regards the instrumentation as generally adequate. The availability of the instrumentation required for accident management measures is also included in the «Lessons Learned» report on the Fukushima accident (Checkpoint 5) and will be followed up within the framework of ENSI's forthcoming oversight activities.

All NPPs have Accident Management (AM) procedures on a variety of measures to deal with scenarios beyond the design basis of the plant. The AM procedures (on these measures outlined next) are elements of the EOP package, the SAMG or both. Generally, the AM equipment (e.g. mobile pumps) needed is available on site. As a back-up provision, AM equipment is also available from an external storage (see Article 16 for more details). The incorporation of the external storage in the AM procedures has been finalised.

Concerning the prevention of fuel damage, the AM measures include, for example, venting of the steam generators without external power, venting of the RPV via alternative trains, the supply (by means of fire brigade pumps) of borated water from the Spent Fuel Pool (SFP) into the RPV, coolant supply via the fire extinguishing system and cross-switching of power supply systems. Inspections (carried out for all NPPs in 2012) of the strategies to deal with a prolonged total loss of AC power (Station Blackout, SBO) generally indicate that sufficient AM measures for core damage prevention are available. Nevertheless, the review of the SBO issues is an ongoing oversight activity. Each plant has a procedure addressing the prioritisation of measures in case of an SBO.

As part of the Severe Accident Management with emphasis on the mitigation of the consequences of fuel damage, the measures include filtered venting of the containment before or after an RPV failure and flooding of the containment. For severe accidents under SBO conditions during shutdown, alternate measures for reclosing large containment openings are prepared and guided.

Concerning the prevention and mitigation of accidents taking place in the SFP, the provided measures include re-injection of water into the SFP, thereby compensating the evaporation and/or vaporisation volume and the isolation of the openings of, plus the control of the ventilation in the SFP building. Due to post-Fukushima backfitting completed so far, all NPPs have connection points allowing AM measures on SFP cooling without entering the SFP building.

Clause 5: Each Contracting Party shall take the appropriate steps to ensure that necessary engineering and technical support in all safety related fields is available throughout the lifetime of a nuclear installation.

NPPs have developed their own on-site technical support covering the surveillance test programme, reactor engineering and fuel management, operational experience feedback, plant modifications and safety-related computer applications. These functions are the responsibility of the various technical departments in an NPP. In most cases, a department at the licensee's headquarters is responsible for core and cycle design and for fuel procurement. If additional expertise is required, each plant can obtain technical support from the reactor supplier by subcontracting work to them. Technical support from the reactor supplier under accident conditions is guaranteed by special agreements. Nevertheless, the licensee must have sufficient expertise within its own organisation to ensure the quality of any outsourced tasks. In case of a severe accident, support by external staff is possible. A set of accident management procedures for each NPP is stored in the external storage facility at Reitnau.

With the deregulation of the electricity market and the current increase in economic pressures, retaining corporate knowledge has become an important issue. The Inspectorate is aware of this and the issue is discussed at the regular management meetings between the Inspectorate and NPPs. To ensure adequate technical support in Switzerland, the level of research has increased. In addition, a master's course in nuclear engineering at ETH has been established.

Clause 6: Each Contracting Party shall take the appropriate steps to ensure that incidents significant to safety are reported in a timely manner by the holder of the relevant licence to the regulatory body.

The Nuclear Energy Act, the Nuclear Energy Ordinance and the Inspectorate's guidelines contain requirements on the notification of events and incidents:

- notification of events to allow early recognition of deviations and their correction;
- notification of incident/accident conditions to alert the Inspectorate's emergency organisation and other authorities;
- notification of events of public interest to allow the Inspectorate to make an independent assessment and inform the public quickly.

The Nuclear Energy Act obliges licensees to notify the supervisory authorities within a specified time of special activities or occurrences relating to the handling of nuclear materials and which might interfere with nuclear safety or security. The Nuclear Energy Ordinance specifies reporting requirements for nuclear safety, security and the transport of nuclear materials. The Inspectorate is required to regulate the detailed reporting procedures and the method of classifying events and findings in accordance with the Nuclear Energy Ordinance. As a result, the Inspectorate's Guideline B03 contains criteria defining the reporting obligation threshold for events. The licensee is responsible for giving a preliminary rating to each reportable event or finding based on INES, whereas the Inspectorate is responsible for the final INES rating. The Nuclear Energy Ordinance specifies the time limits for initial notification, receipt of the event history report and the report on remedial action based on the INES rating. There is an additional class for events of public interest. For example, if ambulances, fire engines or police cars enter the premises of a nuclear installation with sirens wailing, this requires immediate reporting, even if there is no event of significance to nuclear safety. The Inspectorate uses the written confirmation by the licensee of an event as the basis for its initial review of the classification and any immediate action required should an event reveal unexpected barrier degradation. If an event is reported as INES Level 2 or higher or if there is a public interest, the Inspectorate's special emergency team meets as required by its own internal rules on emergency preparedness. The team will review the event and inform the media if necessary. Effective from 1st May 2016, decisions to gather the Inspectorate's special emergency team will no longer depend on the preliminary INES rating by the licensee. Instead, a set of emergency levels depending on the response of the emergency organisation of the NPP and the potential consequences of an event will also be used to decide on the response of the Inspectorate's special emergency team. In doing so, ENSI is implementing a further recommendation from the IRRS mission 2011 and in accordance with the relevant IAEA safety standards. To ensure that nuclear installations apply the Inspectorate's guidelines correctly, event classification is part of both the initial licence exams for shift supervisors and stand-by safety engineers and their relicensing. During the periodic emergency exercises, event classification is an important objective for both NPP and regulatory staff.

As part of its quality management system (see Article 8, Clause 1), the Inspectorate has its own internal procedures for event investigation, which include the independent assessment and classification of all events reported nationally. It has set up a working group consisting of experts in engineering, human factors and radiation protection, which assesses events in co-operation with specialists from individual sections. If the final rating is INES 0, the decision on this final INES rating is taken by the Head of the Division responsible for the oversight of plant operation. If the rating is INES 1 or higher, the decision is taken by the Director General of the Inspectorate. The results are communicated to the licensee and entered in the systematic safety assessment database. For several years, it has been the Inspectorate's practice to include a summary of reported events and their classification in the Inspectorate's annual regulatory oversight report. This report is publicly available.

Clause 7: Each Contracting Party shall take the appropriate steps to ensure that programmes to collect and analyse operating experience are established, the results obtained and the conclusions drawn are acted upon and that existing mechanisms are used to share important experience with international bodies and with other operating organisations and regulatory bodies.

An important process in Swiss NPPs is the process dealing with non-conformance control and remedial action. It is guided by procedures that form part of the management system. Any non-conformance is reported and discussed at the daily morning meeting held by each NPP and where necessary follow-up action (e.g. work authorisations) is initiated.

The safety impact of non-conformances is evaluated. If the event is of interest or significance to safety, the non-conformance must be reported to the Inspectorate. In addition, an internal investigation team in the plant is required to conduct a thorough analysis of the event. If the event is more complex, the NPP will use dedicated root-cause analysis methods. Based on these analyses, the event investigation team will suggest what action is required. These suggestions are reviewed by the plant's internal safety committee before implementation.

Low-level non-conformance events (below the reporting obligation level), near misses and other types of failures or malfunctions are reported to the daily meeting of plant managers and representatives from the main technical divisions. Their significance is then evaluated. Depending on the safety relevance or operational impact of the non-conformance, remedial action is initiated immediately or the problem is transferred for further evaluation to the event investigation team or a technical division.

Having decided what remedies are appropriate, responsibility for implementation is assigned to a division. The final details must be reported to the safety review committee and the resultant operating experience is used to inform future plant improvement programmes.

The CEOs of all NPPs monitor the exchange of operating experience between Swiss NPPs. This CEO group is supported by several working groups who deal with issues such as training, nuclear safety performance, ageing surveillance, management systems, radiological and chemical plant performance, fire services and industrial safety.

Each NPP has a process for dealing with external operating experience, which screens and evaluates information on external events. Depending on their significance and applicability to an individual plant, the information is evaluated in detail and modifications are implemented as necessary. The Inspectorate periodically inspects this process. Furthermore, plants must provide a monthly report to the Inspectorate with information on external events evaluated in detail. Important sources of external information are the World Association of Nuclear Operators (WANO), the Plant Owners' Group, the Incident Reporting System (IRS) of IAEA and NEA and the Association of Power and Heat Generating Utilities in Germany. Specialist groups of experts from Swiss NPPs meet periodically to exchange operational experience, information from abroad and exchange detailed information on recent events in their own plants.

The Ordinance on the Methodology and Boundary Conditions for the Evaluation of the Criteria for the Provisional Taking-out-of-Service of Nuclear Power Plants ensures on the one hand plant specific analysis for all internal events rated INES 1 and above in Swiss NPPs and on the other hand surveys of reported events in NPPs from all over the world rated INES 2 and above.

The Inspectorate has its own process for assessing events in nuclear installations in other countries. If the Inspectorate's assessment indicates potential for safety improvements at Swiss NPPs, the plants are required to analyse the situation in their own installation and take appropriate action. The IRS is the main source of information for the Inspectorate. The Inspectorate has been a member of IRS since it was founded in 1980. Members prepare reports on safety issues of relevance to the nuclear community, attend, and organise meetings and workshops on important safety issues. The Inspectorate sends delegates from amongst its own staff to the OECD/NEA/CSNI «Working Group on Operational Experience» (WGOE) and to the «Working Group on Human and Organisational Factors» (WGHOF).

The Inspectorate obtains other important information from IRS reports, NRC information letters and bilateral contacts (e.g. safety commissions) with its neighbours France and Germany.

The following are some examples of Swiss events reported to the IRS:

- Significant rise in core damage frequency due to unavailability of both the Beznau NPP Unit 1 emergency diesel generator and the offsite power source;
- Exposure of two workers to doses in excess of the statutory annual limit at Beznau NPP Unit 2;
- Exposure of a worker in excess of the statutory annual dose limits at Leibstadt NPP;
- Failure of shafts of primary service water pumps at Beznau NPP Unit 1 and 2
- Damage to the steel primary containment in the Leibstadt NPP

The following are some examples of information on operational experience from abroad that resulted in major modifications at Swiss NPPs:

- Based on the Generic Letter 89-10 of the US-NRC, the Inspectorate required all Swiss licensees to re-evaluate the functional analysis of motor-operated valves in safety related systems. Consequently, all Swiss NPPs modified certain gate valves.
- Following the incident at Barsebäck 2 (Sweden) on 28 July 1992 involving clogging of the suction-line strainers in the suppression pool, the Inspectorate initiated a programme of short-term measures

designed to resolve the problem in all NPPs. The short-term measures included inspections, a detailed review of the types of thermal insulation in use, a clogging analysis of strainers and the preparation of accident management measures in BWR plants. This resulted in the replacement of all suction strainers in the emergency core cooling system of BWRs (Mühleberg and Leibstadt) during their outage periods in 1993. In the new equipment, the strainer area was much larger. For the PWRs, backfitting was not considered necessary at the time and a reassessment of the issue in the light of recent results from French and NRC research showed that the design of PWR suction strainers is still appropriate. However, one licensee has installed new state-of-the-art cassette-type suction strainers in order to improve safety and allow greater flexibility in the type of thermal insulation material used in the containment.

- Two hydrogen explosions occurred in European and Japanese BWRs at the end of 2001, resulting in ruptured pipes. This is a known phenomenon and had been the subject of previous assessments; following those two events, the two BWRs in Switzerland were required to re-evaluate the earlier assessments. This resulted in immediate improvements to procedures (e.g. filling empty pipes with water). Minor hardware modifications (e.g. improved insulation, installation of thermocouples) were made during the annual outage. The investigations were then completed but because of differences in the BWR design in Switzerland, it was not considered necessary to undertake hardware modifications or consider a new design basis accident.
- The reactor vessel head corrosion event at the Davis Besse NPP (USA) in 2002 generated considerable attention in the nuclear community. In this event, a significant amount of boric acid corrosion was detected caused by leakage from cracks in the control-rod nozzles. Both Swiss operators and the Inspectorate had previous experience of this phenomenon and so were already vigilant. A small head corrosion event caused by leakage had occurred in Switzerland in the early 1970s, and 5 years before the above US event, cracks had been found and reported in the control nozzles of US plants. The Inspectorate had used this previous experience to strengthen the requirements for the periodic surveillance by plant operators of nozzle cracks and leakage control. Therefore, the Davis Besse event did not necessitate any additional action.
- The incident at Forsmark 1 NPP (Sweden) on 25 July 2006 also led to major investigations by the Inspectorate. The Inspectorate checked in detail aspects identified as being significant to the sequence of events. All Swiss NPPs carried out a comprehensive check of the technical and organisational measures used to deal with the consequences of a similar type of event. The investigation results were published in a separate report and this is available on the Inspectorate's website. The investigations did not identify any deficiencies in technical and organisational precautions by Swiss NPPs designed to protect plants from the effects of grid disturbances. Nevertheless, the Inspectorate recommended that NPPs intensify simulator training for scenarios involving loss of redundancy in safety or information systems and signals in the control room.
- The Fukushima accident triggered a series of actions taken by the Inspectorate with the goal of understanding the event sequence, its causes and to draw consequences for the safety of Swiss NPPs. The Swiss National Report for the CNS Second Extraordinary Meeting contains more details on lessons identified, analyses performed and measures adopted. The Inspectorate has chosen a stepwise response approach to the Fukushima accident, to allow the incorporation of possible new lessons as soon as they become available from further accident investigations, which are still in progress in Japan. In spite of insights gained from the national response approach and European approach (EU stress test), which confirmed a high safety standard for Swiss NPPs, areas of further improvement were identified. Essential topics to be addressed by the licensees have been protection against earthquakes and flooding, the design of spent fuel pools, the availability of the ultimate heat sink and the availability of accident management equipment from offsite locations. Details are given in Articles 16 and 18.

The Annual Report of the Inspectorate includes information on the use made of information from external operating experience. Special attention is given to analyses and plant modifications performed in response to the Fukushima accident.

Clause 8: Each Contracting Party shall take the appropriate steps to ensure that the generation of radioactive waste resulting from the operation of a nuclear installation is kept to the minimum practicable for the process concerned, both in activity and in volume, and that any necessary treatment and storage of spent fuel and waste directly related to the operation and on the same site as that of the nuclear installation take into consideration conditioning and disposal.

The Nuclear Energy Act includes the principle that the generator of radioactive waste is responsible for its safe management until disposal. Before an NPP is licensed, it must demonstrate that the waste generated by the facility can be safely and permanently managed and disposed of. The Radiological Protection Act and the Radiological Protection Ordinance stipulate that the volume of radioactive waste produced must be kept to the minimum possible. Under the Nuclear Energy Act, radioactive waste originating in Switzerland must be disposed of in Switzerland.

To ensure compliance with legal requirements during the licensing phase, plans for nuclear installations are subject to a critical review by nuclear safety authorities. During the construction and the operation of such installations, the Inspectorate's supervisory activities ensure compliance.

Each NPP stores the spent fuel discharged from the reactor on site for several years. The Nuclear Energy Act prohibited the reprocessing of spent nuclear fuel for a period of ten years starting on 1 July 2006. This moratorium has been prolonged for another 10 years and a permanent ban on reprocessing is part of the pending revision of the Swiss Nuclear Energy Act. In the past, NPP operators had signed contracts with foreign companies for the reprocessing of some 1,139 tonnes of spent fuel. All spent fuel covered by these contacts had been shipped abroad by June 2006 and has finally been reprocessed.

The return of waste from foreign reprocessing facilities to the Central Interim Storage Facility started in 2002 and is proceeding on schedule. By the end of 2015 substantial progress had been achieved by both contractors, AREVA NC in La Hague (F) as well as Sellafield Ltd. (UK) in respect of all waste streams subject to return. Last shipments are expected by the end of 2016 when no further obligations for waste return to Switzerland will remain.

All separated Pu-products from reprocessing of Swiss fuel elements have also been repatriated in the form of MOX-fuel elements, all of which have already been reused in the PWRs at the Beznau and the Gösgen sites. Even a part of the attributed U-products has already been reused in form of U (rep) oxide-fuel elements in Swiss reactors.

Since July 2006, any spent fuel from the Mühleberg NPP and Leibstadt is transported to the Central Interim Storage Facility and stored in dry dual-purpose casks (DPC). Beznau NPP operates its own dry storage facility on site, whereas the Gösgen NPP started on site operation of a separate wet storage facility for spent fuel in May 2008. However even KKG will have to transfer spent fuel elements into DPC in the late 20s due to a licensing condition of the wet storage facility.

Any operational waste from the NPPs is collected and segregated. Waste with such low activity levels that it can be exempted from regulatory control is cleared for re-use or conventional disposal under the supervision of the Inspectorate. The conditions required for clearance are included in Annex 2 of the Radiological Protection Ordinance. The associated procedures are detailed in the regulatory guide ENSI-B04 that is equally applicable to any other (institutional) radioactive waste in Switzerland.

Radioactive waste in the form of resins, sludges or activated components is conditioned as soon as practicable on site at the NPPs. Incinerable waste, however, is conditioned externally at the Central Interim Storage Facility (ZZL), which successfully operates the world's first plasma incinerator for radioactive waste. This facility accepts any waste, which previously used to be super-compacted or otherwise treated in incinerators applying «conventional» incineration techniques at the Paul Scherrer Institute, a facility now waiting for decommissioning. ZZL also provides services for decontamination, segregation, handling of bulky items and, since quite recently, processing of radioactive waste containing asbestos.

According to the Nuclear Energy Ordinance, any procedure for the conditioning of radioactive waste must be approved by the Inspectorate. Approval is only granted if waste products comply with accepted storage criteria, meet the requirements of NAGRA, the disposal-planning organisation and can be transported in compliance with the regulations on the transport of hazardous goods. Detailed requirements for such waste type qualification are documented in the regulatory guide ENSI-B05. The utilities have continuously redocumented and where necessary also reconditioned «historic» waste packages which had originally been conditioned for sea dumping but remained in Switzerland after the stop on this disposal technique. All waste packages are included in a nationwide registration and documentation system by NAGRA and controlled by an independent register at ENSI. This applies also to the PSI research institute in charge of the central waste collection facility for institutional waste.

Specific requirements for interim storage facilities and their operation are detailed in the regulatory guide ENSI-G04, which replaced the previous HSK-R29. ENSI-G04 covers all safety reference levels (SRL) of the WENRA storage report identified as «missing» in the Swiss regulations during the WENRA benchmarking exercise. In February 2013, the working group on waste and decommissioning of WENRA concluded that Switzerland had successfully carried out its national action plan on WENRA waste-SRLs. Current inspections in interim storage facilities confirmed the compliance of operators with the new requirements, especially those asking for monitoring and inspection programmes for stored items to confirm the continuous compliance with acceptance criteria of interim and final storage as well as transportation in between.

Up to date regulatory guides of ENSI in addition to the respective Articles of NEA and NEO comprehensively cover all predisposal aspects of the Swiss national waste management system.

OSART Mission to Switzerland

At the request of the government of Switzerland, an IAEA Operational Safety Review Team (OSART) reviewed the following areas of Mühleberg NPP operation:

- management
- organisation and administration
- training and qualification
- operations
- maintenance
- technical support
- operating experience feedback
- radiation protection
- chemistry
- emergency planning and preparedness

In addition to this full scope OSART review programme, the areas

- long-term operation
- severe accident management

were also covered by special request.

The OSART mission took place from 8–25 October 2012. International experts from Belgium, Czech Republic, Finland, Germany, Hungary, Slovakia, Sweden, United Kingdom, United States of America together with IAEA staff members visited the Mühleberg NPP. The OSART team studied plant specific information, reviewed programmes and procedures; observed work performed and held in-depth discussions with plant personnel counterparts. The findings were recorded in the mission report (NSNI/OSART/012/170). The report was derestricted in January 2013.

The OSART team found several areas of good performance, including the following:

- strategy to manage the core shroud cracking issue and allow long-term operation
- preserving and transferring of knowledge
- response to recent significant external operating experience (OE) events
- support for industry efforts to improve fuel design and monitoring practices

The team offered a number of proposals for improvements. Among the most significant proposals are the following:

- provision of all reasonable protection for persons on the site in an emergency with radioactive release to avoid any unjustified health risks
- use OE throughout the plant in day-to-day activities and ensure timely corrective actions
- reinforce the work-control and risk assessment system with the use of radiation work permits
- improvement of the means for an independent nuclear oversight with a continuous review of safety performance at the NPP

A follow up mission was conducted in 2014 by the IAEA to review the implementation of the proposed 21 improvements. 11 issues were fully resolved and 10 were progressing satisfactorily.

Developments and Conclusion

Switzerland complies with the obligations of Article 19.

Outlook

ENSI will continue to support the efforts to harmonize safety requirements on the European and international level within the IAEA and the Western European Nuclear Regulators Association WENRA. The aim of ENSI has always been to provide regulatory guidelines that are both compatible with IAEA Safety Standards and harmonised with the safety requirements of WENRA. Moreover, ENSI is committed to exceed international standards.

In the next reporting period, ENSI will have to address the following challenges:

Long Time Operation: Three of Switzerland's NPPs have been operating for more than 40 years. As a result, the regulatory activities for these plants will need to focus more on the specific issues arising from long-term operation. Swiss law does not specify any restriction on the period of operation; nuclear power plants can be operated as long as they are safe. For this reason, the assessment of safety is accorded high priority. There is a requirement for systematic annual safety assessments and a comprehensive Periodic Safety Review (PSR) every 10 years.

Decommissioning of Mühleberg NPP: In 2013, the owner of the Mühleberg NPP, BKW Energie LTD., decided to shut down the plant at the end of 2019. Provisions to increase the safety of the plant during the remaining time of operation have been decreed by ENSI (see Article 18). On 18 December 2015, BKW submitted a formal application for the decommissioning order according to Article 28 of the Nuclear Energy Act to DETEC. Planned shutdown is on 20 December 2019.

Flaw Indications in Beznau NPP: While carrying out ultrasonic measurements of the reactor pressure vessel (RPV) of Beznau NPP 1 in 2015, the operator detected flaw indications that require evaluation. The unit is currently in outage while the operator is analysing the flaws. As soon as the operator submits the documents on the characterisation and evaluation of the findings completing the safety case, ENSI will examine these and prepare an opinion report on the safety evaluation of the structural integrity of the Beznau 1 reactor pressure vessel. ENSI will include the opinion of a group of international experts in its assessment of the safety case. For this reason, upon notification of the indications in the Beznau 1 RPV, ENSI decided to call together an International Review Panel with recognised international experts possessing in-depth knowledge in such areas as the safety case of RPV integrity, materials testing, large forging fabrication and non-destructive testing methods.

Post-Fukushima Actions: ENSI undertook a series of actions to understand the event sequence in Fukushima Daiichi and its causes. The knowledge obtained from analysing the events of the accident at Fukushima Daiichi was reviewed to determine its applicability to Switzerland, and a summary of insights was compiled in an ENSI report entitled «Lessons Learned» in the form of a series of checkpoints. Further points were added on completion of the analyses for the EU stress tests. The processing and implementation of the identified points were updated annually in the Fukushima Daiichi Action Plan. Most of the identified checkpoints were implemented by the end of 2015. As of March 2016, there are seven open backfitting measures identified by the ENSI Fukushima Daiichi Action Plan that are currently being implemented and will be finished during the coming review cycle.

Nuclear Phase-Out: The commitment by the Swiss government to a nuclear phase-out will create further challenges to ENSI's supervisory activities, as the schedule for the nuclear phase-out will depend on the outcome of various parliamentary decisions and maybe national referenda. As a result, ENSI will have to adapt its planned activities along with the outcome of these decisions.

Deep Geological Repository: The process to select a site for the disposal of radioactive waste in deep geological formations in Switzerland is continuing. Nagra, Switzerland's National Cooperative for the Disposal of Radioactive Waste will finish the identification of at least two sites each for the HLW and L/ILW repository in the next reporting period and start phase 3 in the site selection process by 2018, during which the selected sites will be subject to further investigations and safety analyses. The site selection process is currently expected to be finished by 2028 and will end with the approval by the Federal Council of the selected sites. A deep geological repository for low and intermediate level radioactive waste is expected to be ready for operation in 2050 at the earliest, and a repository for high-level waste in 2060. (For further details, please refer to the Fifth Swiss National Report of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management[14]). ENSI will continue to refine its Integrated Oversight Strategy in response to the increase in tasks to be undertaken by the regulatory body and the complexity of the oversight required for the long-term operation of existing NPPs and the nuclear phase-out challenges. This will ensure that ENSI maintains a comprehensive view of the safety of each installation and can recognise signs of deteriorating performance as early as possible. It will also enable ENSI to focus its resources on issues of relevance to safety. In the end, ENSI's fundamental strategic objective is to ensure that the conditions required for the safety of operating plants exist despite the additional workload arising from the aforementioned challenges.

[14] http://www.ensi.ch/de/wp-content/uploads/sites/2/2014/10/joint_convention_05_2014_ensi.pdf

Appendix 1: List of Abbreviations

AC	Alternate Current
ADAM	Accident Diagnostics, Analysis and Management system
ALARA	As Low As Reasonably Achievable
AM	Accident Management
AMP	Ageing Management Programme
ANPA	Data system for plant parameters (Anlageparameter)
ASME	American Society of Mechanical Engineers
AUTANOVE	Autarkic Emergency Power Supply (Autarke Notstromversorgung, Project at the Beznau NPP)
BBC	Brown, Boveri & Cie
BDBA	Beyond-Design-Basis Accidents
BKW	Bernische Kraftwerke
BWR	Boiling Water Reactor
BWROG	Boiling Water Reactor Owners Group
CDF	Core Damage Frequency
CEO	Chief Executive Officer
CET	Core Exit Temperature
CHF	Swiss Franks
CNS	Convention on Nuclear Safety
CSNI	Committee on the Safety of Nuclear Installations (OECD-NEA)
DBA	Design-Basis Accidents
DBE	Design Basis Earthquake
DBF	Design Basis Flood
DC	Direct Current
DEC	Design Extension Conditions
DETEC (UVEK)	Department of Environment, Transport, Energy and Communication (Eidgenössisches Departement für Umwelt, Verkehr, Energie und Kommunikation)
DIWANAS	Diversitäre Wärmesenke und Nachwärmeabfuhr-System (Project at the Mühleberg NPP)
DPC	Dual-purpose casks
DSSA	Deterministic Safety Status Analysis
ECCS	Emergency Core Cooling System
ECURIE	European Community Urgent Radiological Information Exchange
ENSI	Swiss Federal Nuclear Safety Inspectorate ENSI (Eidgenössisches Nuklearsicherheitsinspektorat)
ENSREG	European Nuclear Safety Regulatory Group
EOP	Emergency Operating Procedures
ERO	Emergency Response Organisation
ETH	Swiss Federal Institute of Technology

EU	European Union
EURATOM	European Atomic Energy Community
FCVS	Filtered Containment Venting System
FMB NBCN	Federal Nuclear, Biological, Chemical and Natural Crisis Management Board
FN (AN)	File Note (Aktennotiz)
FOCP	Federal Office of Civil Protection
FOEN	Federal Office for the Environment
FOPH	Federal Office of Public Health
GDC	General Design Criteria
GE	General Electric
HEPA	High Efficiency Particle Arrestor
HERCA	Heads of European Radiological protection Competent Authorities Association
HLW	High-Level Waste
HOF	Human and Organisational Factors
HPP	Hydro(electric) Power Plant
HSK	Hauptabteilung für die Sicherheit der Kernanlagen (precursor of ENSI)
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
IDA-NOMEX	Interdepartmental Working Group to Review Emergency Protection Measures in case of Extreme Events in Switzerland (Interdepartementale Arbeitsgruppe zur Überprüfung der Notfallschutzmassnahmen bei Extremereignissen in der Schweiz)
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
INES	International Nuclear and Radiological Event Scale
INEX	International Emergency Exercise
IRRS	Integrated Regulatory Review Service
IRRT	Integrated Regulatory Review Team (precursor of IRRS)
IRS	International Reporting System for Operating Experience
ISO	International Standards Organisation
ISOE	Information System on Occupational Exposure
JRODOS	Java-based Real-time Online Decision Support system
KKB	Nuclear Power Plant Beznau (Kernkraftwerk Beznau)
KKG	Nuclear Power Plant Gösgen (Kernkraftwerk Gösgen)
KKL	Nuclear Power Plant Leibstadt (Kernkraftwerk Leibstadt)
KKM	Nuclear Power Plant Mühleberg (Kernkraftwerk Mühleberg)
KPMG	Klynveld, Peat, Marwick und Goerdeler (Swiss auditor)
KWU	Kraftwerk Union AG
L/ILW	Low-Level and Intermediate-Level Waste

LASAT	Lagrangian Simulation of Aerosol-Transport
LCO	Limiting Conditions for Operation
LOCA	Loss Of Cooling Accident
LTO	Long-Term Operation
LWR	Light Water Reactor
MADUK	Measurement network in the vicinity of NPPs (Messnetz zur automatischen Dosisleistungsüberwachung in der Umgebung der Kernkraftwerke)
MCR	Main Control Room
Nagra	National Cooperative for the Disposal of Radioactive Waste (Nationale Genossenschaft für die Lagerung radioaktiver Abfälle)
NBC	Nuclear, Biological and Chemical
NBCN	Nuclear, Biological, Chemical and Natural
NEA	Nuclear Energy Agency of the OECD
NEO	Nuclear Energy Ordinance
NEOC	National Emergency Operations Centre (Nationale Alarmzentrale NAZ)
NEWS	Nuclear Events Web-based System
NGO	Non-Governmental Organisation
NPP	Nuclear Power Plant
NRC	U.S. Nuclear Regulatory Commission
NSC	Nuclear Safety Commission
OBE	Operating Basis Earthquake
OECD	Organisation for Economic Co-operation and Development
OHSAS	Occupational Health and Safety Assessment Series
OLNC	OnLine Noble Chemistry primary water operation mode
OSART	Operational Safety Review Teams (IAEA)
PC	Primary Circuit
PEGASOS	Probabilistic Earthquake Hazard Analysis for the Locations of the Nuclear Power Plants in Switzerland (Probabilistische Erdbebengefährdungsanalyse für die KKW-Standorte in der Schweiz)
PGA	Peak Ground Acceleration
PRP	PEGASOS Refinement Project
PSA	Probabilistic Safety Analysis
PSI	Paul Scherrer Institute (research institute)
PSR	Periodic Safety Review
PWR	Pressurised Water Reactor
QM	Quality Management
RCIC	Reactor Core Isolation Cooling
RHR	Residual Heat Removal
RPO	Radiological Protection Ordinance
RPV	Reactor Pressure Vessel
SAMG	Severe Accident Management Guidance
SAR	Safety Analysis Report

SBO	Station Blackout
SER	Safety Evaluation Report
SFOE	Swiss Federal Office of Energy
SFP	Spent Fuel Pool
SIA	Swiss Association of Engineers and Architects (Schweizerischer Ingenieur- und Architektenverein)
SQS	Swiss certification company (Schweizerische Vereinigung für Qualitäts- und Management-Systeme)
SRL	Safety Reference Levels (WENRA)
SSC	Structures, Systems, and Components
SSE	Safe Shutdown Earthquake
SSHAC	Senior Seismic Hazard Analysis Committee
SUSAN	Special emergency system of KKM (Selbstständiges, Unabhängiges System zur Abfuhr der Nachzerfallswärme)
Sv	Sievert
Total-SBO	Total Station Blackout
U.S. NRC	U.S. Nuclear Regulatory Commission
VDNS	Vienna Declaration on Nuclear Safety
W	Westinghouse
WANO	World Association of Nuclear Operators
WENRA	Western European Nuclear Regulators' Association
WGHOF	NEA Working Group on Human and Organisational Factors
WGIP	NEA Working Group on Inspection Practices
WGOE	NEA Working Group on Operating Experience
WOG	Westinghouse Owners Group
ZWILAG	Zwischenlager Würenlingen AG
ZZL	Zentrales Zwischenlager

Appendix 2: List of the Inspectorate's guidelines currently in force

Status: March 2016

Languages: All guidelines are originally published in German. Some guidelines have been translated into French and English.

Note:
- All guidelines are available on the ENSI website (www.ensi.ch).
- Guidelines of the series A cover the assessment of facilities, guidelines of the series B cover the surveillance of operations, and guidelines of the series G are guidelines with general requirements, which cover both, the assessment of facilities and surveillance of operations. Guidelines of the series R were issued before the Nuclear Energy Act and the Nuclear Energy Ordinance entered into force in February 2005
- The security guidelines are not listed.

Guideline	Title of guideline	Date of current issue
ENSI-G01	Safety classification for existing nuclear power plants	2011/01
ENSI-G03	Specific design principles for deep geological repositories and requirements for the safety case	2009/04
ENSI-G04	Design and operation of storage facilities for radioactive waste and spent fuel assemblies	2015/06
ENSI-G05	Transport and storage casks for interim storage	2008/04
ENSI-G07	The organisation of nuclear installations	2013/07
ENSI-G08	Systematic safety evaluations of the operation of nuclear installations	2015/06
ENSI-G09	Operational documentation	2014/06
ENSI-G11	Vessels and piping classified as important to safety: Engineering, manufacture and installation	2013/06
ENSI-G13	Radiation protection measuring devices in nuclear installations: Concepts, requirements and testing	2015/10
ENSI-G14	Calculation of radiation exposure in the vicinity due to emission of radioactive substances from nuclear installations	2009/12
ENSI-G15	Radiation protection objectives for nuclear installations	2010/11
ENSI-G17	Decommissioning of nuclear installations	2014/04
ENSI-G20	Reactor core, fuel assemblies and control assemblies: Design and operation	2015/01
ENSI-A01	Requirements for deterministic accident analysis for nuclear installations: Scope, methodology and boundary conditions of the technical accident analysis	2009/07
ENSI-A03	Periodic Safety Review of nuclear power plants	2014/10
ENSI-A04	Application documents for modifications to nuclear installations requiring a permit	2009/09
ENSI-A05	Probabilistic Safety Analysis (PSA): Quality and scope	2009/01
ENSI-A06	Probabilistic Safety Analysis (PSA): Applications	2015/11
ENSI-A08	Analysis of source terms: Extent, methodology and boundary conditions	2010/02

Guideline	Title of guideline	Date of current issue
ENSI-B01	Ageing management	2011/08
ENSI-B02	Periodical reporting for nuclear installations	2015/06
ENSI-B03	Reports for nuclear installations	2012/03
ENSI-B04	Clearance measurement of materials and areas from controlled zones	2009/08
ENSI-B05	Requirements for the conditioning of radioactive waste	2007/02
ENSI-B06	Vessels and piping classified as important to safety: Maintenance	2013/06
ENSI-B07	Vessels and piping classified as important to safety: Qualification of non-destructive testing	2008/09
ENSI-B09	Collecting and reporting of doses of persons exposed to radiation	2011/07
ENSI-B10	Basic training, recurrent training and continuing education of personnel in nuclear installations	2010/10
ENSI-B11	Emergency exercises	2013/01
ENSI-B12	Emergency preparedness in nuclear installations	2015/10
ENSI-B13	Training and continuing education of the radiation protection personnel	2010/11
ENSI-B14	Maintenance of electrical and instrumentation and control equipment classified as important to safety	2010/12
HSK-R-4	Supervisory procedures for the construction of nuclear power plants, project engineering of structures	1990/12
HSK-R-7	Guideline for the radiological monitored area of the nuclear installations and the Paul Scherrer Institute	1995/06
HSK-R-8	Structural safety for nuclear power plants, Swiss Federal supervising procedures for construction work	1976/05
HSK-R-16	Seismic plant instrumentation	1980/02
HSK-R-30	Supervisory procedures for construction and operation of nuclear installations	1992/07
HSK-R-31	Supervisory procedures for construction and backfitting of nuclear power plants, 1E classified electrical equipment	2003/10
HSK-R-40	Filtered containment venting of light-water reactors, design requirements	1993/03
HSK-R-46	Requirements for the application of computer-based instrumentation and control important to safety in nuclear power plants	2005/04
HSK-R-50	Requirements important to safety for fire protection in nuclear installations	2003/03
HSK-R-101	Design criteria for safety systems of nuclear power plants with light-water reactors	1987/05
HSK-R-102	Design criteria for the protection of safety equipment in nuclear power stations against the consequences of airplane crash	1986/12
HSK-R-103	On-site measures against the consequences of severe accidents	1989/11

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Swiss Federal Nuclear Safety Inspectorate ENSI
Industriestrasse 19
CH-5200 Brugg
Phone: +41 56 460 84 00
info@ensi.ch

www.ensi.ch
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ENSI, CH-5200 Brugg, Industriestrasse 19, Telefon +41 (0)56 460 84 00, www.ensi.ch