CONVENTION ON NUCLEAR SAFETY 2022

Switzerland's ninth National Report on Compliance with the Obligations of the Convention on Nuclear Safety

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July 2022

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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 National Reports for the regular Review Meetings of Contracting Parties organised in 1999, 2002, 2005, 2008, 2011, 2014, 2017, 2020 (which was cancelled due to the COVID pandemic) 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 ninth 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 takes into account issues and trends in nuclear safety, such as those identified by the Contracting Parties at the seventh 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 deep 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 2022. The numbering of the following 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 on in a separate chapter. Furthermore, a subchapter of the Summary and Conclusion gives answers to the challenges identified by the Seventh 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 almost 8.7 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 27 % 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 therefore retain 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 2020, Gross Domestic Product in Switzerland per capita was approximately CHF 81,800 (EUR 78,500). The most important industries economically are banking, insurance, commodity trading, tourism, mechanical and electrical engineering, the chemical and pharmaceutical industry, and watchmaking. Its major export partners are Germany, USA, China, Italy, France, United Kingdom and Spain.

Total energy consumption in Switzerland was about 747,400 TJ in 2020. Electricity consumption accounts for about 27 % of energy consumption. The main sources of electricity in Switzerland are hydroelectric (2020: 58 %) and nuclear power (33 %).

Background to nuclear power in Switzerland

Until the late 1960s, Switzerland generated electricity exclusively from hydropower and did not resort to fossil fuels because the latter were not available as a natural resource in Switzerland. By the mid-1950s, there was interest in using 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 per se. During the 1960s, a series of projects for NPPs were initiated and four of them were realised. This resulted in a total of five units, which were commissioned between 1969 and 1984. Several other projects were cancelled. On 20 December 2019, one of the five units, Mühleberg NPP, was permanently shut down (for more information, see Article 6).

Licensing procedures for three new units at existing sites were in progress 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 in relation 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 were to continue operating for as long as they could safely do so.

On 21 May 2017 there was a referendum on the government's Energy Strategy 2050, which was approved by a 58 % majority, with a voter turnout of 42 %. This strategy includes a provision for the gradual withdrawal from nuclear power and a greater reliance on hydro and intermittent renewables. No construction licences are to be issued for new nuclear power reactors.

In May 2016 a people's initiative calling for Swiss nuclear power plants to be shut down after no more than 45 years of operation was rejected by the Swiss voters. This means that the four operating reactors in Switzerland will be allowed to remain in operation for as long as ENSI considers them safe.

The regulatory authority

The first experimental nuclear reactor started operation in Switzerland in 1957. At this time there was no regulatory authority 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, which was established 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 – passed in 2007 – created a statutory framework to make 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. Its members have specialist knowledge of nuclear safety as well as management experience and are elected by the Federal Council for a maximum of two four-year terms. The Board consists of five to seven Members and reports directly to the Federal Council.

Nuclear power plants

Switzerland has three NPPs with four units in commercial operation – Beznau (including Beznau I and II), Gösgen and Leibstadt. They are located on three different sites and have three different reactor and containment designs provided by three different reactor suppliers (Westinghouse, Kraftwerk Union and General Electric). Local suppliers

Table 1: Main technical characteristics of the Swiss NPPs (as of March 2022)

	First generation NPPs			Second generation NPPs	
	Beznau I	**Beznau II**	**Mühleberg**	**Gösgen**	**Leibstadt**
Status	In operation	In operation	In permanent shut-down since December 2019	In operation	In operation
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:

PWR Pressurised Water Reactor

BWR Boiling Water Reactor

W Westinghouse Electric Corporation

KWU Siemens Kraftwerk Union AG (now Areva NP)

BBC Brown Boveri & Cie, AG (now Alstom)

UO_2 Uranium oxide

ECCS Emergency core cooling system

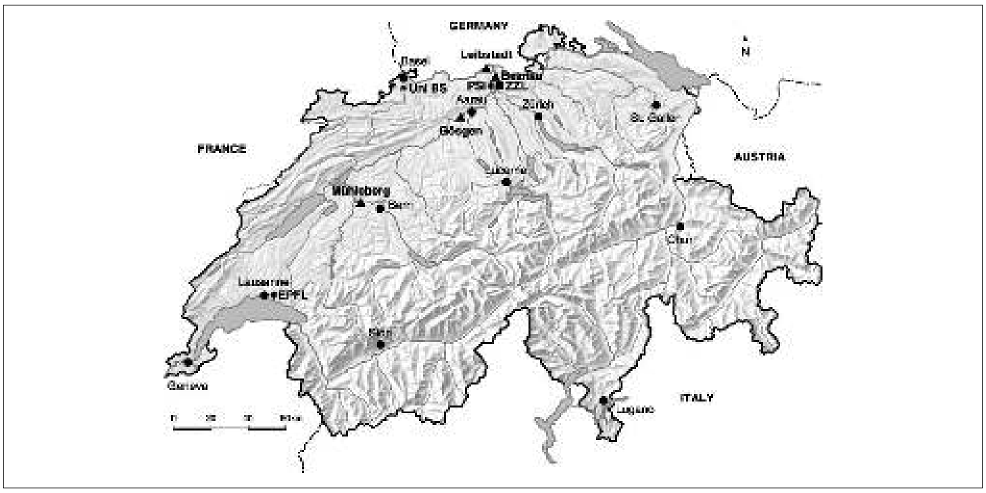

Figure 1: Geographic location of Swiss nuclear facilities. Triangles mark the NPP sites. Asterisks mark experimental and research installations. Squares mark facilities for nuclear waste management. The dots are major cities.

contributed to civil engineering, buildings and mechanical and electrical engineering equipment. One NPP, Mühleberg, was permanently shut-down in December 2019 and is currently undergoing decommissioning. The Beznau NPP is operated by Axpo Power AG, the Gösgen NPP by Kernkraftwerk Gösgen-Däniken AG, and the Leibstadt NPP by Kernkraftwerk Leibstadt AG.

Due to Switzerland's mountainous landscape, the number of suitable sites for NPPs is limited. Two sites are located near to 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.

Facilities for nuclear education, research and development

The Paul Scherrer Institute (PSI) is the largest research institute for natural and engineering sciences in Switzerland, conducting cutting-edge research in three main fields: matter and materials science, energy and environment, and human health. PSI develops, builds and operates complex large research facilities. It is part of the Domain of the Swiss Federal Institutes of Technology.

There are four installations at PSI that can be considered as nuclear research infrastructure: the former research reactors DIORIT, SAPHIR, and PROTEUS, which are in various stages of decommissioning, and the Hot Laboratory, where nuclear research still takes place.

Apart from the above-mentioned former research reactors at PSI, there are two small teaching reactors (P < 2 kWth) at the University of Basel and at the Swiss Federal Institute of Technology in Lausanne. The reactor in Basel was shut down permanently in late 2013. In 2015, the remaining highly enriched uranium from the reactor was sent back to the USA. The University of Basel submitted the decommissioning project for review in February 2017. Based on ENSI's assessment of April 2018, DETEC issued the decommissioning order in February 2019. Dismantling of the facility began in June 2019 and was completed in December 2019. The zero-power (100 W) teaching reactor in Lausanne is the only research reactor still in operation in Switzerland.

Processing and interim storage of nuclear waste

According to Swiss legislation, radioactive waste must be conditioned as quickly as possible. The collection of non-conditioned waste for the purpose of carrying out periodical conditioning campaigns is permitted. 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 operations 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 facilities 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 deep geological repositories

The site selection process in Switzerland is described in detail in the seventh National Report of Switzerland in accordance with the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (pages 12–17).
The third and final stage of the site selection process for deep geological repositories for radioactive waste started in December 2018. In stage 2, three geological siting areas (Jura Ost, Nördlich Lägern, Zürich Nordost) were selected for further investigations for either two separate deep geological repositories, one for low- and intermediate-level waste (LILW) and one for high-level waste (HLW) and spent fuel (SF) or, as an alternative option, a combined disposal facility for LLW, ILW and HLW/SF in the same siting area.
Already during the winters of 2015/2016 and 2016/2017, the Swiss implementer responsible for deep geological disposal, Nagra, initiated 3D-seismic, i.e. non-destructive, investigations in all proposed siting areas. In addition to the seismic investigations, Nagra submitted licence applications for the drilling of boreholes covering a depth range between 800 and 1400 m and therefore penetrating the future host rock and the confining units. Drilling locations were mostly placed around the proposed disposal perimeters. Drilling operations started in 2019 and were completed early in 2022, after the deepening of nine boreholes, two to four in each of the siting areas. In addition to these deep boreholes, Nagra also drilled a total of 15 shallow boreholes into and realised several seismic lines along and across former glacial valleys to investigate the erosional history of the landscape in and around the siting areas during the last few million years. The processing and interpretation of the gathered site-specific data is ongoing.
According to current planning, Nagra will announce the site for which it will prepare the general licence application in September 2022. Originally, Nagra planned to build the encapsulation plant at the surface infrastructure facility for the deep geological repository. Some of the affected siting regions and cantons pushed towards a discussion of this subject, which lead to the evaluation of other options. As a result, the encapsulation plant may also be placed at the existing central interim storage facility. The announcement planned for September 2022 will include this issue as well. The general licence application for a combined repository (including any surface infrastructure facilities) will be submitted by the end of 2024 by Nagra. After the review by the national safety authority, ENSI, and the Federal Nuclear Safety Commission (NSC) and a public consultation, it is expected that the Swiss Government will make a final decision on the general licence in 2029, completed by the approval of the parliament. . A national vote may take place in 2031, if a sufficient number of signatures will be collected.

Summary and Conclusions

On 21 May 2017 the Swiss electorate accepted the revised Federal Energy Act which prohibits the construction of new nuclear power plants. The 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 the safety assessment of the different stages in the lifetime of nuclear installations consist of periodic assessments, and assessments of long-term operation of existing Swiss NPPs. Assessments of long-term operation (LTO) have been performed for two Swiss NPPs which have been in commercial operation for more than 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 Gösgen NPP) within the next 10 years. Nevertheless, the mandatory scheduled ageing management, maintenance and backfitting activities must be continued.

Shutdown of Mühleberg NPP

In late 2013, BKW Energy Ltd announced that Mühleberg NPP would be decommissioned at the end of 2019. The single 373 MWe boiling water reactor began operating in 1972. The plant was shut down on 20 December 2019 and BKW Energy Ltd started dismantling activities on 6 January 2020. Other than the experimental plant of Lucens, it will be the first Swiss nuclear power plant to be decommissioned. Decommissioning is expected to be completed within 11 years, by 2030. More information in Article 6.

International peer reviews and cooperation

Switzerland hosted an IRRS Mission in 2021 which confirmed ENSI to be a mature, competent and independent regulatory authority. The IRRS team identified seven recommendations and 13 suggestions for improvement. One of the main challenges identified, was the maintaining and building competence of the parties responsible for safety in the long term, particularly against the backdrop of the phasing out of nuclear energy. The Swiss government should evaluate the need for specialist knowledge and take measures to ensure the safety of operating nuclear installations, decommissioned nuclear installations and the deep geological storage of radioactive waste.

Further improvement suggestions addressed to the Federal Government:

- Set up legal provisions that also allow prosecution of a licence holder instead of an individual,
- Establish a binding obligation for the authorised parties to inform the public about safety-relevant occurrences associated with the operation of their facilities, and
- Create a legal basis to ensure that all nuclear facilities will be subject to periodic safety reviews in accordance with a graded approach.

Improvement suggestions directed at ENSI:

- Update the enforcement procedures for clarifying the roles of inspectors in the enforcement process,
- Further harmonisation of ENSI's regulatory guides with the IAEA safety standards, and
- Further revision of the management system.

The IRRS team also highlighted ENSI's continuously developed and improved safety culture as a good practice. A second good practice identified is the manner in which

ENSI promotes the safety culture of the licence holders by holding periodic dialogues in the format of focus groups with the senior leadership teams and safety culture specialists of the NPP licence holders.

In addition, the following areas where identified as areas of good performance:

- The role of ENSI in implementing the regulatory policy and the associated requirements for continued safety improvement at nuclear power plants,
- The anticipated dialogue and collaboration amongst all federal and cantonal authorities involved in the licensing process of nuclear facilities, and
- The periodic personal security background tests for ENSI's staff, including evaluation of possible lack of impartiality.

ENSI will address the suggestions for improvement from the IRRS Mission in conjunction with the authorities concerned. In the coming years, the IAEA will undertake a follow-up mission to obtain an overview of developments. The final report is available on ENSI's website.[1]
Furthermore, Switzerland also voluntarily participated in the EU Stress Tests and the 2017 European Topical Peer Review (TPR) on Ageing Management. Switzerland also confirmed its voluntary full participation in the 2023–2024 Second TPR. An IPPAS mission was conducted in Switzerland in 2018. The IPPAS Follow-up Mission in Switzerland will be held in 2023.

Safety and oversight culture

ENSI has continued its effort to oversee human and organisational factors during plant modernisation projects, and by event analysis and has implemented specialist discussions on safety culture issues to establish a platform where the licence holders can reflect on safety culture topics previously set by ENSI. In 2021, a specialist discussion on the topic "Leadership in a resilient organisation" was held. The specialist discussion on safety culture was rated as a good practice by the 2021 IRRS mission.
In 2020 ENSI began to revise the guideline "Organisation of Nuclear Power Installations" (ENSI-G07) which specifies the organisational requirements stated in the Nuclear Energy Ordinance. The revised guideline will meet the requirements of the IAEA (i.e. GSR Part 2) as well as several WENRA reference levels and will consider a new safety concept, namely "Organisational Resilience". ENSI has developed a mutual understanding of safety and security culture. Its approach to safety and security culture is based on an integrated understanding of the culture of a (nuclear) organisation. Nuclear safety and security both serve the same purpose of protecting people and the environment. Thus, ENSI explicitly refrains from distinguishing between safety and security culture in its oversight activities, although it does consider the specific requirements for security and nuclear safety. The themes of safety and security are considered under the generic term safety culture. The ENSI reports "Integrated Oversight"[2] and "Oversight of Safety Culture"[3] contain basic statements on the oversight culture of ENSI. The report "Integrated Oversight" is the result of the increasing systematisation of all oversight activities in recent years. The reports are available to the public.

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"

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[1] **https://www.ensi.ch/en/documents/report-of-the-integrated-regulatory-review-service-irrs-mission-to-switzerland/**
[2] **http://www.ensi.ch/en/documents/integrated-oversight/**
[3] **http://www.ensi.ch/en/documents/oversight-of-safety-culture-in-nuclear-installations/**

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 and published annually in the Fukushima Action Plan until February 2015. With the publication of the summary report containing all measures identified and implemented post-Fukushima at the end of 2016, Switzerland concluded its post-Fukushima Action Plan. Apart from the Action Plan, ENSI has further published a three-part series with a focus on "Fukushima Daiichi: Human and Organisational Factors". The third part of the series was published in 2021. The full reporting on the Swiss Fukushima activities can be found on the ENSI website[4].

[4] **https://www.ensi.ch/en/topic/fukushima-schweizer-kernkraftwerke/**

Response to the COVID-19 pandemic

Difficulties faced and measures taken due to the pandemic

Regulatory body

The Swiss Federal Nuclear Safety Inspectorate ENSI was fully operational at all times despite the unusual situation since the COVID-19 outbreak. Switzerland applied a three-part pandemic action model (normal situation, particular situation, and extraordinary situation) with varying degrees of mandated protection measures including mandatory working from home. Therefore, staff worked from home whenever possible, and meetings were primarily held by videoconferencing.

To protect its staff and keep ENSI functional, a "pandemic task force" was established, which monitored the situation and suggested protection measures and their eventual relaxation to the Executive Management Board. Most ENSI staff reported that, apart from occasional technical glitches, they were able to carry out their work from home office satisfactorily. Depending on the pandemic situation, a minimum of 15–20 % of ENSI staff were working in ENSI's offices. Staff reported that they missed social contact with colleagues and a lack of direct professional exchange.

Further measures such as the wearing of protective masks, hygiene measures, increased distances in meeting rooms, and the closing of recreation areas were implemented depending on the level of the pandemic action model.

Emergency preparedness exercises were conducted with a minimum number of staff and under strict protective measures.

In terms of inspections, ENSI considered video inspections and carried out a limited number of such inspections. The use of video inspections was judged to be of limited use and hence the majority of inspections was carried out on site with minimum number of ENSI staff. A limited number of non-safety relevant inspections were postponed from 2020 to 2021.

Licence holders

All active Swiss NPPs were fully operational during the pandemic. The relevant research facilities subject to the oversight of ENSI operated on a reduced daily business but never shut down entirely. The work to dismantle NPP Mühleberg was continued where possible and remained on schedule. All NPPs implemented pandemic plans early on to prevent infection from and between employees and consequently comply with the provisions specified by the Federal Council concerning social distancing and hygiene rules.

The pandemic plans contained measures to prevent contagion from and between employees and to maintain safe and reliable electricity production. The measures included, for example, "split operation" (half of the staff of a department works on site, the other half works from home), ban on holidays for all employees, reducing the number of meetings, and maintaining distancing during shift changeover. The measures were primarily aimed at ensuring that the minimum number of qualified personnel was maintained at any given time, as required by the operating regulations. This applied especially to licensed personnel (e.g. reactor operators), radiation protection personnel and plant security staff. At any given time, the NPP licence holders reported that sufficient personnel were available for safe operations.

The 2020 outages were heavily influenced by the start of the pandemic. Due to ambiguities about the handling of the pandemic, most NPPs decided to reduce the scope of tests and maintenance work, hence shortened outages resulted. Only non-safety relevant maintenance work was postponed. This procedure was assessed and approved by ENSI.

Response to the COVID-19 pandemic

Extensive measures, in addition to the standard measures such as the wearing of hygiene masks, distancing, and washing hands, were established to reduce the risk of a COVID-19 spreading in the NPP during the outages. This included the introduction of Corona-task forces, the introduction of time slots for breaks to prevent clustering, medical controls at the entrance to the premises, as well as mandatory visits to a doctor in order to access the site, and health self-declarations. NPP Beznau-1 flew in some essential personnel from abroad to carry out maintenance work. The workers were quarantined for two weeks before they started their work.

In 2021 all outages were carried out as planned, some of them extended due to a backlog of work from the previous year, and extensive back fitting took place in NPP Leibstadt.

All licence holders carried out emergency drills according to the legislation. Due to the circumstances, the scope of the emergency exercises was adapted and staff levels were reduced. Additionally, all licence holders submitted documentation on measures to guarantee emergency preparedness and response under the pandemic circumstances, for review.

Lessons learned

The sudden arrival of an unexpected pandemic demanded a high level of flexibility from the staff and flexibility in the scheduling of equipment use, especially in the IT-sector. Due to well trained staff and readily available equipment, the home work situation was managed well and no notable delays occurred in any sector.

During the pandemic it was realised that ENSI's previously written, theoretical pandemic plan, although not wrong, needed to be updated and made more suitable for real-life application. Furthermore, due to remote working, several internal processes had to be reviewed, such as the process regulating occupational health and safety, the risk analysis process, or the business continuity management process.

Another lesson learned was that not all sectors can carry out video-based inspections efficiently, at least not with the current equipment and organisation. Furthermore, the legal situation is unclear in respect of to what extent it is possible to stream live information from an NPP.

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

Challenges from the Seventh Review Meeting:

The following challenges were identified for Switzerland during the Sixth Review Meeting of the CNS:

Challenge 1: Open issues from the IRRS Follow Up Mission in 2015:

"The government should:

- strengthen ENSI's independent regulatory authority by giving ENSI the ability to issue binding technical safety requirements, licence conditions on nuclear safety, security and radiation protection
- and strengthen ENSI's position as the competent, technical authority, by having NSC provide their technical safety input to ENSI solely in an open and transparent manner."

Activity performed in this regard:

Addressing Challenge 1 would require an amendment of the Nuclear Energy Act. The strict implementation of the mentioned recommendations would imply the fundamental questioning of the Swiss system of nuclear oversight. This system of nuclear oversight, enshrined in the Nuclear Energy Act, is the result of a long and controversial political process and reflects peculiarities of the Swiss system of government. This topic was discussed in parliament and a report from the Swiss Federal Council was requested. The report concluded that both R6 of the 2011 IRRS mission and RF1 of the 2015 follow-up mission require a shift in competence from the licensing authority to ENSI. In the view of the Swiss Federal Council, implementation of this recommendation would result in a weakening of the role of both DETEC and the Nuclear Safety Commission (NSC). This would oppose the division of roles expressly intended by parliament. Moreover, it would interfere with the concept of plan approval procedures, which is prescribed not only in the NEA, but also in other infrastructure legislation. The Swiss Federal Council does not share the opinion of the IRRS mission that the existing legislation could lead to incorrect decisions in the area of nuclear safety. These concerns are sufficiently considered with the existing legislation and case law. In its report, the Swiss Federal Council thus advocated not to adopt recommendation RF1. As a result, the parliament agrees with the Swiss Federal Council's assessment not to adopt Recommendation RF1. Therefore, currently, the implementation of these recommendations will not be possible from a political perspective.

Based on the above argumentation, the Recommendation RF1 was not retained in the IRRS mission 2021.

Challenge 2: Finalizing the investigations concerning UT indications at Beznau RPV

Activity performed in this regard:

After completing an extended materials characterisation programme and a validation of the ultrasonic testing (UT) techniques, Beznau NPP submitted its final Safety Case for Beznau Unit I. Review of the UT validation and the Safety Case by ENSI and its international expert group (International Review Panel IRP) was completed early in 2018. The IRP and ENSI came to the conclusion that the UT indications are caused by agglomerates of alumina oxide inclusions, formed during manufacturing, which do not significantly affect the materials properties relevant for the structural integrity or the irradiation sensitivity. It could be confirmed that the applied ultrasonic testing procedures are reliable and able to detect all relevant flaws. A fracture mechanics assessment of the flaws, using highly conservative assumptions, demonstrated that the safety case is robust. After ENSI accepted the Beznau 1

RPV Safety Case, the unit returned to operation in March 2018. ENSI has issued the requirement to repeat the UT inspection of the base material of the RPV Shell C where the indications with the highest UT amplitudes are located. The follow-up UT is planned for the 2022 refuelling outage.

Challenge 3: Decommissioning of Mühleberg NPP

Activity performed in this regard:

See separate chapter under Article 6.

Suggestion 1: Report on the progress of the root cause analysis concerning the dry out issue of the Leibstadt NPP during the 8th RM

Activity performed in this regard:

For a detailed explanation of the root cause analyses see the Eight Swiss National Report to the CNS. A short update from March 2019 until March 2022 is presented below.

The basic knowledge, that Zn-rich CRUD-deposition was the reason for the V-shaped marks has not changed. Since March 2019 the operator carried out further intensive investigations. The results were made available to an international review team led by EPRI.

Since the beginning of the investigations, more than 350 fuel assemblies (FA), which have been operated on affected side entry orifice positions (SEO), have been inspected. These inspections included each type of fuel, which is used in Leibstadt NPP. One type of FA has been operated without restrictions and without any sign of V-shaped marks. The design that has been affected in the past, has a restriction in bundle power for its first cycle of operation. No new findings have been identified.

A gamma-scan campaign was carried out. Based on the results, the plant-manufacturer published Safety Information Communications in June 2020 and June 2021. The latter involves an adjustment of the thermal hydraulic loss coefficients of SEO and their impact on CPR monitoring. Leibstadt NPP implemented this finding by a CPR penalty in its online system.

The increased CRUD formation was numerically evaluated by the fuel vendor of the affected FAs. The program can support the avoidance of V-marks in Leibstadt NPP.

It can be summarized, that the measures were successful and no new V-marks have occurred in Leibstadt NPP. The fundamental investigations are finished.

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 decided to phase out nuclear energy. Therefore, no nuclear new builds are allowed.

The nuclear phase-out was decided upon as part of the Energy Strategy 2050, which entailed a partial revision of the Nuclear Energy Act. Following these discussions, both chambers of parliament decided to refrain from restricting the operational lifetimes of the existing Swiss nuclear power plants. This was also confirmed by the Swiss voters in a referendum in November 2016, where the Swiss voters rejected a Green Party initiative that called for a 45-year limit to be placed on the operating periods of existing plants. Beyond that, parliament also rejected a proposition based on which the operators of NPPs would have had to submit LTO concepts to ENSI before the completion of 40 years of operation (and then again on a 10-year basis).

Apart from the revision of the Nuclear Energy Act, the following relevant legal documents relating to nuclear energy have been revised since the eight Swiss CNS National Report.

- Nuclear Energy Ordinance (SR 732.11)
- Radiation Protection Ordinance (814.501)
- Ordinance on the Staff of the Federal Council National Emergency Operations Center (SR 513.12)
- Federal Law on Civil Protection and Civil Defence (SR 520.1)
- Ordinance on Civil Protection (520.12)

- Ordinance on the Federal Civil Protection Staff (SR 520.17)
- Ordinance on Safeguards (SR 732.12)
- Ordinance on the Decommissioning Fund and the Disposal Fund for Nuclear Installations (Decommissioning and Disposal Fund Ordinance, SR 732.17)
- Ordinance on Emergency Protection in the Vicinity of Nuclear Installations (Emergency Protection Ordinance, SR 732.33)
- Ordinance of the FDHA on basic and advanced training and permitted activities in radiation protection (SR 814.501.261)

New regulatory guidelines issued by ENSI have been introduced (see appendix 2). By involving the stakeholders and the general public in the procedure of issuing guidelines, the regulatory process is transparent. Furthermore, each new regulatory guideline includes the related international WENRA and IAEA requirements. (See Introduction, Articles 7 and 8.)

Major Common Issues from the Seventh Review Meeting

During the peer review of the Seventh Review Meeting, a number of common issues were identified and listed in the Summary Report (para 25–35). The issues identified have been dealt with in the corresponding chapters mentioned in the table below.

Issue	Reported
Vienna Declaration on Nuclear Safety	Separate chapter on VDNS
Safety Culture	Articles 8, 12
International Peer Reviews	Summary, Articles 7, 8
Legal Framework and Independence of Regulatory Body	Articles 7, 8
Financial and human resources	Article 8
Knowledge management	Articles 9, 12
Supply Chain	
Managing the Safety of Ageing Nuclear Facilities and Plant Life Extension	Articles 6, 14, 18
Emergency Preparedness	Article 16
Stakeholder Consultation & Communication	Articles 7, 8
Cyber Security	See Switzerland's eighth national report

Table 2: Major Common Issues from the Seventh Review Meeting

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 backfitting 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. The most recent periodic safety review (PSR) for Beznau NPP was submitted towards the end of 2017 and ENSI's review report was published in 2021 including long-term operation evaluation. The second generation of NPPs (Gösgen and Leibstadt) incorporated various safety and operating improvements in their initial design. The analogue control technology in Gösgen NPP is currently being replaced by a modern digital system. The project is scheduled to end in 2022. Further project stages are being planned. Preparations for a similar replacement of the control technology in Leibstadt NPP are under way. Upgrading of the bunkered emergency systems in Gösgen NPP started in 2018. The purpose of backfitting is to cope with a broader spectrum of external hazards. All PSRs conducted in Switzerland are reviewed in depth by ENSI. ENSI's final review reports are available on ENSI 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 their respective safety review reports. The Swiss policy of continuously improving 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 legislative and regulatory framework for nuclear installations is well established in Switzerland. It provides the formal basis for the oversight and continuous improvement of nuclear installations. The main legal provisions for authorisations and regulation, oversight 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 over 40 regulatory guidelines issued by ENSI, 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 ENSI, 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. The decision to phase out nuclear energy is incorporated in the revised versions. ENSI has also issued new guidelines. By involving the stakeholders in the procedure of issuing guidelines and publishing draft guidelines 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 regulatory authority for nuclear safety including radiological protection and nuclear security. ENSI's responsibilities and tasks have increased over the last 25 years, causing the workforce to gradually increase to about 153, with 141 FTEs, including more than 100 specialists in reactor safety, radiation protection, waste management, etc. In addition, its structure has been adapted to reflect changed requirements. ENSI 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 by an Act of Parliament on 1 January 2009, it is controlled by its own strategic board (ENSI Board), and has its own budget. ENSI uses a process-oriented management system, which was initially awarded ISO 9001 certification in December 2001. Accreditation of the inspection activities according to ISO/IEC 17020 was achieved in 2015. 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, ENSI's management system is well established and provides effective support for both management and daily operations. The IRRS Mission in 2021 demonstrated that ENSI's quality management is effective. At the same time it also revealed potential for improvement. 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.

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. ENSI conducts a variety of oversight activities (inspections, document reviews, safety reviews and regulatory meetings) to ensure that the licence holders assume full responsibility for the safety of their installations. ENSI's senior management team meet periodically with the licence holders' senior management to address technical, financial and human aspects of the NPPs. The Swiss nuclear industry has undergone drastic changes in recent years. ENSI addressed the related challenges posed by these changes and their safety implications as part of an experts' discussion on safety culture in 2018. In addition, as part of periodic safety reviews, ENSI required the power plant management and the licence holder's corporate management to demonstrate how decision-making takes into account the responsibilities of both parties.

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 licence holders have fulfilled this obligation in their management system and this is also demonstrated by these organisations' commitment to external comparison, peer review and improvement. All Swiss NPPs have undergone OSART missions, including follow-up missions. All Swiss NPPs regularly take 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. Since 2013, all of the licence holders have been involved in Corporate Peer Reviews and the subsequent follow-up missions. In 2019, the first IAEA Safety Culture Self-Assessment was conducted in Switzerland and more have been conducted or planned in the subsequent years.

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 an NPP. Should an 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 financed by dedicated funds. As required by the Swiss Nuclear Energy Act, corresponding ordinances and regulatory guidelines, the installations have sufficient qualified staff who are 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 instruction and training. Ongoing training is provided so that personnel can keep abreast of advances in science and technology, and plant modifications. All operating Swiss NPPs possess plant-specific full-scope replica simulators.

Article 12 – Human factors

The licence holder's obligation to establish a suitable organisation 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 ENSI-G07 "Organisation of Nuclear Power Installations", which is currently under revision. Attention is also given to the safety culture concept for which ENSI applies a special oversight method: Specialist discussions on safety culture issues. The nuclear industry has been confronted with a variety of changes that might have an impact on safety (e.g. changes in the energy, supplier and labour markets, loss of know-how, new technical safety requirements). Accordingly, ENSI is committed to closely monitoring and examining these changes and their impact on safety. 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". ENSI pays particular attention to this principle in its oversight of plant modernisation projects. In all NPPs workstations and processes for the operation and maintenance of the installations are evaluated by human performance specialists to ensure that they take account of human capabilities and their limits to avoid safety relevant events. In case of an event 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 quality standards. All NPPs have incorporated appropriate self-assessment processes in their management systems.

ENSI regularly performs inspections on the safety relevant processes of the licence holder's management systems to assess the effectiveness of quality assurance measures. This includes the use of internal and external (supplier) audits.

As part of the continuous improvement of management systems, ENSI pays particular attention to how the senior management fulfils its responsibilities regarding the assessment of the effectiveness of their management systems.

Article 14 – Summary

In Switzerland, the review and assessment procedures include an evaluation of deterministic as well as probabilistic safety analyses (DSA & PSA) within the framework of periodic safety reviews (PSR), long term operation (LTO) assessments, safety-relevant plant modifications, and reports on ageing surveillance programmes together with other safety-related documents as requested by ENSI. As part of the integrated oversight approach, 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 licence holder reports. The assessment of the periodic safety review by an NPP is documented in a corresponding evaluation report. PSRs and, since 2017, a LTO assessment are required at least every 10 years. Plant documentation must be regularly updated, including the safety analysis report (SAR) and PSA. The licence document includes important conditions and operating requirements. An Ageing Surveillance Programme is in place for all Swiss NPPs. This programme serves to collect information on the structures, systems and components (SSCs) of relevance for the monitoring of ageing and understanding of ageing mechanisms in order to maintain safety margins and the safety functions of SSCs throughout the life of a plant. As such, the programme is a prerequisite for long-term operation. Backfitting and replacement of safety-related equipment are necessary when existing equipment no longer satisfies current standards or when it becomes difficult to maintain. ENSI reviews and closely monitors the process for such activities. ENSI must approve the design, installation, modification and commissioning of safety-classified equipment.

Article 15 – Radiation protection

The present Radiological Protection Act came into force in 1994. Based on the recommendations of the International Commission on Radiological Protection (ICRP), the Radiological Protection Ordinance as well as subsidiary ordinances relating to particular aspects such as the handling of radioactive materials, training or dosimetry, were revised and then enacted in 2018. These ordinances have also been revised to obtain, inter alia, compatibility with the latest European Safety Directive and the IAEA Basic Safety Standards. ENSI has subsequently issued revised versions of most of its relevant guidelines. The oversight and control methods currently applied by ENSI comply with the Convention's requirement to maintain radioactive doses to personnel, the public and the environment as low as reasonably achievable as well as to maintain the generation of radioactive waste associated with the use of nuclear power at the lowest possible level. Calculated doses on the basis of annual emissions for a virtual most exposed population group, including exposure due to deposition from former years, have always been well below 0.2 mSv per year. Since 1994, calculated doses to the public resulting from 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 has been accumulated by plant personnel or contractors during their work in Swiss NPPs. Since 1987, all annual collective doses have remained well below 4 man-Sv per unit and, moreover, all have been maintained at around 2.0 man-Sv since 1995, with the exception of when the annual collective dose for the year 2021 at NPP Leibstadt amounted to 3.6 man-Sv due to extensive back fitting resulting in an outage exceeding six months. The low annual averaged individual and collective doses prove the effectiveness of the implemented measures based on the most recent recommendations of the ICRP (e.g. guidelines, job planning and oversight). ENSI reviews the NPPs' radiation planning process as part of its regulatory duties. Additionally, ENSI reviews all periodic reports relating to radiation protection measures that are issued by the power plants.

Article 16 – Emergency preparedness

The legal basis of emergency preparedness and concepts relevant to emergency preparedness and response have been revised as a result of the efforts of the official federal working group on the review of emergency preparedness measures in the event of extreme events in Switzerland (IDA NOMEX). The scenario used for emergency planning purposes is characterised by an unfiltered source term. As a consequence, awareness of emergency preparedness and response beyond the outer radius of Zone 2 (i.e. 20 km) has been raised, and this is reflected in the concept for emergency protection in the event of an accident at a nuclear power plant. 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. 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 ENSI, the National Emergency Operations Centre and the Ministry of the Environment of Baden-Württemberg (Germany). The ANPA system also provides ENSI with online access to measurement data for approximately 25 important plant parameters. ENSI 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. Switzerland's approach to emergency preparedness and response is regularly verified at the international level 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. Amongst other documents, applicants for a construction licence must submit an updated SAR. ENSI 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 signatory to the ESPOO convention. Site-related factors are re-evaluated periodically. In May 2011 the Swiss Government decided to phase out nuclear power in Switzerland. This is enshrined in Article 12a of the revised Federal Energy Act which has been in force since January 1, 2018.

The applicability and effectiveness of ENSI'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 licence holders in response to a requirement in ENSI's PSA review process. In 2008, Swiss licence holders launched a follow-up project, the PEGASOS Refinement Project (PRP), to take advantage of recent findings in the earth sciences and new geological and geophysical investigations at existing NPP sites. PRP is aimed at reducing the uncertainty range of the prior PEGASOS results. The PRP was completed and submitted by the end of 2013. At the end of 2015, ENSI defined new hazard assumptions, based on PRP, known as ENSI-2015.

Due to the insights resulting from the Fukushima Daiichi accident, ENSI asked the licence holders to re-assess 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., on one site, improving the system for protecting the water intake against blockage). After implementing these measures, ENSI concluded that all Swiss plants have sufficient safety margins beyond their design basis. Led by the Federal Office for the Environment together with other regulatory bodies including ENSI, a comprehensive re-assessment of the external flood hazard was carried out in 2021.

Finally, considering extreme weather conditions, ENSI set out the requirements for probabilistic hazard analyses and safety cases in greater detail. At the end of 2012, in compliance with an ENSI request to this effect, the plant operators submitted a document illustrating how they intended 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. Resulting from ENSI's review, the Swiss NPPs were required to update their hazard analyses. All licence holders submitted updated hazard analyses in the course of their periodic safety review. In general, the new studies showed an improvement in the quality of the studies. Based on these studies ENSI will define new hazard assumptions.

Article 18 – Design and construction

The Swiss nuclear power plants (NPPs) were designed, constructed and backfitted in accordance with the defence-in-depth concept. 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, appropriate measures are in place to prevent or mitigate the release of radioactive materials into the environment in the event of beyond-design-basis accidents. Design, materials and components are subject to rigorous control by regular testing in order to verify their required quality. Safety assessments for the LTO of the Swiss NPPs have been performed as part of the periodic safety reviews. Backfitting is carried out when necessary or reasonable. All Swiss NPPs possess a filtered containment venting system to mitigate radiological effects on the environment in the most severe accident scenarios. After the Fukushima Daiichi accident, protection of the Swiss NPPs and their spent fuel pools (SFP) against external events was reassessed by the licence holders. Furthermore, the Swiss nuclear safety Inspectorate (ENSI) ordered all licence holders to immediately implement two physically separate lines / connections to feed 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, ENSI conducted several inspections to assess the situation in the Swiss NPPs regarding issues that resulted from the accident management actions performed at Fukushima Daiichi. Additionally, the safety of an NPP must be demonstrated for natural hazards with an exceedance frequency of 10^{-4} per annum. At the end of 2015, ENSI defined a new seismic hazard, known as ENSI-2015. According to the Swiss regulations, the licence holders 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 ENSI in 2016. Verifying seismic safety involves four phases. In the first phase the licence holders developed and submitted the general concept for a safety assessment. ENSI approved the concepts in 2017. The following verifications (update of post-Fukushima verification and probabilistic safety assessment) were finished with positive results and the deterministic verifications phase is ongoing.

The external flooding analyses were reassessed 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 carried out 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 enshrined in the Nuclear Energy Act, the Nuclear Energy Ordinance and the guidelines issued by ENSI, ensuring that these principles are implemented in the plants as far as possible and reasonable.

Article 19 – Operation

The requirements for the safe operation of Swiss NPPs are specified in the operating licence granted to each NPP. The operating licence includes commissioning approval. The commissioning programme, which requires the approval of ENSI, comprises pre-operational and start-up tests as well as procedures for testing any equipment that is important for safety. The most important operating procedures are the Technical Specifications, which include the limiting conditions for operation and similarly require the approval of ENSI. The operating procedures for an NPP also cover maintenance, testing and surveillance of equipment. Engineering and technical support in all fields relevant to safety is available to all NPP staff. The Nuclear Energy Act, the Nuclear Energy Ordinance and regulatory guidelines include requirements for the notification of events and incidents. Under the Ordinance, each NPP must use dedicated Emergency Operating Procedures (EOPs) for operational anomalies and emergency conditions. The ultimate objective of EOPs is to bring the plant into a safe operating state. A Severe Accident Management Guidance (SAMG) programme is designed to prevent or at least minimise any impact on the environment. SAMG is implemented in all Swiss NPPs and covers all relevant operating states. All NPPs have Accident Management (AM) procedures and a variety of measures to deal with scenarios beyond the plant design basis. All Swiss NPPs are equipped with special bunkered safety systems designed to withstand extreme external events. 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, operating experience feedback, plant modifications and safety-related computer applications. The Swiss legal and regulatory basis contain requirements for the notification of events and incidents. The process dealing with non-conformance control and remedial action is very important in Swiss NPPs. 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. ENSI has its own process for assessing events in nuclear installations in other countries. In addition to its general inspection activities, ENSI gains further insight into the operations of an NPP through a system of comprehensive operator reporting. Both ENSI 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 those generating radioactive waste are responsible for its safe and permanent management. Thanks to high fuel quality and plant cleanliness, the radioactive waste generated at NPPs is kept to the minimum level possible. The resultant waste is collected and separated. As a general rule, radioactive waste is conditioned as soon as practicable. All procedures for conditioning radioactive waste require the approval of ENSI. 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 with effect from 1 July 2006. This ban has been made permanent as part of the revised Swiss Nuclear Energy Act. At present, spent fuel is also stored in transport and storage casks at the Central Interim Storage Facility (ZZL).

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 the design and construction of nuclear power plants are specified in the Nuclear Energy Act (NEA), the Nuclear Energy Ordinance (NEO) and ENSI guidelines (for detailed information on the Swiss regulatory system, see Article 7). According to Article 12, paragraph 1 of the NEA, anyone intending to construct or operate a nuclear installation requires a general licence issued by the Federal Council. With the Swiss energy strategy 2050, several affected acts were revised and the granting of general licenses for the construction of new nuclear power plants has been prohibited since January 2018 (see Article 12a of the NEA). Nevertheless, the preventive and protective principles for new nuclear power plants are still valid, in particular as a basis for backfitting requirements for existing power plants.

Article 4, paragraph 1 of the NEA stipulates that "Special care must be taken to prevent the release of impermissible quantities of radioactive substances and to protect humans and the environment 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.

Furthermore, Article 4 NEA, paragraph 3, letter a, entails a dynamic requirement stipulating that "all measures must be taken" that are "required in accordance with experience and the state of art in science and technology". The state of the art in science and technology is essentially based on the safety standards set by the IAEA, which are reflected in the Swiss national requirements.

Moreover, Article 4 NEA, paragraph 3, letter b, requires additional measures that "contribute towards an further reduction of risk insofar as they are appropriate" beyond the minimal requirements and the state of the art in science and technology.

The NEO is legally binding and describes the minimal requirements of Article 5 of the NEA regarding the 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 targeted, and that safety functions should preferably be conducted 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). For the design of a nuclear installation, accidents not triggered by natural events are classified into three categories by the frequencies specified in Article 123 paragraph 2 RPO. In addition to the initiating event, an independent single failure and additional conservative boundary conditions must also be assumed. Proof must be provided that the requirements relating to maximum radiation doses in accordance with Article 123 paragraph 2 RPO are met. Any accident with an exceedance frequency of between 1.0E-1 and 1.0E-2 per year must not lead to an additional dose which exceeds the relevant source-related dose constraints. An accident with an exceedance frequency of between 1.0E-2 and 1.0E-4 per year must not cause a dose for members of the public larger than 1 mSv. And accidents with an exceedance frequency of between 1.0E-4 and 1.0E-6 per year must not result in a dose larger than 100 mSv; the licensing authority may specify a lower dose in individual cases. It is required that the safety of a NPP must also be demonstrated for natural hazards. An accident resulting from a natural hazard with an exceedance frequency of 1.0E-4 per year must not result in a dose for members of the public larger than 100 mSv. For the case of a natural event with an exceedance frequency of 1.0E-3 per year, it must be demonstrated that the dose is no larger than 1 mSv.

The dynamic requirements (see Article 4, paragraph 3, letter a NEA) mainly apply the contents of the IAEA safety standards. More detailed guidance for special cases is given in ENSI's guidelines.

The dynamic requirements in the Swiss legal framework ensure that new nuclear power plants are designed, sited and constructed in a manner 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 periodic safety review (PSR) at least every 10 years. Within these safety evaluation processes, potential improvements have to be identified and implemented as appropriate. Further improvements may be required in the course of the safety assessment regarding long-term operation (for more information on the PSR, see Article 14). In addition, there is an annual systematic assessment of nuclear safety for each NPP based on event analyses, inspection results, safety-indicator data and information in the periodic licence holder reports.

The legal requirement for PSRs is stipulated in Article 22, para. 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. According to Article 34, para. 4 of the NEO, which was revised in 2017, additionally for the period following the fourth operating decade, proof of safety for long-term operations in accordance to the added Article 34a must be submitted additionally as part of the PSR. The proof of safety for long-term operations shall comprise a) the basic period of operation, b) proof that the design limits for the parts of the plant technically of safety relevance will not be reached during the planned period of operation, c) the backfitting and technical or organisational improvements planned for the following operating decade, and d) the measures intended to guarantee sufficient numbers of staff with the required expertise for the planned period of operation. 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 public.

The Ordinance on the Methodology and the General Conditions for Checking the Criteria for the Provisional Taking out of Service of Nuclear Power Plants (SSR.732.114.5) defines a set of minimal criteria to be met by the existing NPPs. If these criteria are not met, the plant has to be immediately taken out of service and backfitted.

There is a dynamic requirement for existing NPPs. Article 22, para. 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 operating 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 recent Guideline ENSI-G02 "Design Principles for Existing NPPs" concretises the state of backfitting technology used in Article 22. para. 2, letter g, of the NEA. This guideline has been in force since 2019. It outlines the fundamental safety concepts and the design basis requirements. It specifies the primary safety objectives, the multiple barrier, and the defence-in-depth concept in concrete terms. The primary safety function requirements are detailed for safety levels 1–3 and safety level 4. The design-basis requirements focus in particular on protection against design-basis (level 3) and selected beyond-design-basis accidents (level 4a) as outlined in the recent update of Guideline ENSI-A01 (September 2018). Guideline ENSI-G02 then outlines in more detail the design requirements for selected structures, systems and components (SSC). This guideline concretises relevant safety requirements set by the IAEA and WENRA.

Furthermore, Article 12 of the DETEC Ordinance on the Hazard Assumptions and the Assessment of the Protection against Accidents in Nuclear Installations SR 732.112.2 and Guideline ENSI-A06 define criteria from the risk perspective in order to assess whether risk mitigation measures have to be identified and, to the extent appropriate, implemented.

ENSI reviews the backfitting projects and in doing so, closely monitors the process. The projects and modifications are subject to a four-step approval procedure, consisting of the concept, the detailed design, the installation, and the commissioning of the systems. ENSI grants permissions for each step of the procedure after thorough examination of the appropriateness, and after checking compliance with national and international safety requirements.

In conclusion, it can be stated that the dynamic requirement 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 of backfitting projects in Switzerland. As early as 1987,ENSI required that NPPs had to be protected against extreme external hazards such as aircraft impact, explosion, and third-party action . 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.

Implementation of the Vienna Declaration

Article 4, paragraph 1 of the NEA stipulates that "Special care must be taken to prevent the release of impermissible quantities of radioactive substances and to protect humans and the environment against impermissible levels of radiation during normal operation and accidents." 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." 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.

Furthermore, Article 4 paragraph 3, letter a of the NEA 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 in science and technology is essentially based on the safety standards set by the IAEA. In addition, a so-called precautionary principle anchored in Article 4, paragraph 3, letter b requires precautionary measures throughout the lifetime of nuclear power plants that "contribute towards an additional reduction of risk insofar as they are appropriate" beyond the minimal requirements and the state of the art in science and technology.

Consequently, internationally accepted principles must be taken into account including the 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, because the IAEA safety standards are essentially being used to define the latest state of the art in science and technology. Other good practices are taken into account through the precautionary principle.

Developments and Conclusion

The NEA requires the Swiss licence holders to perform a PSR, in compliance with the NEO, at least every 10 years, and to backfit the installation to the necessary extent such that it complies with operating experience and the current state of backfitting technology. According to Article 34, para. 4 of the NEO, proof of safety for long-term operations must be additionally submitted as part of the PSR for the period following the fourth operating decade. According to Article 12a of the NEA, the granting of general licenses for the construction of new nuclear power plants is prohibited.

Switzerland complies with the principles of the Vienna Declaration on Nuclear Safety.

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, para. 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, para. 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 operating 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 backfitting project consisted primarily of adding one or two fully separate shutdown and RHR systems, including support systems, which addressed the above four issues.

In addition to the NANO feedwater system, an emergency feedwater 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

Figure 2: Aerial view of Beznau NPP – Source Axpo Power AG

feedwater 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 the NANO and SUSAN 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 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 second PSR for Beznau NPP was submitted towards the end of 2012. ENSI's review report was published at the end of 2016. In 2017 the Nuclear Energy Ordinance (NEO) was amended. If a NPP is to be operated for more than 40 years, a proof of safety for long-term operation has to be submitted as part of the PSR. The most recent periodic safety review (PSR) for Beznau NPP was submitted towards the end of 2017 and ENSI's review report was published in 2021 including further long-term operation evaluation.

The most recent PSR for the Mühleberg NPP was submitted towards the end of 2010 and ENSI's review report was published in 2013. In December 2012, ENSI published its review report on the long-term operation of the 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 were decreed by ENSI (see Article 18). Following the decision to shut down the plant at the end of 2019 the strategy for the long-term operation of the Mühleberg NPP became obsolete.

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 of 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. A significant part of the old control technology has already been replaced. The actual end of the project is scheduled for 2022. Further project stages are being planned. Preparations for a similar replacement of the control technology of the Leibstadt NPP are under way. In 2018 the upgrade of the bunkered emergency systems of the Gösgen NPP started. The objective of the backfitting is 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 second PSR for Leibstadt NPP was submitted at the end of 2006 to ENSI, which published its review report in August 2009. The third PSR was submitted at the end of 2016. The review report was published in 2019. The first PSR for the Gösgen plant was completed in 1999. The second PSR for Gösgen NPP was submitted to ENSI at the end of 2008. ENSI published its corresponding review report in August 2012. The third PSR was submitted at the end of 2018. The publication of the review report is planned for 2023 including a long-term operation evaluation.

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. It contains various operational resources for emergencies that can readily be called up. If transport by road is not possible, air transport by helicopter is possible. 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

BKW Energy Ltd announced in late 2013 that Mühleberg NPP would be permanently shut down at the end of 2019. The single 372 MWe boiling water reactor began operation in 1972. Aside from the experimental plant at Lucens, it is the first Swiss nuclear power plant to be decommissioned.

On 18 December 2015, BKW submitted the application documents to decommission its NPP (the final decommissioning plan) to the Federal Department of the Environment, Transport, Energy and Communication (DETEC). The application comprised 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 established a cross-institutional monitoring group. All stakeholders are member of this group: the Federal Office of Energy, the Federal Office for the Environment, the Canton of Bern, ENSI and BKW. There are three subgroups on technical aspects, legal procedure and communication. In March 2015, June 2017 and September 2018 the communications subgroup organised six public events around the Mühleberg NPP. In total more than 1500 people visited these events and demonstrated a lot of interest in the decommissioning plan, the funding, the costs, the waste treatment and disposal.

The requirements for the final decommissioning plan are described in the Nuclear Energy Act, the Nuclear Energy Ordinance and in Guideline ENSI-G17. The decommissioning Guideline ENSI-G17 complies with the WENRA Safety Reference Levels and the respective IAEA Safety Standards on decommissioning.

The documents were reviewed by the authorities. ENSI also wrote an advisory opinion. Based on authorities' advisory opinions, DETEC issued the decommissioning order that regulates the decommissioning process in June 2018, more than one year before final shutdown. There were no complaints against the order to the Federal Administrative Court. The decommissioning order is legally binding.

Immediately after the shutdown on 20 December 2019, BKW Energy Ltd started dismantling activities with spent fuel still on site. The activities planned in the first two years included the clearing of the turbine floor and the installation of decontamination and waste treatment facilities as well as the removal of the RPV internals. Nearly all decontamination and waste treatment facilities in the turbine building could be installed and logistics infrastructure was extended. Due to transport route and logistics optimisations, a new zone for free release measures in the turbine building could be set up and put into operation.

Dismantling activities in the turbine and reactor building were intensified in 2021. The focus of the dismantling work in the turbine building is on the area of the condenser and in dealing with conventional pollutants, the main focus being asbestos remediation. In the reactor building, the systems no longer required for spent fuel elements were taken out of service and successively dismantled. In addition to other minor dismantling activities, the internals of the torus were removed. The completion of the dismantling of the torus itself is planned for 2022.

After the preparatory assembly work for cutting, packaging and removal of the RPV internals was completed, dismantling of the steam dryer started. These activities had to be stopped at the end of 2021 to expedite the necessary preparatory work for the transport of spent fuel to the Swiss central interim storage in Würenlingen (Zwilag). These transports will be carried out over the next two years.

According to the plans of BKW, decommissioning will be completed within 11 years, by 2030.

Developments and Conclusion

Backfitting required in response to technical advancements, or as a result of the hazard analyses of the Fukushima accident has been tracked continuously in all NPPs. Where the final shutdown of NPPs is concerned, ENSI will not permit any safety compromises 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 nuclear energy and on radiological protection are 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 on 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[5]

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. The provisions prescribe the obligation to take preventive and protective measures in accordance with internationally accepted principles when designing, constructing and operating nuclear installations;
- 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 licence holder, 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 operating 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 licence holder'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 regulatory authority for nuclear safety and security;
- provisions regarding the authority and powers of the regulatory authorities, including the right to (i) access all relevant in-

[5] **The English translation of the Nuclear Energy Act is available on the website of the Swiss Confederation (www.admin.ch/opc/en/classified-compilation/20010233/index.html).**

formation 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 regulatory authorities by fees collected from the licence holders and applicants;
- criminal sanctions.

Radiological Protection Act[6]

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 ENSI was separated from SFOE, in order to comply with the international requirement of independence. ENSI 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]). The ENSI Act asks ENSI to implement a system of quality control and sets an obligation for ENSI to check the quality of its task fulfilment and services periodically by external parties and to ensure long-term quality assurance. In this context the Ordinance on the Swiss Federal Nuclear Safety Inspectorate from 2008 prescribes that ENSI subjects itself periodically to a review by external experts with regard to its compliance with the requirements of the Nuclear Energy Agency (IAEA).

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[7];
- Radiological Protection Ordinance[8] (revised in 2017);
- Ordinance on Safety-Classified Vessels and Piping in Nuclear Installations;
- Ordinance on the Qualifications of Personnel in Nuclear Installations;
- Ordinance on the Hazard Assumptions and the Assessment of Protection 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;

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[6] **The English translation of the Radiological Protection Act is available on the website of the Swiss Confederation (www.admin.ch/opc/en/classified-compilation/19910045/index.html).**

[7] **The English translation of the Nuclear Energy Ordinance is available on the website of the Swiss Confederation (https://www.fedlex.admin.ch/eli/cc/2005/68/en).**

[8] **The English translation of the Radiological Protection Ordinance is available on the website of the Swiss Confederation (www.admin.ch/opc/en/classified-compilation/20163016/index.html).**

- 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)

ENSI 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. Whereas acts and ordinances have legal force, guidelines are semi-mandatory. ENSI 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, including all neighbouring 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. 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 ENSI's website.[9]

With respect to regulatory guidelines, ENSI has established a Committee for Regulatory Basis which meets monthly to examine and survey the guidelines, and review 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 safety 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 be-

[9] **https://www.ensi.ch/en/documents/document-category/guidelines/**

long all existing nuclear facilities, the Federal Offices of Energy and of Public Health, Federal Commissions, 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 or the underlying legislation, 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.

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 held the chair of WENRA from 2011 to 2019. 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. As a WENRA member, Switzerland has committed itself to adopt and incorporate the SRLs into its national legal and regulatory framework. The implementation is monitored by the corresponding WENRA working group.

ENSI participates in the two standing WENRA working groups: "Reactor Harmonisation Working Group" and "Working Group on Waste and Decommissioning", as well as various ad-hoc groups and task forces. The Swiss self-assessment in the area of "Reactor Harmonisation" identified a number of SRLs to be incorporated into the Swiss regulatory framework. The corresponding WENRA peer-review showed that implementation in Switzerland is well under way. Currently, 97 % of the reactor SRLs are already implemented in the Swiss regulations. All WENRA SRLs for spent fuel and waste storage as well as for decommissioning are implemented in the Swiss regulatory framework. The latest published Safety Reference Levels Report about Radioactive Waste Treatment and Conditioning still needs to be assessed. The Swiss assessment of this newer WENRA SRLs is scheduled for the coming months. Given the recent revision and publication of several safety guidelines in this field (ENSI-B17, ENSI-G05 and ENSI-G23); a high degree of compliance is to be expected.

ENSI participates in all IAEA Safety Standard Committees, the Commission on Safety Standards and the Nuclear Security Guidance Committee to promote high international standards in nuclear safety and security. On the other hand, ENSI harmonises its guidelines with IAEA Safety Standards. Therefore, when issuing a new guideline or revising an existing one, ENSI 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 ENSI's guidelines it is implemented.

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

In 2015, ENSI 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 frame 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 especially 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 regulatory 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 frame 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, several 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 the start-up levels that require a permit from the relevant regulatory 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 regulatory 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 ENSI is provided in the Nuclear Energy Act. It grants ENSI 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 licence holder complies with its primary responsibility for safety. ENSI, with the help of experts working on its behalf, reviews the licence holder's programmes and independently assesses the performance of the licence holder 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. ENSI has the authority to suspend or withdraw permits.

The regulatory 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, ENSI 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 regulatory 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 regulatory 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.

Stakeholder consultation

Stakeholder consultation is an important instrument in the Swiss legislative process, in the decision-making process with regard to the granting of licences for nuclear installations and in the procedure for issuing guidelines. In the Swiss legislative process, the relevant stakeholders are consulted before the law is presented to parliament for approval or, in the case of an ordinance, to the Federal Council. With regard to licensing processes (general, construction and operating licenses) stakeholder consultations have to be carried out by the authority preparing the decision. In the guideline issuing procedure, the draft guideline and the guideline's explanatory report are subject to an internal hearing and an external consultation round.

Stakeholder consultation provides transparency and can lead to more appropriate and balanced solutions.

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 ENSI have been introduced. Since coming into force, the Nuclear Energy Act as well as the Nuclear Energy Ordinance have been subject to specific changes. So too have some of the guidelines.

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.

Establishment 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.

Oversight

ENSI is the regulatory 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 operating 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 regulatory authorities.

The NSC consists of five to nine 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 and include, amongst others, 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 opinions regarding the 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;
- the **Supervision and Safety Division (ASI) of the SFOE** is responsible for the national accounting and control system for nuclear materials as well as other regulatory 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.

Organisation of the Regulatory Body

Costs incurred by the safety authorities (with exception of the legal framework and information to the public) totalling some 63 million Swiss Francs per year, are mainly covered by fees from licence holders. Nuclear safety research promoted and endorsed by the regulatory body has a budget of about 5.8 million Swiss Francs: some 2 million Swiss Francs come from public funds and 3.8 million Swiss Francs come from NPPs.

ENSI is a stand-alone organisation (separate from the SFOE) controlled by its own management board (ENSI board) and with its own budget. This gives ENSI complete flexibility over budget decisions and independence when recruiting personnel. The ENSI Board does not take the regulatory decisions, nor does it have the legal authority to overturn regulatory decisions that ENSI's Executive Management has taken. The ENSI Board consists of the members elected by the Federal Council (Swiss Government). ENSI is managed by ENSI's Executive Management, which is composed of seven members (two of whom attend the board's meeting in an advisory capacity). Each of the members manages a division.

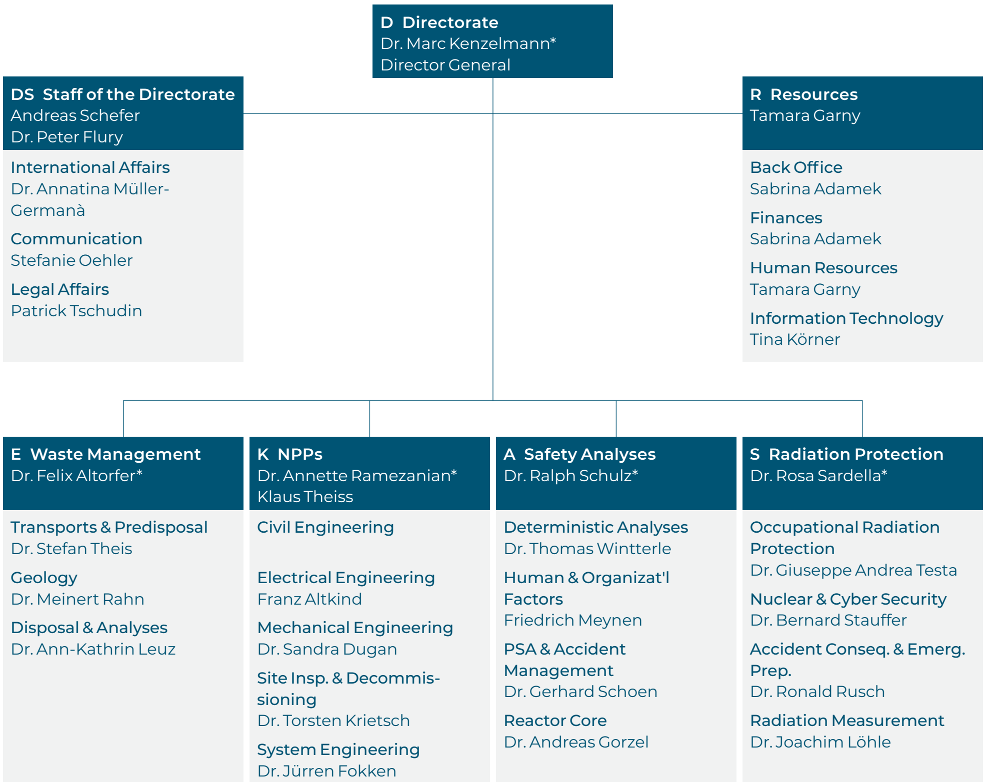
ENSI currently has a staff of 153 specialists covering the following fields:

- **Directorate D:** Director General, assistant, senior advisor (3)
- **Division K (Nuclear Power Plants):** oversight of nuclear power plants, including decommissioning and dismantling aspects ,reactor safety, site inspection (36);
- **Division S (Radiation Protection):** occupational radiation protection, accident consequences and emergency preparedness, radiation measurement, nuclear and cyber security (29);
- **Division E (Waste Management):** deep geological repository sectoral plan, waste management and transport safety (20);
- **Division A (Safety Analyses):** probabilistic and deterministic safety analyses, accident management, safety of the reactor core and human and organisational factors (27);
- **Division DS (Staff of the Directorate):** support of the Director General and the Executive Management, communications, regulatory framework, legal and international affairs and information security (16)
- **Division R (Resources):** human resources, IT and infrastructure, finances and back office (22).

The number of employees has been constant over the past few years. In March 2022, ENSI had 153 employees representing 141 FTE.

While the additional workload caused by the accident in Fukushima has decreased significantly, the public interest in the work of the ENSI has grown. Since 2011, legal affairs have become more and more important as sever-

Figure 3: ENSI Organisational Chart March 2022 – Source ENSI



* **Members of the executive board**

al stakeholders have appealed against decisions made by ENSI. Other areas of growing importance are information security and sustaining the level of competencies needed by staff in the future.
To maintain the necessary amount of staff and competencies needed in future years, several projects and instruments have been launched and implemented based on ENSI's Human Resources Strategy. These include measures in the fields of recruiting, education and training, resource and succession planning, employer branding, terms of employment and workplace-health-management.

Independent consultants are commissioned to advise ENSI 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

ENSI 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 certificate for ISO 9001 is valid until December 2022. Taking into consideration the costs and benefits, the certification of the environmental management system was abandoned in 2017. For the same reason, the project to obtain an ISO 45001 certification (health & safety management) was suspended. The laboratory for radiation measurement has been accredited in accordance with ISO 17025 since 2005, ENSI was accredited as an inspection body according to ISO 17020 in 2015.

The Management System is applied to all relevant activities and includes ENSI's safety, quality and environmental policies as well as the performance agreement between the ENSI board and ENSI. The performance agreement includes strategic and operational objectives as well as a budget allowance for ENSI 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 conducts 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 13 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 ENSI 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 2021, an IRRS mission was carried out in Switzerland. The mission showed that ENSI's quality management is effective. At the same time, it also revealed potential for improvement. In addition, the annual supervisory and renewal audits required for the ISO 9001 certification were carried out 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 ENSI's regulatory effectiveness.

Knowledge management and training

Some activities related to knowledge management and training measures are integrated in ENSI's Management System. ENSI has launched several new projects relating to human resources management. The projects concern several topics including Competence & Performance Management, Employer Branding, Personnel Development and training, Workplace-Health-Management, modernisation of the terms of employment and digitalisation of HR-workflows, and, based on the current schedule, will be completed by the autumn of 2023:

ENSI has 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).

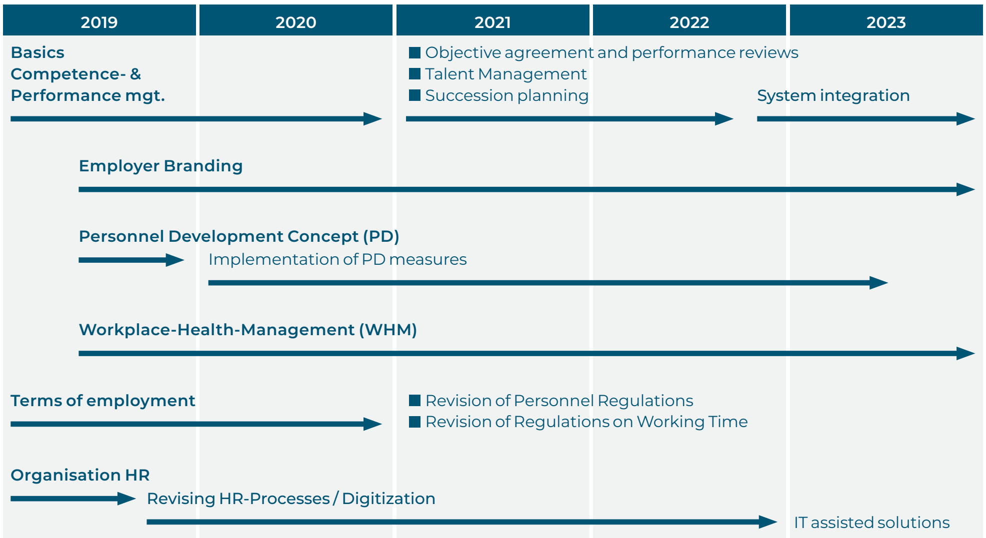


Figure 4: ENSI Key Aspects of Human Resources Strategy and Personnel Development – Source ENSI

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 at least one 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 oversight 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 strategic planning of the direction of communication and the organisation and implementation of the communication activities and work closely with the ENSI Executive Board and, to a lesser degree, with the ENSI-Board.

Under the Nuclear Energy Act (Article 74), ENSI "shall regularly inform the public of any special occurrences". In addition to which, ENSI 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. All ENSI documents generated after 1 July 2006 are made public with a few exceptions relating to security, personal data or proprietary information.

The information services of ENSI go well beyond these legal requirements. ENSI'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, and, to a lesser degree, in Italian and English. ENSI regularly publishes information on its website about incidents and overhauls at nuclear power plants, projects and events, updates to the regulations, research activities, and the disposal of radioactive waste. A weekly newsletter highlights the latest website articles. Background series provide an in-depth insight into ENSI's activities. For example, several series have already been published on the topics of "Ten years on from Fukushima" and the nuclear accident in Chernobyl. The website contributions are accompanied by parallel posts on social media platforms, namely Twitter and LinkedIn. In addition to issuing technical publications, ENSI also publishes four annual reports: the Regulatory Oversight Report, the Research and Operating experience Report, the Radiation Protection Report and the Business Report of the ENSI Board.

ENSI informed the public about the IRRS mission 2021 and its findings. The report will be published on ENSI's website by the end of April 2022.

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 releases and interviews on nuclear safety issues that are the subject of current media discussion, and background discussions with journalists. In addition to this, the ENSI Communication Section participates as part of the core team in the ENSI Emergency Organisation that is integrated into the national emergency organisation.

In 2016, a crisis communication concept and handbook were developed. This document, in line with the communication strategy, defines the rules and responsibilities for communication in different crisis situations. The main objectives of this concept are that all relevant stakeholders are addressed in time and that information is provided at the appropriate level.

The ENSI Board has commissioned the Communications Section to review and adapt the communication strategy. ENSI's current communication strategy was drawn up in 2012 and last updated in 2016. In this context, it was decided as an immediate measure in May 2021 to conduct dynamic in-depth interviews with representatives of the various stakeholder groups and spontaneous street interviews as part of the analysis work for the communication concept with integrated communication strategy. In cooperation with the Executive Board and the ENSI-Board this strategy work is continuing with the aim of elaborating the Communication Strategy 2022 and onwards by the end of May 2022.

ENSI runs two series of events: the Technical Forum on Nuclear Power Plants (TFK) and the Technical Forum on Safety (TFS) that are held three to four times a year.

The Technical Forum on Safety(TFS), led by ENSI, was set up in 2009, in connection with the search for sites for deep geological repositories. 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.

The Technical Forum on Nuclear Power Plants (TFK), created in 2012 and also led by ENSI, is a platform where questions from the general public regarding the safety of Swiss Nuclear Power Plants are discussed and answered by ENSI, operators or other offices. The forum consists of representatives of municipalities near NPP sites, cantons, non-governmental organisations, NPP op-

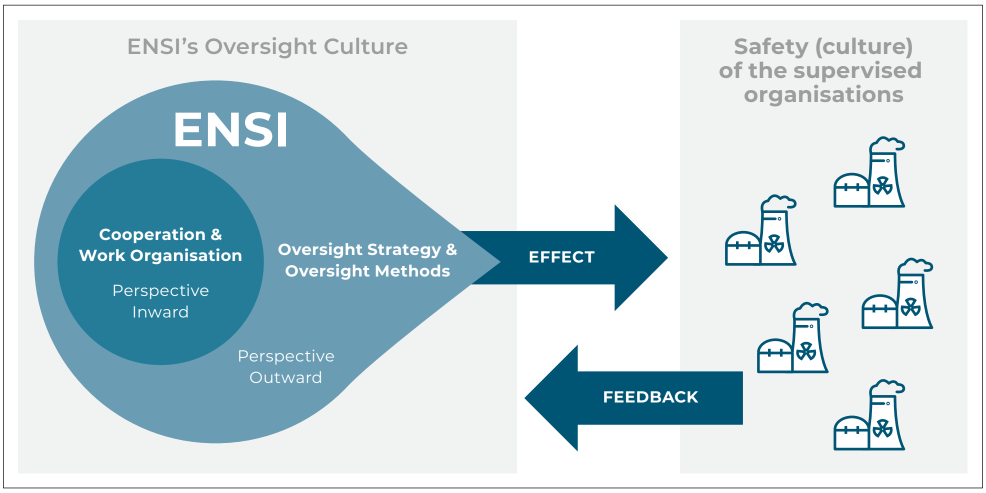


Figure 5: ENSI's oversight culture

erators and authorities. ENSI publishes all questions and answers on its website.

Oversight culture

ENSI uses the term "oversight culture" to refer to all characteristics and attitudes within ENSI that relate to the exercise of its core mission: the oversight of Swiss nuclear installations. ENSI began its engagement with oversight culture in 2012 when it launched a project to examine its oversight culture. The aim of the project was to describe ENSI's oversight culture and identify areas of improvement. 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 ENSI.

In the following years, further efforts were made to improve ENSI's oversight culture. For example, feedback was obtained from NPP operators on oversight activities, and ENSI started an examination of its own oversight activities in order to derive lessons learned.In 2020, ENSI introduced a leadership programme for supervisors and their deputies, and in 2021 implemented resilience training for employees. Since then, annual follow-up training has been conducted in respect of both leadership and resilience. Similarly, two workplace stress analyses were conducted involving the entire ENSI workforce. The second analysis was carried out in 2021 and its data is currently being evaluated.

ENSI also contributes its experience and expertise in the area of oversight culture to the relevant bodies of the IAEA or the NEA.

All efforts to continuously improve the oversight activities were recognised as a Good Practice by the 2021 IRRS Mission to Switzerland.

Following the 2021 IRRS Mission to Switzerland, ENSI launched new initiatives in the area of oversight culture. These include, in particular, the development of its understanding of oversight culture (see Figure 5) and the creation of a new position to coordinate its oversight culture activities.

Figure 5 illustrates ENSI's understanding of oversight culture, which is based on two perspectives: an inward and an outward perspective. The inward perspective refers to the cooperation and work organisation within ENSI, while the outward perspective refers to its oversight strategy and method. The further development of the oversight culture thus involves the continuous improvement of both perspectives. Hence, the aim of the above-mentioned position to coordinate the oversight culture activities within ENSI, is to systematically address the two perspectives of the oversight culture and, in doing so, to initiate and implement the process of continuous improvement of ENSI's oversight activities. ENSI employees will be involved in this continuous improvement, and existing meeting and information forums and processes will be utilised. For example, a close cooperation is planned with the ENSI Organisational Health Management/Oversight Culture steering group. Due to their cross-organisational scope, the jobholder works independently of the line manager and reports to ENSI's executive management.

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

The Nuclear Energy Act requires the regulatory authorities to be independent on technical matters by directives and formally independent of the licensing authorities. It also clarifies and expands the position, duties and responsibilities of ENSI as the regulatory 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 (Article 70) stipulates that regulatory authorities 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 ENSI regulatory independence and ensures the separation between ENSI and the licensing authorities. In passing this Act on 22 June 2007, the two parliamentary chambers in Switzerland resolved to convert ENSI into a body constituted under public law to be formally, institutionally and financially independent. The ENSI Act (Article 18) stipulates that ENSI shall exercise its supervisory powers autonomously and independently.

The Act on the Swiss Federal Nuclear Safety Inspectorate ENSI came into force on 1 January 2009. ENSI 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 ENSI is well established and provides effective support for both management and daily operations. Suggestions for improvement from the IRRS Mission 2021 regarding quality management will be followed up in a separate project. 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 out in the related ISO and IAEA standards.

ENSI is the legally, institutionally, politically and financially independent national regulatory body, responsible for supervising the nuclear safety and security of the Swiss nuclear facilities. ENSI is supervised by the ENSI Board whose members are elected by the Federal Council and report directly to it.

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[10];
- 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 operating 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, ENSI verifies that decisions taken by the licence holder 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 Swiss nuclear industry has undergone drastic changes in recent years. The political decisions made by Switzerland as well as other countries on the (medium-term) phasing out of nuclear energy has led to restructuring amongst the suppliers of Swiss nuclear power plants, with the concomitant consequence that the Swiss nuclear industry is confronted by a loss of nuclear competencies. In addition, the liberalisation of the European electricity market has meanwhile been completed. Amongst other things, this led to electricity prices falling sharply which has forced the energy companies and thus the nuclear power plants to implement unprecedented austerity measures (see Leibstadt and Beznau NPP below). ENSI addressed the related challenges of these changes and their safety implications as part of an experts' discussion on safety culture in 2018. The assumption of responsibility for safety at the

[10] **Art. 34 para. 1 of the Nuclear Energy Ordinance further obliges the license holder to conduct periodic safety reviews every 10 years**

time of such changes was also a subject for these discussions. All NPPs have a well-established network of contractors and good contacts with their vendors. In case of changes due to, e.g., restructuring (see above), the NPPs are considering remedial actions. One of these is, for example, the insourcing of specific skills in order to keep the specific nuclear competencies in-house.

During the review period, both plants were confronted with the continuing consequences of the liberalisation of the electricity markets and the Swiss Federal Government's decision to phase out nuclear energy and the associated developments in the nuclear energy sector. In both plants, these developments led to staff reductions and centralisation within the licence holder's corporation. Both NPPs were forced to deal increasingly with issues relating to the provision and organisation, and thus the preservation of safety-relevant resources (personnel, funds, knowledge), and corresponding decisions had to be made by the power plant management and the licence holder's corporate management. According to the nuclear energy legislation, the responsibility for safety is assigned to the licence holder as well as the power plant manager. However, due to the hierarchical organisation of the licence holder, the power plant manager is in a relationship in which they are dependent on the licence holder's corporate management. This constellation must be considered in decision-making processes that involve both parties. Care must be taken to ensure that the dependency implicit in their relationship does not have any unfavourable influences on safety. As a result, ENSI requested both facilities in 2018 and 2020, respectively, to submit a report to ENSI outlining the procedure for safety-related decisions in the event of divergent opinions or conflicts between the licence holder corporation and power plant management. In particular, it must be explained how it is ensured that the dependency implicit in the relationship between the licence holder corporation and power plant management does not have an unfavourable influence on safety (see Guideline ENSI-G07). The review of the reports as well as the oversight on this issue has not been completed at the time of writing of this National Report.

In late summer 2020, the incumbent power plant manager of the Beznau NPP was dismissed by the licence holder, necessitating a new appointment to this position. ENSI oversaw this replacement and found that senior management had been consulted on the matter. The requirements for organisational changes specified in ENSI-G07, in particular the consideration of employee-related aspects, were also met. The position of the power plant manager was filled within a few weeks by a person who met all regulatory requirements both professionally and personally. ENSI considers the replacement of the manager to be a good example of the Beznau NPP organisation's responsibility in ensuring good and long-term personnel planning.

All Swiss NPPs are members of the World Association of Nuclear Operators WANO and benefit from an extensive exchange of information on operating 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 that have been recommended by WANO (e.g. operational decision-making, pre-job-briefing) are implemented in the Swiss NPPs.

In the Leibstadt and Beznau NPPs, a safety controlling function has been 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 controlling function is a voluntarily initiative. It is one element of the NPPs' commitment to continually improve safety. The safety controller independently reviews a whole range of safety aspects, e.g. safety awareness and safety 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.

At the start 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 to swap experience and develop new concepts. Furthermore, the Swiss NPPs are represented in different European and international groups like ENISS (European Nuclear Installation Safety Standards).

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 licence holders 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 ENSI. 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 WANO and, since 2005, all Swiss NPPs have been involved in the WANO peer review process. The cycle for WANO peer reviews and WANO follow-up missions is about four to six years, i.e. every two to three years, the NPPs participate either in a WANO peer review or in a WANO follow-up mission. Since 2013 all the Swiss licence holders have participated in Corporate Peer Reviews and the subsequent follow-up missions.

During 2019–2022, the following WANO peer reviews, WANO follow-up missions and WANO Corporate Peer Reviews and Follow-up missions took place in Switzerland:

- **2019:** WANO follow-up mission at Beznau NPP
- **2019:** WANO Corporate follow-up mission at Axpo Power AG (License holder of Beznau NPP and managing organisation of Leibstadt NPP)
- **2020:** WANO follow-up mission at Gösgen NPP was planned but had to be cancelled due to the COVID-19 pandemic situation.
- **2020:** WANO Corporate peer review at Gösgen AG (licence holder of Gösgen NPP)
- **2022:** WANO peer review at Leibstadt NPP
- **2022:** WANO peer review at Beznau NPP
- In addition to activities organised by WANO, the Swiss NPPs also conducted the following IAEA missions:
- **2019:** IAEA Safety Culture Self-Assessment at Beznau NPP
- **2020:** IAEA Safety Culture Self-Assessment at Beznau NPP
- **2022:** IAEA Safety Culture Self-Assessment at Gösgen NPP

All Swiss NPPs are regularly involved in the WANO peer review process (see above). 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 (see Article 18). 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 for fostering high levels of safety (see Article 12).

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 licence holders 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 licence holder must provide persons with responsibility for the safe operation of a nuclear installation with the necessary resources.

In the majority, the Swiss licence holders are owned by cantons (states) or municipalities. This public ownership ensures a solid financial situation of the licence holders. 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 have voluntarily implemented many modifications or backfitting measures shown to be necessary as a result 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 licence holders also cover the costs for radiological emergency protection.

If, for any reason (e.g. inadequate financial resources), the licence holder could not 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 were 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 dismantling. It is financed by regular contributions from the licence holder. If after the final shutdown the resources paid into the fund during the operation of the plant were insufficient to cover the cost of decommissioning an NPP, the licence holder would still be required to cover the difference. If the licence holder were financially not capable of doing so, the licence holders of the other NPPs would be required to intervene and cover the deficit. The decommissioning cost-studies are reviewed every 5 years and were updated in 2021 according to the increased 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 an adequate number of staff are present in the plant at all times for operation 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 ENSI 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 2021, Mühleberg NPP had a workforce of 279, the twin-unit Beznau NPP had a workforce of 481, Gösgen NPP had a workforce of 585 and Leibstadt NPP had a workforce of 506.

All Swiss plants have long been implementing programmes to ensure early replacement of retiring staff to ensure 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, licence holders use contractors, particularly for maintenance during the annual refuelling outages and plant modifications. They include specialists from the manufacturers or suppliers of major components or systems and other external experts for specific tasks. During these outages, ENSI oversees the qualification and reliability of the contractors' personnel.

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 on Education and Training in Radiation Protection", in Guideline ENSI-B10 "Basic Training, Recurrent Training and Continuing Education of Personnel in Nuclear Installations", in Guideline ENSI-B11 "Emergency Exercises" and in Guideline ENSI-B13 "Training and Continuing Education of Radiation Protection Personnel", which cover actions in radiation protection in incidents and accidents. ENSI examines the fulfilment of these requirements by recognition of education and training courses and/or the recognition of individual competencies. 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 are able to act in accident situations in appropriate ways. Finally, Guideline ENSI-B11 requires plant emergency exercises to be carried out with an emphasis on the participation of the plant fire brigade. Such exercises must be organised on a regular basis and the participation of plant-external fire brigades is now also envisaged. 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 must hold 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 plant licence holder 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 plant licence holder and ENSI. To pass an examination, the candidate must be approved by 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 a degree from an engineering school or university.

The School for Nuclear Technicians 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 post together with management experience and experience in the relevant NPP.

The education and training required by control room personnel to obtain a licence is summarised 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 School for Nuclear Technicians 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 post 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 foreign institution. ENSI supervises the final examinations of candidates for both posts.
Adequate periodic training exists for all of the above posts. It comprises simulator training (except for radiation protection experts), plant-specific courses and theoretical courses, usually at the School for Nuclear Technicians 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. The members of the training section are professionals and are trained in adult education.
All operating 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. ENSI monitors 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 an NPP and ENSI includes an overview of this budget.
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, and 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.

Oversight Approach and Strategy

In recent years, the nuclear industry has been confronted with a variety of changes (e.g. changes in the energy, supplier and labour markets, loss of know-how, new technical safety requirements). The challenges associated with these changes requires nuclear facilities to adapt to these changes. This adaptive performance of an organisation is denoted by organisational resilience. Organisational resilience is the ability of an organisation to responsibly manage situations that affect or may affect safety unfavourably by adapting to situational conditions and evolving in response to changing conditions. To develop and maintain good organisational resilience, it is not enough for an organisation merely to focus on mistakes and shortcomings or on correcting them and avoiding the same or similar mistakes in the future (Safety-I approach). Rather, it is necessary for the organisation to also learn from the positive or normal functioning and observe and analyse how and why things go right and not wrong (Safety-II approach). Accordingly, ENSI has begun to explore how the Safety-II approach can be integrated into its existing oversight activities, which are mainly Safety-I oriented. The team of HOF (Human and Organisational Factors) specialists is taking the lead in these deliberations. In various workshops, it has already discussed the elements of effective Safety-II oriented supervision in the HOF area.

The understanding of the Safety-II approach and the possibility of incorporating it into oversight activities is described in the ENSI report "Fukushima Daiichi: Human and Organisational Factors Part 3 – Implications for Regulatory Oversight of Human and Organisational Factors" (https://www.ensi.ch/en/wp-content/uploads/sites/5/2021/10/ENSI-AN-11071_EN-1.pdf). This report is part of a three-part series on "Fukushima Daiichi: Human and Organisational Factors". In 2011, ENSI published the first part, in 2015 the second part, and finally in 2021, on the occasion of the 10th anniversary of the Fukushima accident, the third part.

Organisation and Safety Culture

Following incidents (INES 1 level) in the Leibstadt NPP in 2014 and subsequent years, as well as in the Gösgen NPP in 2016 that revealed major or recurring deficiencies of an organisational nature, ENSI requested in-depth analyses of these power plants. In both plants, these analyses revealed safety culture weaknesses. Accordingly, both plants improved their safety culture programs continuously and implemented it during the reporting period. To monitor these programmes, ENSI has intensified its oversight activities and, in particular, examined the impact and effects of the initiated programmes on the safety culture.

In December 2019, the NPP Mühleberg underwent final shut-down and comprehensive decommissioning work began. Since then, its organisation has been gradually changing. These organisational changes have been closely monitored by ENSI.

The obligation of the licence holder to establish a suitable organisation is firmly embedded in 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 ENSI-G07 "Organisation of Nuclear Power Installations". In 2020, ENSI started to revise this guideline. The revised guideline will meet the requirements of the IAEA (i.e. GSR Part 2) as well as several WENRA reference levels and will consider new safety concepts such as "Organisational Resilience" and "Safety-II". In summer 2022, the draft guideline will enter the external consultation phase.

ENSI has conducted a series of oversight activities, e.g. inspections and technical discussions in the area of organisation as well as safety culture. In addition to these ordinary oversight instruments for organisational as well as plant engineering issues, ENSI 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 licence holders can consider safety culture topics previously raised by ENSI. ENSI facilitates the discussions in an open and constructive way. This specialist discussion on safety culture was awarded a "good practice" rating by the IRRS Mission 2021 experts.

In 2021, ENSI conducted such a discussion on the subject "Leadership in a resilient organisation".

During the review period, both plants were confronted with the continuing consequences of the liberalisation of the electricity markets and the Swiss Federal Government's decision to phase out nuclear energy and the associated developments in the nuclear energy sector. These led to staff reductions, centralisation in the licence holder's corporation and to restructuring on the part of manufacturers and suppliers. Both facilities were therefore forced to increasingly deal with issues relating to the provision and organisation and thus the preservation of safety-relevant resources (personnel, funds, knowledge) and corresponding decisions had to be made by the power plant and corporation management. According to the nuclear energy legislation, the responsibility for safety is assigned to all actors (i.e. the representatives of the licence holder as well as of the power plant management). Due to the hierarchical organisation, however, the power plant manager is dependent on the licence holder or its representatives. According to the Guideline on the organisation of nuclear power plants (ENSI-G07), it must be ensured that the dependency implicit in their relationship does not have any unfavourable influences on safety. Particular attention must be paid to this requirement, particularly in the event of conflicts or differing opinions on safety issues.

Therefore, ENSI has raised the following requirement: The plants must report in detail on the procedure for safety-related decisions in the event of differing opinions or conflicts between corporate and power plant management. In particular, how it is ensured that the dependency implicit in the relationship between the management of the power plant and the corporation does not have an unfavourable influence on safety (see Guideline ENSI-G07).

All Swiss nuclear power plants have had pandemic plans since the end of the 2000s. These plans have been further developed in recent years and updated for the current COVID-19 outbreak (for more information on the Swiss reaction to the pandemic, see separate chapter in Summary and Conclusions). The pandemic plans contain measures to prevent disease transmission between employees and to maintain safe and reliable electricity production. They should ensure that the number of staff required for safe operation does not fall below a critical threshold and that the greatest possible redundancy of staff is maintained. With the outbreak of the pandemic and continuously during the pandemic, ENSI conducted technical discussions on the implementation of the pandemic plans at all nuclear facilities.

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". ENSI pays particular attention to this principle when it oversees modifications that affect human-machine interfaces. Since 2007, ENSI has required a human factors engineering programme in conjunction with the initial concept of modernisation projects. Within the human factors engineering programme, the licence holder 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 requirement 7 “Application of the graded approach to the management system” of the IAEA Safety Standard GSR Part 2.

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, the members of which receive adequate education and training on a regular basis.

Developments and Conclusion

The continuing consequences of the liberalisation of the electricity markets, the Swiss Federal Government’s decision to phase out nuclear energy as well as the associated developments in the nuclear energy sector have led to nuclear facilities being subject to various changes. The response of power plants to these changes, as well as organisational weaknesses revealed during events, have been closely monitored by ENSI. With the Safety-II approach, the HOF team has started to introduce new oversight activities in the field of human and organisational factors. ENSI has continued to pursue its efforts 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 NPPs have an integrated management system and all are certified according to DIN ISO 9001 (Quality Management). According to the certification roles, the management systems are audited periodically by the certification institute and the certificates are renewed on a regular basis. NPPs apply well-established methods for self-assessment of their management system. Major changes in the management system require notification to ENSI.

By applying a graded approach, ENSI concentrates its oversight activities on the aspects of the licence holder's management system that are most relevant to nuclear safety. These safety-relevant processes need to ensure an appropriate quality assurance of their outputs. They are supervised by ENSI within the framework of different oversight activities such as in the event analysis process, outage management and the process for plant modifications. Due to the ageing issues, plant life extension and the Swiss regulatory requirement for maintaining the plant up to the latest state-of-the-art of science and technology, there is an ongoing need for plant modifications. All NPP activities other than normal operation activities, and which are relevant for safety, e. g. backfitting, replacement and modifications to systems and components, need a permit. To be able to grant its regulatory approval, ENSI assesses the quality assurance programme paying special attention to the performance of an independent verification of all safety-relevant information within the framework of the quality assurance process.

On a yearly basis, ENSI performs a series of inspections relating to the management system of all nuclear installations which are always dedicated to an actual oversight topic. The recent series of inspections addressed how the senior management meets its responsibility regarding the assessment of the effectiveness of the quality management systems within the framework of the continuous improvement cycle (PDCA cycle). The licence holders demonstrated how the process of information gathering and aggregation up to the senior management level works. The senior management then takes decisions and implements actions based on this information reflecting their own strategy and objectives as well as the actual external context the licence holder organisation is facing.

Another inspection series was performed on the auditing process as a part of the licence holder's self-assessment programme. Alongside the internal processes, proper quality assurance is required for the products and services provided by external suppliers for which the licence holders must take full responsibility for in accordance with Article 30 of the Swiss Nuclear Ordinance. In this respect, the licence holder indicated how supplier audits are used to ensure appropriate quality of the supplied products and services. Where the supply chain is concerned, the licence holders have identified issues in respect of the diminishing number of suppliers, and inappropriate quality assurance processes of the suppliers. In the future, this will become a major challenge.

Overall, ENSI confirmed the fulfilment of the regulatory requirements for both topics. ENSI made suggestions for continuous improvements including the sharing of good practices in the way the topics are considered within the different licence holder organisations.

Developments and Conclusion

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

The NPPs apply internal and external audits as well as established self-assessment methods in order to advance the continuous improvement of their management systems. These processes have been recently inspected by ENSI. With respect to the quality assurance of external products and services, ENSI also looked at the supplier audit process.

ENSI regularly performs inspections to assess the effectiveness of quality assurance measures within the management system. As part of the continuous improvement of the management systems, ENSI has paid particular attention to how the senior management meets its responsibilities in assessing the effectiveness of the quality management systems within the framework of the continuous improvement cycle (PDCA cycle).

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 ENSI'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 ENSI. ENSI'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 licence holders must perform annual safety assessments according to the requirements given in Guideline ENSI-G08 and probabilistic evaluations of their operating experience according to 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 or higher have occurred in a national or international NPP. As a direct consequence of the major accident in Japan, ENSI issued three formal orders in which the operators of the Swiss nuclear power plants were required to implement immediate actions and to conduct additional reassessments. ENSI ordered immediate actions comprising the establishment of an external emergency storage facility for the Swiss NPPs, including implementation of the necessary plant-specific connections and undertaking of the necessary backfitting measures to ensure the provision of external injection means into the spent fuel pools The additional reassessments, which had to be carried out immediately, focused on the design basis of Swiss NPPs in respect of protection against earthquakes, external flooding, extreme weather conditions and credible 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.

The DETEC Ordinance on the Hazard Assumptions and the Assessment of the Protection against Accidents in Nuclear Installations SR 732.112.2 demands that, in the case of new or changed hazard assumptions, the deterministic and the probabilistic safety assessments have to be updated. Accordingly, after definition of the new earthquake hazard ENSI-2015 (see Article 17 and 18) in May 2016, ENSI issued a formal order to the operators of the Swiss nuclear power plants to update the earthquakes safety assessment: a) by the end of 2018 the safety case originally required by ENSI after the Fukushima reactor accident in March 2011, b) by mid-2019 the probabilistic safety analysis, and c) by the end of September 2020 a detailed and refined deterministic safety analysis. Due to the effects of the COVID pandemic, ENSI accepted a phased submission of part c) by the end of September 2021. While safety case a) is based on the 10^{-4} per year earthquake and some simplified assumptions, the full deterministic safety analysis c) requires a more detailed analysis of both the 10^{-3} per year and the 10^{-4} per year earthquakes (see deterministic analysis in this article). The operators of the Swiss nuclear power plants have updated their earthquake safety assessment accordingly. After an in-depth assessment, ENSI has accepted the updated safety case a) for all Swiss nuclear power plants and the corresponding update of the probabilistic safety analyses [case b)]. Case c) (i.e., the refined deterministic safety analyses) is currently under scrutiny.

A comprehensive reassessment of the external flood hazard at the Aare river was carried out under the lead of the Federal Office for the Environment together with other regulatory bodies including ENSI. The project established a common basis for the flood hazard assessment of various regulatory bodies. A Probabilistic Flood Hazard Analysis (PFHA) methodology was developed so that extremely rare events can also be assessed. The results consist of water level hazard curves that also take into account effects like debris or blockage of bridges. The water levels at the sites with an exceedance frequency of 10^{-4} per year are in the same range as those used for prior safety analyses and are covered by the safety margins of the nuclear facilities. The results of the project also include the hydraulic parameters needed for a closer evaluation of morphological effects such as the erosion of the surface or the shore. ENSI requested the licence holders to perform a new safety assessment that also includes the morphological effects.

Extreme weather conditions of increased relevance for the Swiss nuclear plants such as extreme wind, tornados, heavy rain, extreme air and water temperatures in winter and summer and extreme snowfall have been examined within the scope of the EU stress test and were updated (the review will be concluded in 2022). As far as possible, the evaluation is based on the IAEA Specific Safety Guide SSG-18 on Meteorological and Hydrological Hazards in Site Evaluation for Nuclear Installations.

The recent update of Guideline ENSI-A01 (September 2018) explicitly requires that a safety margin analysis is performed for natural hazards as part of a DEC-A evaluation.

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

Due to the accident at the Fukushima Daiichi NPP, the Swiss government has suspended plans for new-builds. On-going activities concerning safety assessments for the different stages in the lifetime of nuclear installations comprise:

- periodic safety assessments (PSR) and
- assessments of long-term operation (LTO).

Long-Term Operation

ENSI's approach for long-term operation (LTO) is based on international recommendations, IAEA-Safety Guides NS-G-2.6 and SSG-48, IAEA-SALTO Guidelines, WENRA Reactor Safety Reference Levels (Issues K and I), and on the Swiss legislative basis – the Nuclear Energy Act, Nuclear Energy Ordinance, DETEC Ordinance on the Methodology and the General Conditions for Checking the Criteria for the Provisional Taking out of Service of Nuclear Power Plants, Guidelines ENSI-B01, ENSI-B06 and the Guideline of the Swiss Association for Technical Inspections (SVTI) SVTI NE-14. According to Article 34, para. 4 of the Nuclear Energy Ordinance, which has been in force since June 2017, an additional LTO safety proof must be submitted as part of the PSR for the period following the fourth operating decade. Included within this, according to Article 34a, which has also been in force since June 2017, must be proof that the design limits of plant components relevant for safety will not be reached during the planned period of operation;

moreover, backfitting and organisational improvements for the following operating decade must also be shown. Furthermore, 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 programmes (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) in respect of the relevant ageing mechanisms, including forecast analyses for the next reporting period. Within the area of conceptual considerations on ageing, the focus is on the plant safety concept (updated deterministic and probabilistic analyses) and on backfittings (taking into consideration the advancements in the state-of-the-art of backfitting technology). In particular, the licence holder is required to demonstrate that the limits described in the recently updated DETEC Ordinance on the Methodology and Conditions for the Assessment of the Criteria for Provisional Shutdown of Nuclear Power Plants (SR 732.114.5) are adhered to. An infringement of these limits implies that the NPP must be provisionally shut down.

The licence holders of the following Swiss NPPs have submitted the required LTO safety proofs. Beznau NPP submitted its documents in 2008 and 2018, Mühleberg NPP (undergoing decommissioning) in 2010, and Gösgen NPP in 2018. The LTO safety assessment of Leibstadt NPP will be performed with the upcoming PSR in 2022. Results of the ENSI review are described in the LTO safety evaluation reports dated November 2010 and November 2021 for Beznau NPP and December 2012 for Mühleberg NPP, while the 2018 Gösgen documents are currently under review by ENSI. As a result of the LTO review, it was confirmed by ENSI that Beznau NPP meets the Swiss safety objectives at least for an additional 10 years of operation. There is no indication that the terms and conditions for a provisional shutdown (DETEC Ordinance SR 732.112.5) will be reached. In 2013, the licence holder of Mühleberg NPP decided to cease operation in 2019 for commercial reasons and cancelled the planned LTO backfitting programme. ENSI issued a formal order to establish binding conditions for operation until 2019, requesting that alternative measures be implemented.

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 licence holders and ENSI. It enables them to identify and assess the actual state of safety in a plant in order to ensure compliance with legal requirements, the provisions of the licenses and the official stipulations of ENSI. 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 licence holder carries out the PSR and ENSI evaluates the PSR report submitted by the licence holder. ENSI adds its own experience from previous inspections, assessments and reviews.

The concept of defence in depth, as described in the IAEA Specific Safety Requirements SSR-2/1 (Rev. 1), plays a central role in the PSR and its evaluation. In its report, the licence holder is required:

- to specify 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 licence holder 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 licence holder 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 from the last 10 years, the licence holder must pay particular attention to human and organisational factors and their impact on safety. ENSI's assessment also considers the licence holder's safety culture. The PSR not only includes a review of the plant's current safety status but also an assessment of its future safety status.

Deterministic analysis

The Nuclear Energy Ordinance (NEO) Article 34 requires Swiss NPPs to implement a Deterministic Safety Status Analysis (DSSA). The deterministic analyses consist of technical analyses to be performed according to Guideline ENSI-A01 and radiological analyses according to Guideline ENSI-A08 and Guideline ENSI-G14. The requirements focus on protection against design-basis accidents and selected beyond design-basis accidents. The initiating events to be considered in the design are listed in paragraphs 2 and 3 of Article 8 of the NEO. More specific requirements regarding hazard assumptions and assessment of the degree of protection against initiating events are given in the Ordinance on Hazard Assumptions and Evaluation of Protection Measures against Accidents in Nuclear Installations (SR 732.112.2). This Ordinance assigns one of three categories to the design-basis accidents dependent on their frequency of occurrence and defines technical compliance criteria and related technical and radiological safety objectives dependent on the assigned accident category. Design Basis Accidents (DBA) with an origin other than from natural hazards must be considered down to a frequency greater than 10^{-6} per year. For accidents arising from natural hazards according to the recent amendment of Article 8 of the NEO (amendment of 1 February 2019) deterministic analyses for design-basis accidents with frequencies of 10^{-3} per year and 10^{-4} per year must be performed, and compliance with dose limits of 1 mSv and 100 mSv respectively must be demonstrated. In particular, the verification for the 10^{-3} per year natural hazard event is new and the dose limit for this accident category (1 mSv) in Switzerland is very strict.

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

- suitability, validation and compliance with best estimate calculation programmes;
- 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.

ENSI's review also includes independent DBA analyses using appropriate computer codes and own plant models, which are still being further developed. Additionally, the requirements in particular on the Safety Level 3 accidents of nuclear installations as distinct from NPPs have been expressed in more detail in the recent amendment of Guideline ENSI-A01 (September 2018).

The requirements for the radiological analyses for the determination of the source term to the environment are given in Guideline ENSI-A08 for both NPPs and other nuclear installations. Radiological inventories, pathways and thermal-hydraulic conditions for the transport of radionuclides within the plant are considered. Guideline ENSI-G14 specifies the requirements for the subsequent calculation of the radiological consequences for the neighbouring population considering the dispersion of radionuclides in the environment and exposure pathways.

Furthermore, selected beyond-design-basis accidents (BDBA) must be considered in the deterministic safety analyses. Recent amendments to ENSI's Guideline ENSI-A01 distinguish between Safety Level 4a (SL4a) and Safety Level 4b (SL4b) accidents in nuclear power plants. These correspond to the Design Extension Conditions (DEC) A and DEC B from the WENRA RHWG Guidance Document for Issue F: Design Extension of Existing Reactors. For SL4a accidents (e.g. Anticipated Transient Without Scram or Total Station Blackout) prevention of severe fuel damage in the core or in the spent fuel pool has to be demonstrated. The list of SL4a accidents is derived from the WENRA Safety Reference Levels for Existing Reactors, 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, requirements for the periodic maintenance and updating of the PSA, the scope of mandatory PSA applications and also defines corresponding risk measures and/or evaluation criteria.

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

Furthermore, the PSAs of Swiss NPPs also consider the risk of radioactive release from the spent fuel pool. For non-power operation, consideration of the spent fuel pool in the PSA is mandatory. For power operation, consideration of the spent fuel pool in the PSA depends on criteria defined in Guideline ENSI-A05.

The licence holders update PSAs at regular intervals. Every 10 years, as part of the 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 to include 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 are the main basis of the regulatory review of the PSA studies. The regulatory review aims to develop a thorough understanding of plant attributes, plant-specific operating characteristics, and the plant's vulnerability to potential severe accidents. The review focuses on a general evaluation of PSA models, assumptions, analytical methods, data and numerical results. 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, ENSI submits requests for additional information to the licence holder 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.

Guideline ENSI-A06 formalises the application of PSA in the regulatory framework with the aim of identifying potential plant improvements, complementing safety assessments within the integrated reactor oversight process and defining relevant risk measures and/or evaluation criteria. With the aim of achieving these objectives, 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 operating experience, including reportable events.

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

- Probabilistic hazard assessment for external events. The hazard curves are used for the PSA itself and as an input for the specification of the 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 their 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, if necessary, be submitted to ENSI in support of an application for a modification of or backfitting to safety-related systems or components before any such work is performed. 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 startup tests as required, procedure for periodic inspections and audits, and finally probabilistic evaluation in respect of the impact of the modification or backfitting 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

ENSI's arrangements and regulatory requirements for the verification of safety relate to the outage activities and refuelling process, backfitting and replacement programmes, inspections, information meetings, and the review of extraordinary licence holder's reports, and plant modifications derived by ENSI as a result of national or international events of INES 2 and higher.

Fukushima

Within the scope of the EU stress test performed on ENSI's orders following the Fukushima accident, the operators of the Swiss nuclear power plants submitted their reports. The results of ENSI's review confirmed that the Swiss NPPs displayed 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.

A complete summary of the 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 ENSI. Finally, the compliance of the plant condition with the approval bases is examined in the course of ongoing oversight and during inspections by and technical discussions with the regulatory 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 multi-facetted review. Below are some examples:

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

ENSI issues a letter granting permission to restart plant operation after the maintenance/refuelling outage. In this letter, ENSI 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. ENSI documents its own activities during the outage in a separate outage report.

During the past two years, the activities during outage and refuelling were significantly affected by the COVID pandemic. The licence holders needed to adjust their outage planning and set up a concept for protection against the pandemic. Due to the pandemic situation, ENSI was temporarily forced to reduce the number of on-site inspections. ENSI continued the verification of safety by increased performance of remote-inspections and document review. ENSI also carried out specific inspections to make sure that there was no negative impact on nuclear safety as a result of the protective measures against the pandemic. The reported lessons learned of the licence holders concluded that some protective measures against the pandemic even contributed positively to nuclear safety. For instance, the staggered shift working hours (including breaks), the setup of a second transfer gate to the controlled zone and mask-wearing obligation in the controlled zone contributed to a safer workflow.

Backfitting and replacement

Backfitting and replacement of safety-related equipment are necessary when existing equipment no longer satisfies current standards or when it becomes difficult to maintain. ENSI may also require backfitting or replacement of equipment in other circumstances, e.g. following a PSR. In addition, a backfitting programme is required when an NPP enters long term operation (i.e., after 40 years of operation). New equipment is mainly installed and commissioned during plant outages. ENSI reviews the process for such activities and in so doing is able to monitor the process closely. ENSI approves the design, installation, modification and commissioning of safety classified equipment.
A list of backfittings and improvements is given in Article 18.

Inspection

Inspections in nuclear installations are primarily performed by ENSI. In the area of mechanical engineering, some aspects of inspections are delegated to external experts who act exclusively on behalf of ENSI.
The regulatory inspections by ENSI form 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 (e.g. fire or flooding protection), the relevant natural sciences disciplines (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.

ENSI 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, ENSI's management defines **issue-based inspections.** These 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 operating experience, events, or plant modifications proposed by the licence holder. Since its shutdown on 20 December 2019, inspections at Mühleberg NPP have been performed in accordance with decommissioning progress.
Inspections may be performed at any time but are more frequent during outages than during normal operation. In most cases, the licence holder 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 operating life of nuclear installations, although a few inspections cover nuclear installations, for instance research reactors, which have been shut down.

A full-time site inspector is appointed for each NPP. Other nuclear installations are allotted part-time installation inspectors. As ENSI's offices in Brugg and the NPP sites are relatively close geographically, regional offices are not required. For the same reason, there are no resident inspectors but offices are available to the site inspectors of the NPPs.

During normal operation, the site inspector is, on average, present at the site one day per week. During outages, the site inspector is present for four or five days. Since the shutdown of Mühleberg NPP, the presence of the site inspector has been adjusted and largely increased. 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 ENSI. The duties of site inspectors are not limited to inspections. They also act as a vital link between the licence holder and ENSI. Site inspectors take the lead role in the systematic safety assessments (see below), which are part of the process of integrated oversight.

Information meetings

Each site inspector (see above) conducts monthly meetings with the respective licence holder in order to obtain the latest information on plant status and performance. Further members of the management of ENSI and the licence holder meet annually for an information meeting at which the licence holder reports on plant operation. The meetings also discuss special issues and on-going or planned projects. ENSI then gives its view on the various topics and clarifies current or future requirements (safety-related requirements are normally presented to the licence holder before any enforcement).

In addition, there is an annual meeting between senior managers from ENSI and the NPP in order to discuss current safety issues. There are also annual management meetings between ENSI's senior management and senior managers from Zwilag, PSI, Nagra and the TSO SVTI.

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

Elements of ageing management programme(s)

Review of the Ageing Surveillance Programme

The safety-relevant aspects of material ageing must be taken into account for all classified systems, structures and components (SSCs). Switzerland was one of the first countries to introduce systematic ageing management programmes (AMPs). All licence holders started their plant specific AMPs in 1992. The regulatory expectations for AMPs in Switzerland are provided within the current Guideline ENSI-B01 (issued 2011), which superseded guideline HSK-R51 (issued in 2004). Guideline ENSI-B01 is based on the legal framework in Switzerland (Nuclear Energy Ordinance and Nuclear Energy Act) and the Guideline refers to the requirements in IAEA Safety Guide NS-G-2.12 that relate to material ageing issues. ENSI has checked IAEA Safety Guide SSG-48, published in November 2018 and superseding Safety Guide NS-G-2.12, in respect of its implications for the existing AMPs. Thus far, no need for immediate implementation of new requirements has been identified. References to the new IAEA Safety Guide will be updated in the next revision of Guideline ENSI-B01.

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

AMPs cover the areas of mechanical, electrical and civil engineering SSCs. There are specific requirements for the individual implementation of AMPs 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; this is also based on the approach according to IAEA TECDOC-1736. The documentation of AMPs in Switzerland comprises:

- Technology-specific assessment of the potential possible ageing mechanisms;
- Plant-specific or generic guidelines;
- Fact sheets on ageing management with structural-element specific / component-part-specific or component-specific categorisation of the relevant ageing mechanisms and their assignment to the respective maintenance programmes. The guideline requires the updating of fact sheets to reflect any new safety-related results or, if not, updating at least once every ten years;
- Annual status reports that include a compilation of: updated fact-sheets and complementary measures; evaluation of ageing-relevant internal and external operating experience and the 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 scope and the qualification process of the respective in-service inspection programmes (ISIs) for mechanical components and are considered as 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 of specific material degradation issues (e.g. material degradation susceptibility under specific conditions, root cause analysis of flaws);
- Modification/adjustment of in-service inspection programmes (temporary or permanent);
- Mitigation techniques;

Switzerland voluntarily took part in the first ENSREG Topical Peer Review (TPR) Process which started in 2017 based on the EU Nuclear Safety Directive 2014/87/EURATOM. This first Topical Peer Review was focused on the overall ageing management programmes as well as some specific ageing supervision programmes implemented in Nuclear Power Plants (NPPs) and Research Reactors (RRs) above 1 MWth (not relevant for Switzerland). In the first phase of the review, national self-assessments consisting of a description and assessment of AMPs were conducted and the results were documented in the National Assessment Reports (NARs), published at the end of 2017. The second phase started in January 2018 when the National Assessment Reports were made available for questions and comments from stakeholders. The self-assessments, questions from stakeholders and the participating countries' responses were discussed during a one-week workshop in May 2018. The identified generic and country-specific findings on AMPs were compiled by ENSREG and published in October 2018 to provide input for national action plans. The TPR report confirmed that the Swiss NPPs have implemented effective AMPs. The TPR board defined categories for the evaluation of different aspects within AMPs: "good practice" (an aspect of ageing management which is considered to go beyond what is required in meeting the appropriate international standard), "good performance / TPR expected level of performance" (level of performance that should be reached to ensure consistent and acceptable management of ageing throughout Europe), and "area for improvement." In addition, challenges which are common to many or all countries were identified. Switzerland was issued a number of good practices for:

- Application of a method for inspection, monitoring and assessment of inaccessible structures
- Use of hydrogen water chemistry and noble metal injection in BWRs (NPP Leibstadt, formerly also NPP Mühleberg) as a measure to prevent or delay stress corrosion cracking
- External peer review services to provide independent advice and assessment of licence holders' ageing management programmes
- Performance checks on the behaviour of new types of materials by inspection of original material samples aged under realistic operational conditions.

Another six aspects were considered as good performance:

- Participation in international projects and groups and use of existing international databases
- Adaptation of AMPs during extended shutdown
- Inspection of safety-related pipe penetrations through concrete structures
- Volumetric inspection of nickel base alloy penetrations which are susceptible to primary water stress corrosion cracking (PWSCC)
- Non-destructive inspections of the RPV base material
- Fatigue analyses taking into consideration the environmental effect of the coolant.

The following aspects were identified as areas for improvement:

- Review of the scope of existing AMPs against new IAEA requirements and updating if necessary
- Include non-safety-related inaccessible pipework whose failure may impact SSCs performing safety functions in AMPs
- Application of opportunistic inspections of inaccessible pipework when they become accessible for other purposes.

In 2018, ENSI conducted a set of topical inspections on AMPs for inaccessible structures and piping in all of the Swiss NPPs. These inspections showed that most inaccessible areas are included in either AMPs or maintenance programmes. Opportunistic inspections on inaccessible structures and pipes have been carried out by some of the NPPs and are planned for all of the Swiss NPPs.

To address the results of the TPR process and the inspections conducted, a Swiss National Action Plan was established and published in 2019. The following actions have been defined:

- Guideline ENSI-B02 (Periodic Reporting by the Nuclear Installations) will be revised. The required content of the annual reporting will be defined more precisely in order to obtain more consistent information from the Swiss NPPs concerning the updated fact sheets, the evaluation of international operating experience and the assessment of the effectiveness of the opportunistic AMPs in particular.
- Guideline ENSI-B01 (Ageing Management) will be revised. Subsequently, the scope of the AMPs and the approach for determining which SSCs are to be reviewed to ensure that they are consistent with the new IAEA Safety Guide SSG-48.
- Requirements for the ageing management of concealed pipework will be explicitly addressed in the next revision of Guideline ENSI-B01. The requirements for the content of fact sheets will be updated to include a statement on safety-relevant concealed pipework section for each system.

Guideline ENSI-B02 was revised in 2020 and issued in February 2021. The following changes were implemented:

- The way in which new or changed fact sheets are to be documented has been clarified.
- The information sources that are to be used as a minimum for the evaluation of external operating experience have been defined.
- The topics to be evaluated as part of the monitoring of the state of art in science and technology have been expanded with a focus on long-term plant operation.

- The evaluation of the effectiveness of the ageing management programme is to be assessed on the basis of the trend of findings from maintenance over a period of several years.

The revision of Guideline ENSI-B01 has begun and will be completed by no later than the end of 2023.

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 periodic 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 defines the detailed requirements in terms of the content of the report to ENSI. These aspects are covered in Guidelines ENSI-B02 and ENSI-B03, both of which came into force in 2009 and were updated in 2021. 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 licence holder 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 licence holders may trigger regulatory requirements or recommendations for improvement. ENSI 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 licence holder.

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 ENSI's integrated oversight approach, all aspects of relevance to nuclear safety are integrated into a single comprehensive oversight strategy. The aim is twofold: firstly, ENSI 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, ENSI must ensure it takes adequate and effective measures after detecting a weakness in a safety provision. Every assessment and action must be justified and traceable.

To obtain a realistic picture of the safety of each installation, ENSI 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 the state and behaviour of the plant, and human and organisational factors.
- Secondly, information is structured based on the following safety objectives:
- safety functions;
- levels of defence in depth and barrier integrity.

Table 3: Safety Assessment Table – Defence in Depth

Subject / Goals		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 4: 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				

For each NPP, data is collected as shown in Table 3 and Table 4.

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

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 ENSI fall into this category
- **Category A:** Deviation – deviations from normal operation within operational limits and conditions or deviations from a law, an ordinance, an inspection requirement or from occupational safety regulations that could be relevant to nuclear safety.
- **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 decide 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 licence holder 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 ENSI.

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.

Overview of the Contracting Party's arrangements and regulatory requirements concerning radiation protection at nuclear installations, including applicable laws not mentioned under Article 7

The Radiological Protection Act came into force in 1994. Based on the recommendations of the International Commission on Radiological Protection (ICRP) (e.g. Publication No. 103), the Radiological Protection Ordinance was totally revised and came into force in 2018. The Ordinance's contents are arranged according to the recommended layout into planned, emergency, and existing exposure situations. Relevant changes, amongst others, were the distinctions between dose factors for infants (1 y), children (10 y) and adults as well as dose factors for irradiation from airborne plume and the ground. The objective of the latest revision of the Ordinance was to achieve compatibility with the new European Safety Directive, 2013/59/EURATOM of 5 December 2013, and the IAEA Basic Safety Standard, GSR Part 3 of July 2014.

The Radiological Protection Act specifies the roles, functions, and duties of participating parties or personnel e.g. the licence holder, the licensing authority, the regulatory authority as well as the radiation protection experts appointed by the licence holder.

In addition to the Radiological Protection Ordinance, the following ordinances relevant for nuclear installations were also revised and enacted in 2018:

- Ordinance on Personal and Environmental Dosimetry (Dosimetry Ordinance)
- Ordinance on Education and Training in Radiological Protection (Radiological Protection Education Ordinance)
- Ordinance on the Handling of Radioactive Materials
- Ordinance on Radiological Protection in non-medical installations for the production of ionising radiation
- Ordinance on Measuring Equipment for Ionising Radiation

The new Guideline ENSI-G12 "Nuclear Facility internal Radiation Protection Measures" was enacted on 1 November 2021. It comprises all aspects regarding the radiation protection objectives "source term reduction", "containment of radioactivity using barriers in the radiological controlled area", "limiting and optimisation of external exposure" as well as "prevention of radionuclide incorporation and contamination of personnel". Guideline ENSI-G12 replaces the guideline HSK-R-07, enacted in 1995, and specifies the Radiation Protection Ordinance for application in nuclear facilities.

ENSI has revised or is in the process of revising and adapting all of its other guidelines relevant for radiation protection:

- **ENSI-B04:** Clearance of materials and zones from controlled areas (revised and issued in November 2018);
- **ENSI-B09:** Determining and reporting of doses from occupationally radiation-exposed personnel (revised and issued in July 2018);
- **ENSI-G13:** Radiation protection measuring instruments in nuclear facilities, basic concepts, standards and testing (revised and issued in July 2018);
- **ENSI-G14:** Calculation of the radiation exposure in the vicinity of nuclear installations due to emissions of radioactive materials (revision started 2019 and is ongoing);

- **ENSI-G15:** Radiation protection objectives of nuclear installations (revision started 2021 and is ongoing).

Regulatory expectations for the licence holder's processes to optimise radiation doses and to implement the "as low as reasonably achievable" (ALARA) principle

In addition to the main radiation protection objectives, the new Guideline ENSI-G12 contains detailed requirements about the implementation of justification, limitation and optimisation in radiation protection.
To verify the justification of the risk of exposure caused by a proposed activity/work, the responsible person has to check at the beginning of the planning process whether the activity/work is part of the scope of the licensed object, such as the operation of an NPP to produce power including its maintenance as well as all activities ensuring nuclear safety and security. In the event that the proposed activity is not connected to a licence, the justification must be presented when applying for an additional licence.

In order to ensure compliance with the annual dose limits for all persons on the site of a nuclear installation, the licence holder or appointed radiation protection experts must set up several dose constraints (for particular individuals or for groups, different facilities, different periods, and different activities) and consider optimised RP provisions when adding up all job doses/daily doses. These dose constraints may be expressed in terms of annual dose planning targets, dose quota (for working in different facilities or during different periods), collective dose planning targets, and individual job dose planning targets, daily dose limits etc.

The most important tool for the implementation of ALARA is the establishment and ongoing development of a radiation protection planning process and its consistent application by experienced RP staff. Therefore, Guideline ENSI-G12 requires the inclusion of an RP planning process in the radiation protection programme, and furthermore, it has to be incorporated in the management system of the nuclear installation.
In its Publication 75, the ICRP recommends the use of operational dose constraints based on good practice together with optimisation. Analogously, Guideline ENSI-G12 requires an NPP to determine an optimisation step within the radiation protection planning process by checking whether additional or improved RP measures may be taken to reduce the ALARA doses based on:

- empirical values from comparable activities in its own or in a comparable facility;
- the current radiological situation;
- international operating experience;

resulting in the determination of dose planning objectives (e.g. maximum individual doses or collective job doses) for the respective planned activities.

Implementation of radiation protection programmes by the licence holders

The Nuclear Energy Ordinance requires the implementation of a radiation protection regulation by the licence holder, which according to IAEA GSR 3 Requirement 24 may be called a radiation protection programme. The regulation/programme has to regulate all procedures relevant for covering the duties of the operating licence holder in respect of radiation protection. Guideline ENSI-G09 comprises further and more detailed requirements about the radiation protection programme. In addition to being the guideline for radiation protection planning, ENSI-G09 specifies a total of 26 different duties in RP that must be transformed into procedures. In particular, duties such as the measurement of radioactivity released into the atmosphere and the protection of personnel working in the controlled area of a nuclear installation. The implementation as well as each modification of the radiation protection programme must be checked and permitted by ENSI.

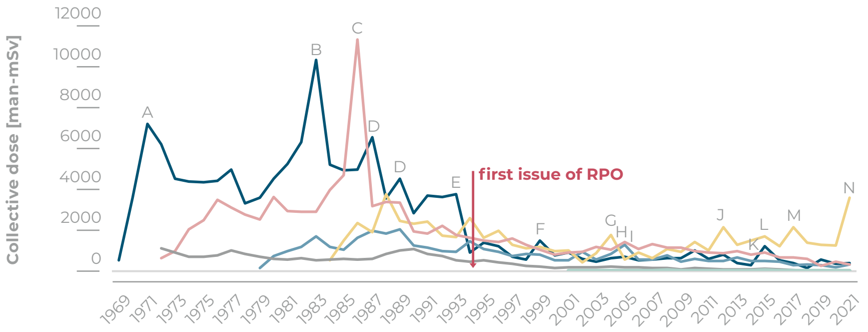
Observation of dose limits and main results for doses to exposed workers Dose limits

The Radiological Protection Ordinance limits the general maximum individual total dose for NPP personnel (plant personnel and contractors) to 20 mSv per year.

The total number of plant personnel and contractors occupationally exposed to ionising radiation in all Swiss nuclear facilities is around 6000. The annual collective doses of the last 20 years are presented in Figure 6.

The cause of the collective dose value peaks in Figure 6 are explained as extraordinary projects as described in Figure 6. With the enactment of the first Radiation Protection Ordinance in 1994 the Swiss nuclear facilities implemented the principle of optimisation, as well as lower dose limits.

Figure 6: Annual collective dose from 1969 to 2021



Annual collective doses for the personnel in Swiss NPPs, the Central Interim Storage Facility (ZZL) and the research institute PSI. All peaks relate to extraordinary work performed. (note: the Beznau NPP consists of two units, both located on the same site)

KKB I + II **KKG** **KKL** **KKM** **PSI** **ZZL**

A damaged fuel element replacement at NPP Beznau 1

B steam generators antivibration system installation NPP Beznau 1 & 2

C cooling circuit replacement NPP Mühleberg

D steam generators maintenance NPP Beznau

E steam generators replacement NPP Beznau 1

F steam generators replacement NPP Beznau 2

G extensive revision and generator replacement NPP Leibstadt

H tests in drywell, control-rod maintenance and operations in reactor pool

I replacement of safety valves in the pressuriser NPP Gösgen

J N5-noozle repair NPP Leibstadt

K reactor pressure vessel closure heads replacement NPP Beznau 1 & 2

L preparatory work on cooling circuit replacement NPP Leibstadt

M extensive non-destructive tests on the primary system NPP Leibstadt

N cooling circuit replacement NPP Leibstadt

Processes implemented and steps taken to ensure that radiation exposures are kept as low as reasonably achievable for all operational and maintenance activities

Over the years, more and more NPP-specific measures have been taken to keep radiation exposure, resulting from the operation and maintenance of NPPs, as low as reasonably achievable. In 1994 the new annual dose limit for individuals of 20 mSv per year was introduced. This limit was exceeded only during two incidents: in Beznau NPP I in 2009 and in Leibstadt NPP in 2010. In both cases, the individual doses did not exceed 50 mSv. The lessons learned from these incidents were used to improve and to enhance the radiation protection measures, which helped to prevent a repetition of such exposure situations. The mean individual doses for plant personnel and contractors show a stable evolution in all NPPs over the past few years. The significant dose reducing efforts made particularly between 1988 and 1995 are of note. Since 2013, extended maintenance works have caused a slight increase in the annual collective doses as well as the mean individual doses measured in Leibstadt NPP as a result of extended maintenance works in spite of further optimisation having been carried out. The increase in the mean individual doses in Beznau NPP can be explained by the extended outage periods of both units, in which various projects supported by numerous contractors were performed on site.

The most significant dose reduction measures implemented in Swiss NPPs during the last years, are compiled in Table 5.

Regulatory review and control activities

As mentioned above, ENSI reviews the radiation protection planning process of the NPPs as a part of its regulatory duties. Additionally, the licence holder, represented by the appointed radiation protection expert, must submit the radiation protection plan for a pending outage to ENSI in advance of the outage. The plan must comprise a description by the expert of the intended radiation protection measures and optimisation areas and must report the planned dose objectives.

The most important part of inspections concerning radiation protection are focused on the outage phases of each NPP. Usually, these inspections are planned several weeks in advance, based on the radiation protection plans provided by the plant. Other routine inspections are performed during operation in addition to specific inspections focused on special topics, such as source term reduction, contamination barriers, provisions implemented to limit and optimise external doses, protective measures to prevent committed doses, radiation monitoring instrumentation, dosimetry, resources / presence of radiation protection staff etc.

Additionally, ENSI reviews all periodic reports of the NPPs relating to radiation protection measures. ENSI operates a computerised database containing radiological and chemical plant data provided monthly by the licence holders.

Conditions for the release of radioactive material to the environment, environmental monitoring and main results

The Ordinance on Radiological Protection sets the dose limit for members of the public at an annual effective dose of 1 mSv. The sum of the doses due to radioactive emissions into the atmosphere, discharges into water and direct radiation from any nuclear site shall not exceed a source-related dose constraint, which is set in Guideline ENSI-G15 at 0.3 mSv per year per person. The dose guide value for direct radiation is set at 0.1 mSv per year per person in the same guideline.

With regard to design-basis accidents (potential exposure situations), the Swiss legislation (RPO and NEO) sets a series of dose criteria for the public. In particular the licence holder must demonstrate by means of accident analyses with an environmental dispersion calculation, that for failures with an occurrence probability greater than 1E-2 per year the maximum dose to the public does

Table 5: Main dose reduction measures in Swiss NPPs.

Radiation protection objective	Main dose reduction measures
Source term reduction	■ reducing fixation of colloids on primary system surfaces by mechanical and chemical treatment of internal surfaces ■ use of improved water chemistry to prevent corrosion ■ replacing of components with «Stellite» parts by components made from a cobalt-free alloy ■ feeding Zn-64-depleted zinc into the primary water to prevent the adsorption of Co-nuclides in the corrosion layer in PWRs ■ introducing online noble chemistry (OLNC) for primary water operation mode resulting in a reduction of the dose rates of the recirculation pipes in BWRs ■ stopping the addition of hydrogen to the primary water system a few hours before the reactor is shut down for its outage resulting in corrosion of the top layer for the easy elimination of radionuclides in this layer during the subsequent cleaning procedure ■ using soft shutdown and optimised RHR operation during refuelling outage ■ consideration of foreign material exclusion during all work on open primary cooling systems ■ chemical decontamination of contaminated systems or components, such as reactor coolant pumps, as required and where possible
Containment of radioactivity	■ introduction of highly compartmentalised buildings containing the radiological controlled area ■ use of temporary covers such as plastic sheets ■ covering of unsealed radioactive material by water in pools ■ avoiding the spread of air contamination by use of mobile ventilation systems with suitable filters
Limiting and optimisation of external exposure	■ establishing low dose rate areas (< 0.005 mSv/h) for personnel inside the radiological controlled area who are not required for the work steps ■ installing of temporary lead shields or water bags in frequently entered areas with high dose rates ■ constructing highly compartmentalised radiological controlled areas with compartments made out of concrete. ■ use of wireless dosimeters/teledosimetry for special kinds of work in order to monitor and control the dose and dose rate online ■ use of remote tools for primary system inspections ■ development and use of permanent racks for supporting removable lead shielding ■ introduction of job dosimetry (bar code) with online follow up ■ use of individual dosimeters with acoustic dose and dose rate warnings in conjunction with further optimisation measures such as maximisation of the distance to radiological sources ■ replacing of the old isolation system with new isolation cassettes on the primary coolant pipes to minimise the time taken for dismantling and assembly. ■ introduction of highly compartmentalised building containment with compartments made out of concrete ■ extensive mock-up training to avoid or reduce time consuming work steps ■ intensive supervision of high-dose or high-risk work on site ■ planning of work taking into account reasonable system conditions (filled pipes or compounds, closed systems etc.) to use the shielding capability of water or construction material ■ reducing the number of operator walk-downs in steam-affected areas by using extensive camera systems in the turbine building
Prevention of radionuclide incorporation and contamination of personnel	■ use of remote tools for inspections in highly contaminated areas. ■ adjusting shut-down procedures on an individual basis to match the current activity of the primary coolant water, e.g. limitation of the number of personnel during lifting of the vessel head.
Management measures related to radiation protection objectives	■ improving training and motivating of personnel ■ implementation of a radiation protection planning procedure for jobs involving collective radiation exposure > 10 man-mSv including radio-logical risk analyses, setting up job specific radiation protection measures and monitoring, improvement of workflow for infrequent or high dose tasks/work. ■ daily follow-up of selected job-specific actual collective doses vs. planning doses resulting in additional or improved measures ■ daily follow-up of total individual doses vs. planning including interven-tions if necessary to adhere to the NPP-internal dose constraint of 10 mSv p.a. for workers. ■ use of wireless telephone set with noise cancelling capability for work in noisy areas to improve communication

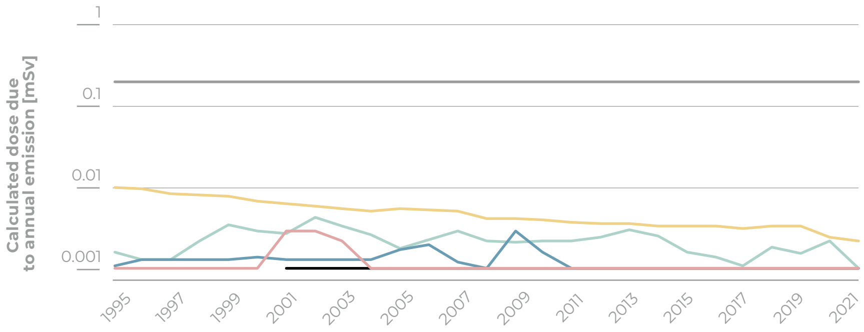
not exceed 0.3 mSv per year, for failures with an occurrence probability greater than 1E-4 per year (but less than 1E-2 per year) the maximum dose to the public does not exceed 1 mSv per year, for failures with an occurrence probability greater than 1E-6 per year (but less than 1E-4 per year) the maximum dose to the public does not exceed 100 mSv per year.

The discharge limits are fixed in the operating licence of each facility; they correspond to the source-related dose constraint of 0.3 mSv per year per person. The concentration of radioactive substances (in terms of a nuclide-specific weighted sum) within discharges into water are further constrained with reference to immission limits set in the RPO.
Emission monitoring to assure the compliance with the relevant Articles 111 to 116 of the RPO and emission limits stipulated in the operating licence (or a specific licence for the emission of radioactive substances) is carried out by the licensees. The processes for controlling the radioactive discharges by the licensees are verified by the relevant authorities (i.e. ENSI and FOPH) by inspections (accountancy inspections, inspections of discharge instrumentation in the installations) and measurements of random samples of discharges from the installations. The result of the annual dose evaluations by ENSI are published in the annual reports on radiological protection by ENSI and, according to Art. 194 RPO, in the annual report of the FOPH on the surveillance of radioactivity in the environment. The emission results are published in annual reports of ENSI. A summary of the results of the nationwide environmental radiological surveillance is also published in the annual report of the FOPH.
The methodology for estimating a dose is laid down in Guideline ENSI-G14. The models and parameters used in this guideline are taken or derived from international guidelines (e.g. IAEA, ICRP) or regulations from neighbouring countries (e.g. the German administrative regulation “Allgemeine Verwaltungsvorschrift”).

The dose calculations are performed for a virtual individual who lives and works at the place with the highest total dose resulting from the considered pathways. The following pathways are considered: immersion from the plume, inhalation, ground radiation and ingestion of fruits, vegetables, milk, meat, fish, and drinking water from the river downstream of the facility. It is assumed that the consumed food (fruits, vegetables, milk and meat) is produced locally. It is further assumed that the fish and all the drinking water are taken from the river downstream of the given facility.
Contributions due to annual releases have been below 0.01 mSv per year for all Swiss NPPs since 2015. This is shown in figure 7.

Doses due to direct radiation have always been below 0.1 mSv per year for all Swiss NPPs. To conclude, the data show that the sum of the annual dose caused by direct radiation and emissions has always been below the source-related dose constraint.
In all Swiss NPPs, the contaminated waste water is collected and treated in batches. However, each plant applies customised reduction techniques for the treatment of this waste water. In Beznau NPP, the radioactivity in the waste water is reduced by nanofiltration and/or, if necessary, chemical precipitation. In Gösgen NPP, an evaporation technique is used to reduce the amount of contaminated waste water and produce a concentrated slurry. Leibstadt NPP employs a centrifugation or evaporation technique sometimes combined with ion-exchange to treat their contaminated waste water, while Mühleberg NPP applies filtration and ion exchange methods as well as evaporation.
Three of the Swiss NPPs, Gösgen, Leibstadt and Mühleberg, have conventional off-gas treatment systems, which consist of catalytic recombiners, off-gas condensers, hold-up lines, activated carbon filter columns, HEPA filters and off-gas pumps. Beznau NPP has a slightly different system, which works with three pressurised hold-up-tanks and a volume compensation tank within a chemical and volume control system. Each NPP has

Figure 7: Doses calculated based on annual emissions



Doses calculated based on annual emissions from the Swiss NPPs and the Central Interim Storage Facility (ZZL) without 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 source-related dose constraint of 0.2 mSv/year (the dose constraint of 0.1 mSv/year from direct radiation has been subtracted) is also shown. Values below 0.001 mSv per year are shown at the level of 0.001 mSv per year.

Beznau I + II NPP **Leibstadt NPP** **Gösgen NPP** **Mühleberg NPP**
Central Interim Storage for Nuclear Waste (ZZL)
Source-ralated dose constraint

formulated site-specific targets for liquid and gaseous discharges with the intention of keeping doses as low as possible – and well below the statutory limits for members of the public by use of reasonable, justifiable effort.

The NEO requires a periodic safety review to be performed by the licence holder of a nuclear power plant every ten years. Within the framework of these periodic safety reviews, the licence holder must assess the liquid and gaseous discharges and benchmark them against the corresponding discharges from similar European reactors. Should its own discharges exceed the benchmark, the licence holder must analyse the causes and suggest proportionate means of reduction. As the nuclear regulatory body, ENSI performs a safety evaluation of the licence holder's periodic safety reviews and addresses the adequacy of the adopted measures. As a result of these evaluations, a site-specific target of 1GBq/year for liquid discharge (excluding tritium) was introduced for Beznau and Mühleberg NPPs as a requirement of the licensing authority. Subsequently, Beznau NPP introduced nanofiltration in 2007 while Mühleberg NPP installed an evaporator, which eventually lead to releases below the target value.

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 Ordinance on Contaminants. The discharge and environment monitoring regulations issued by ENSI are based on the above-mentioned legislation. These regulations include constraints on the control of discharges, as well as a complete programme of environmental monitoring of radioactivity and direct radiation in the vicinity of the facility that is to be performed by the licence holder.

According to Art.191 RPO, the FOPH is responsible for the monitoring of ionising radiation and radioactivity in the environment in Switzerland. ENSI additionally monitor ionising radiation and radioactivity in the vicinity of nuclear facilities. For nuclear facilities, the environmental monitoring program is established by ENSI in cooperation with the FOPH and is stipulated together with the discharges limits in the specific regulation mentioned above. According to Art. 194 RPO, the results of environmental monitoring in the vicinity of the NPPs are published in the annual report of the FOPH, together with all the results obtained in the framework of the general environmental radiological monitoring program.

Following art. 17 of the RPA and art. 191 ff. of the RPO, environmental monitoring of radioactivity is mainly performed by the FOPH, with additional monitoring capabilities from ENSI in the vicinity of NPPs (MADUK, see Art 16). National authorities (FOPH/ENSI) with the assistance of national other federal laboratories (in particular PSI, Swiss Federal Institute of Aquatic Science and Technology, Spiez Laboratory) are required to cooperate to the monitoring programm. IRA, the Institute of Radiation Physics in Lausanne (with a laboratory accredited according to ISO 17025–17020) also provides technical services for environmental monitoring. Cantons monitor radioactivity in foodstuffs and in articles of daily use (art. 191(4) RPO).

Developments and Conclusion

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, emergency plans must be established and approved by ENSI. The general requirements for emergency preparedness are based on the following acts, ordinances, ENSI 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 Federal Civil Protection Crisis Management Board
- Ordinance on Iodine Prophylactics in the Case of a Nuclear Accident;
- Ordinance on Civil Protection
- Ordinance on Maximum Levels for Contaminants.

Guidelines

- Emergency exercises (Guideline ENSI-B11)
- Emergency preparedness in nuclear installations (Guideline ENSI-B12)
- Organisation of nuclear installations (Guideline ENSI-G07)

Concepts

- Emergency protection concept in case of a nuclear power plant accident in Switzerland, Federal Office for Civil Protection FOCP (2015).
- National Planning and Measures Concept: Large-scale evacuation in case of a nuclear power plant accident (2016)

A working group was set up by the Federal Council (IDA NOMEX)[11] 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 ENSI'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 conducted review. As a consequence of IDA NOMEX, the legal basis, as well as concepts pertinent to emergency preparedness and response, were revised. The scenario used for emergency planning purposes is characterised by an unfiltered source term.

Following a recommendation from the IRRS mission in November 2011, ENSI has 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 still to be finalised under the lead of the Federal Office for Civil Protection (FOCP).

[11] **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»**

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 ENSI and to the National Emergency Operations Centre
- procedure for reporting to the cantonal police on fast-evolving accidents

The emergency preparedness regulations of the NPP must be approved and granted a permit by ENSI. Additional emergency preparedness documentation is regularly reviewed.

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 and for low power or shut down conditions. They are validated based on emergency exercises that ENSI attends as an observer in its role as safety oversight authority. Strategies to cope with Total Station Blackout (T-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 NPP by road is not possible, the material transport will be carried out by the Swiss Air Force using helicopters. The operators test the severe accident equipment stored at Reitnau on a regular basis and during their periodic emergency exercises.

As a result of the transition from analogue to digital communication, former fax communication has been replaced by email communication. Most emergency partners have also acquired satellite phones. In addition, an encrypted digital security radio system is also available for use. These communication systems are regularly tested. 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 by ENSI for monitoring (plant parameters and environmental dose rate measurement data) and forecasting systems.

All NPPs are able to relocate emergency staff to one of several external emergency facilities.

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 Civil Protection Crisis Management Board co-ordinates the response of all involved federal offices (ministries) including the civil and military support at federal and regional levels.

The Federal Civil Protection Crisis Management Board, whose legal basis is laid down in the corresponding Ordinance, is responsible for suggesting appropriate measures to the Federal Council (government), which then issues the associated instructions to cantonal authorities and the general population. The Federal Civil Protection Crisis Management Board runs a stand-by emergency service, the National Emergency Operations Center (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 ENSI.
- ENSI is responsible for judging the adequacy of on-site countermeasures implemented by NPP staff. It makes predictions about the possible dispersion of radioactivity in the environment and about the consequences of such dispersion 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. ENSI operates a redundant system at its alternative emergency premises, thus ensuring a full redundancy. Yet another JRODOS system is operated at the National Emergency Operations Centre. The ANPA system provides ENSI with online access to measurement data of about 25 important plant parameters. ENSI 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 taking into consideration actual plant parameters. ENSI advises the NEOC and the Federal Civil Protection Crisis Management Board in ordering protective actions for the population. In addition, an automatic dose rate monitoring and emergency response data system (MADUK) has been installed in the surroundings of all NPPs in Switzerland. The system monitors dose rates continuously at 12 to 17 locations in the vicinity of each NPP. The data is transmitted online to ENSI (alternatively also by satellite communication) 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 available on ENSI'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. Every hour Switzerland transmits the mean values of the last hour of all stations to EURDEP, which are then transmitted to IRMIS.
- NEOC is responsible for triggering the deployment of the Federal Civil Protection Crisis Management Board, which has the task of preparing the decisions to be taken by the Federal Council on protective actions following 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 alarms (sirens) together with instructions regarding behaviour that are disseminated by radio broadcast. The NEOC is responsible for coordinating measurement teams, data processing and evaluation, assessing the radiological situation and sharing these results and other emergency-related information with all the relevant response organisations on a secured electronic platform. It is also responsible for information exchange and communicating with international partners (neighbouring countries and international organisations).
- The Federal Civil Protection Crisis Management Board is responsible for cooperation during events relevant to civil protection on a national level, and the coordination of operations. The Federal Civil Protection Crisis Management 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 preparing and executing protective actions for the public. Since 2018 the responsibilities for cantonal and communal authorities have been more precisely described in the updated Emergency Preparedness Ordinance.
- The Swiss Armed Forces Pharmacy 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

According to the Emergency Preparedness Ordinance 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 actions are required. Depending on the NPP's power rating and the exhaust height of its vent 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 Zones 1 and 2 encompasses the rest of Switzerland. As a basis for the planning and preparation of specific measures, so-called planning areas can be defined. The sectors and 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 defined in the Ordinance on Civil Protection. The integration time has been extended from two to seven days, in line with recommendations from the IAEA. The protective measure of ordering the sheltering of children, adolescents and pregnant women at a dose threshold of 1 mSv over two days has been replaced by a behavioural recommendation. This Concept describes the protective measures to be considered (see Table 6). Generally, all available information, such as practicability of measures, meteorology and the overall situation, are considered in the decision-making process. In addition, the Ordinance on Maximum Levels for Contaminants contains limit levels for foodstuffs. The limits correspond to a large extent to the maximum levels set under EU legislation.

Measures have also been introduced for events where rapid action is required but no in-depth assessment is available within a reasonable time, e.g., because the release was not expected or because access to information is prevented inside a reasonable timescale. In this case, initial immediate measures must be ordered based on the nature of the event. This procedure corresponds to the implementation of the HERCA-WENRA Approach Part II in the event of a severe accident requiring rapid decisions for protective actions, while very little is known about the situation.

Table 6: Intervention levels

Protective measures	Dose	Dose intervention level	Integration time
Sheltering (at home, in a cellar or in a shelter)	Effective dose due to external radiation and inhalation in the open air	10 mSv	7 days
Precautionary evacuation or sheltering	Effective dose due to external radiation and inhalation in the open air	100 mSv	7 days
Taking iodine tablets	Thyroid dose due to inhaling radioactive iodine in the open air	50 mSv	7 days
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	–	

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 obligation arising from the civil protection act to provide shelters for the whole population in Switzerland mean that in most cases sufficient protection is provided against the radioactive cloudshine during the cloud phase of an accident by sheltering in houses, cellars or shelters. Therefore, this is considered as the most important protective action. 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 NPPs. Outside 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 case of a nuclear power plant accident, 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 actions during the ground phase are based on the actual radiological situation in the environment as indicated by measurement data. Important protective measures are remaining indoors, evacuation after the cloud passage, restricted access to certain areas, restrictions on certain foodstuffs, countermeasures for agriculture, decontamination and medical support. Under the updated Emergency Preparedness Ordinance, cantons outside Zones 1 and 2 have been assigned new duties in preparedness and response.

Alert procedures

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

- An **alert** is issued at the latest when a high dose-rate is detected by monitoring inside the containment. The alert (by a dedicated electronic system) puts federal, cantonal and municipal organisations (within Switzerland) on stand-by for a possible subsequent alarm. The National Emergency Operations Centre (NEOC) informs the IAEA and authorities in neighbouring countries. It also activates the hotline operated by a professional medical call centre.

- The first **alarm** 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 alarm 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. In 2019, in addition to the annual testing of the sirens, alarms were also sent via push notification to mobile phones (AlertSwiss App) for test purposes.
- Further siren **alarms** are issued if necessary in order to advice the population on taking iodine tablets, staying indoors, using shelters, etc.

Special regulations exist for the initiation of protective actions in the event of rapidly evolving accidents when thresholds for the release of radioactive substances from a nuclear installation are exceeded in less than one hour. In such a case, precautionary action will be taken for the population in Emergency Planning Zone 1. 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 protective actions 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 annual emergency exercise under the observation of the regulatory body. The outcomes of an exercise may lead to new measures to improve the functioning of the emergency organisation. Such measures are incorporated into the training programmes of the members of the emergency organisation. According to Guideline ENSI-B11, the annual emergency exercise of each plant takes place in the presence of several representatives of ENSI. This guideline allows ENSI 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. A full-scale emergency exercise is conducted every two years. Regular participants of the full-scale exercise are at least one NPP, ENSI, NEOC, the Federal Civil Protection Crisis Management Board, FOPC, Department of Defence and the canton in which the NPP is located as well as emergency organisations from the surrounding countries.

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 alerting and alarming 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 ENSI. For other radiological incidents, it is the 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).

Similarly, an expert group on nuclear emergency matters has been set up for France. A yearly exchange of information takes place with Austria. An exchange of information with Italy also takes place on an annual basis. Furthermore, the canton of Geneva has been represented in the "Commission locale d'information" of the Bugey NPP since spring 2016.

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 Bugey NPP, which is located about 70 km from the Swiss border.

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 ENSI 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 eighth Swiss National report, the Dose Measures Concept has been revised in the course of the revision of the Civil Protection Act and the Ordinance on Civil Protection. 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.

Switzerland complies with the obligations of Article 16.

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 chapter on Article 7. The granting of general licences for the construction of new NPPs is prohibited according to the revised Nuclear Energy Act which has been in force since January 2018.

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 development plan of the area.

The Nuclear Energy Ordinance contains requirements relating to measures designed to prevent accidents initiated either inside or outside the installations. Based on the Nuclear Energy Ordinance, the following documents shall be submitted with the application for a general licence:

- safety analysis report;
- security report;
- environmental impact report;
- report on compliance with spatial planning requirements;
- concept for decommissioning, or for the monitoring period and closure;
- feasibility demonstration of the management and disposal of resulting 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 Safety Analysis Report (SAR) shall incorporate all relevant factors relating to the site (natural characteristics and human activities), in particular:

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

During the licensing procedure, ENSI evaluates the site-related factors likely to affect the safety of a nuclear installation and produces a Safety Evaluation Report (SER) in which additional requirements for plant design are defined, if deemed necessary.

The results of the hazard analysis are also incorporated into the Probabilistic Safety Analysis (PSA) for existing NPPs, which are regularly updated (for additional information see Article 14).

Safety assessments shall be updated whenever relevant new findings or experience is available. For example, relevant safety factors shall be re-evaluated whenever there are plans to build a relevant new facility (e.g. gas pipeline or industrial building) in the vicinity of a NPP.

Site-related factors are re-evaluated every ten years as part of the Periodic Safety Review (PSR). In particular, the safety analysis report (including the deterministic safety analysis) and the PSA are updated by the licence holder and reviewed by ENSI.

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 concept of safety through distance encounters natural limitations in Switzerland. In 2011, the government decided to phase out the use of nuclear power in Switzerland. According to Article 12a of the Nuclear Energy Act the granting of general licenses for the construction of nuclear power plants is prohibited.

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.

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 licence holder of such modifications normally includes an assessment of their possible consequences. Site-related factors are re-evaluated as part of the PSR. In particular, the SAR (including the deterministic safety analysis) and the PSA are updated by the licence holder and reviewed by ENSI.

In essence, the re-evaluation processes help to ensure the continued acceptability from a safety point of view 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 ENSI'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 PEGASOS project, a German acronym for "Probabilistic Seismic Hazard Analysis for Swiss Nuclear Power Plant Sites", was carried out from 2001 to 2004 by the Swiss licence holders in response to a requirement that came out of ENSI's PSA review process. In 2008, the Swiss licence holders launched the PEGASOS Refinement Project (PRP) with the aim of reducing 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. The PRP took advantage of substantial scientific and technical advancements achieved following completion of the PEGASOS project, in particular internationally developed ground motion attenuation equations and new soil investigations at the Swiss NPP sites

In order to achieve a thorough quantification of the uncertainty of seismic hazard estimates, the projects PEGASOS and PRP were designed according to the Senior Seismic Hazard Analysis Committee (SSHAC) Level 4 methodology. The projects involved technical experts, scientific institutions and engineering organisations from several European countries and the USA and made use of an extensive expert elicitation process. The participatory peer review, which is a strongly recommended part of the SSHAC Level 4 approach, was carried out in both projects by ENSI with the help of an experienced team of contracted experts.

The PRP summary report was submitted to ENSI at the end of 2013. In comparison with the PEGASOS project, the level of the computed seismic hazard and the spread of the hazard results turned out to be generally smaller. A breakdown (disaggregation) of the seismic hazard results into partial contributions confirmed the finding of the PEGASOS project according to which nearby earthquakes with relatively low magnitudes between 5 and 6 have higher hazard contributions than stronger and more distant earthquakes.

In its final review report on PRP ENSI acknowledged that the state-of-the-art in probabilistic seismic hazard assessment was further improved by the project. ENSI assessed the achieved refinements in the project focal points – the "ground motion characterisation" (subproject 2) and the "site response characterisation" (subproject 3) – to be well-founded. In contrast, the "seismic source characterisation" (subproject 1) was not investigated in sufficient detail according to ENSI. After it became evident late in the project that the model modifications in subproject 1 had a significant influence on the computed seismic hazard, the experts did not have the opportunity to question or to confirm their assessments. The "seismic hazard computation" (subproject 4) was conducted in an appropriate manner and the applied software met the accepted specification. Nevertheless, due to the concerns regarding subproject 1, ENSI could not accept the final results of the PRP.

Due to the reservations concerning PRP subproject 1, ENSI initiated a sensitivity analysis in which the model for subproject 1 was replaced by the corresponding model of the Swiss Seismological Service (SED). The results of this combined "SED-PRP model" were found to be higher than the results of both the PRP and the SED model. In May 2016, ENSI ordered the implementation of the results of the "SED-PRP model", denoted as seismic hazard assumptions ENSI-2015 (in German «Erdbebengefährdungsannahmen ENSI-2015»). At the same time, as required by Swiss regulation in the case of a change in hazard results, ENSI required the licence holders to assess the consequences on the safety of the NPP and, in particular, on the risk (for additional information see Article 14).

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 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 by extrapolation of river discharge data taking into consideration historical flood records as 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 NPPs. Additionally, to evaluate the flooding risk comprehensively, ENSI required the licence holders to analyse the effects of a total debris blockage of bridges or hydraulic installations near the sites. The analyses of the licence holders, based on two-dimensional flooding simulations and incorporating sediment transport and appropriate particle size distributions, indicate that total debris blockage does not cause cliff-edge effects for the plants.

Under the lead of the Federal Office for the Environment together with other regulatory bodies including ENSI, a comprehensive reassessment of the external flood hazard was accomplished. The project established a common basis for the flood hazard assessment for various regulatory bodies. A Probabilistic Flood Hazard Analysis (PFHA) methodology was developed in order to also assess extremely rare events (with exceedance frequency even lower than 1E-4/yr). The results consist of hazard curves for the water level that also take into account effects such as debris or blockage of bridges and indicate that even for rare events, water levels are controllable. The results of the project also include the hydraulic parameters needed for a closer evaluation of morphological effects such as erosion of the surface or the shore. ENSI requested the licence holders to perform a new safety assessment that also includes the morphological effects.

Extreme weather conditions

In the course of the EU stress test, ENSI 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 as part of their PSR. Provisional hazard values were defined to be used for the proof of adequate protection. In the meantime, all Swiss NPPs submitted their updated hazard analyses. In general, the review of the updated studies showed an improvement in the quality of the studies. Based on these investigations ENSI will define new hazard assumptions concerning extreme weather conditions.

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 operating 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, operating experience in nuclear installations and the legislative framework for nuclear safety and radiation protection.

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 internationally accepted 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 SAMG (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 the assessment are part of the safety analysis report (SAR) 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 ENSI Guideline R-101.
After a licence has been granted, the design and construction of existing NPPs are periodically reassessed. Guideline R-101 was replaced in 2019 by the Guideline ENSI-G02 "Auslegungsgrundsätze für in Betrieb stehende Kernkraftwerke (Design principles for existing nuclear power plants)". 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) and the fulfilment of the requirements according to ENSI-G02 is as a minimum reassessed in these reviews.
It is also important to note that the Swiss Nuclear Energy Act Article 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,II and 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 ceased operation in 2019 and is now in its decommissioning phase. It was a General Electric BWR/4 type with a net electrical output of 373 MW. These NPPs 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 already 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;
- Well water system for (long term) steam generator cooling (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 regulatory body 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 insufficient. Furthermore, a lack of separation of safety-relevant systems was revealed.
The regulatory Body 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 (Project SUSAN in Mühleberg and Project NANO in Beznau, 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 up to 1992 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 primary pressure relief, and conducting of a feed and bleed operation.
In the early nineties, within the framework of the "Measures against Severe Accidents" developed by ENSI after Chernobyl, hardened filtered containment venting systems were backfitted at the NPPs Beznau (Project SIDRENT, 1992) and Mühleberg (Project CDS, 1992), allowing active or passive venting of the containment in the event of severe accidents. Also, as early as 1988, the containment atmosphere of Mühleberg NPP was inertised with nitrogen to prevent the formation of ignitable gas mixtures. 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 feedwater system, in addition to the existing auxiliary and emergency feedwater system, was completed at Beznau NPP unit 2. The system is located in a bunkered building protected against external hazards. The emergency feedwater system for unit 1, located in the same building, has been operational since 2000. The feedwater supply to the steam generators is backed up by a third system – the special emergency feedwater system, which is integrated in the bunkered NANO system. Taken as a whole, the feedwater supply at Beznau NPP is very reliable because of the high degree of redundancy und diversity.
Further measures for improving safety were completed in 2015. At Beznau NPP units 1 and 2, the hydroelectric emergency power supply was replaced by two additional state-of-the-art, seismically robust emergency diesel generator systems per unit. The new emergency diesel generators are air cooled so that they are independent of any cooling water supply. This backfitting project had already been initiated before the Fukushima accident. In this project, each unit was equipped with an additional seal water injection pump and a well water pump for long term water supply to the emergency feedwater system, both installed in the bunkered buildings. ENSI 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 46 years and 44 years respec-

tively. 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, ENSI 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, ENSI 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 was required to improve the earthquake resistance of the SFP storage building, and constructed a venting duct to remove heat and pressure generated by boiling SFP water in order to protect the building structure should beyond-design-basis accidents occur. This backfitting project was realised in 2017. The earthquake analyses for 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 transported by the Aare River. This was performed 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. Since then, a diverse cooling water supply, independent of the Aare River, has been realised. The flooding analyses for Beznau NPP confirmed that the flood protection measures are adequate, and no additional measures are required.

Mühleberg NPP was in operation for 47 years before being shut down in December 2019. In order to assess the requirements for a potential long-term operation (LTO), in 2012 ENSI conducted a thorough safety review of the documents provided by the licence holder within the framework of the 2010 PSR. Next to the required backfittings identified in the Fukushima reassessment process as mentioned above, ENSI addressed deficiencies in the spatial separation of safety systems in the lower floor of the reactor building and improvements for stabilising the core shroud which is affected by cracks. In 2012, the licence holder planned a backfitting project for LTO that contained 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 commercial reasons and cancelled the planned LTO backfitting program. ENSI issued a formal order to establish binding conditions for operation until 2019, requesting alternative measures be implemented. On this basis in 2014 the licence holder submitted an alternative backfitting program, which was evaluated by ENSI. The following main backfitting measures were installed:

- In 2015, the licence holder finished the installation of the new emergency system to feed cooling water from a groundwater well to 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 was installed in 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 was 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.
- In 2016, an additional, earthquake and flood resistant, single line emergency water injection into the reactor pressure vessel was installed. 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, ENSI 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. ENSI 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 **Gösgen NPP,** a Siemens/KWU PWR with a gross electrical output of 1060 MW, has been continuously enhanced since its commissioning. In 1993, a filtered containment venting system was installed, allowing passive or active venting of the containment for 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.

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

The provisions for conducting primary pressure relief, the installation of three pilot-operated pressuriser safety/relief valves, were implemented in 2005. These valves make it possible to conduct primary pressure relief and a feed and bleed operation in beyond-design-basis 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) to provide increased protection against external hazards, using groundwater from a protected well as an ultimate heat sink.

Over the course of time, several backfitting measures have been realised. The alternative rod insertion system ARI was introduced in 1988; this 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 2 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 the opening of a valve or passive venting via 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 in respect of 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 demonstrated compliance with the current licensing basis, and demonstrated that the fundamental safety functions are ensured (see Article 14). Nevertheless, the safety of Gösgen NPP was further enhanced by several improvements regarding protection against flooding and earthquake. The seismic robustness of specific equipment important for safety is being continuously improved (especially cable trays and control cabinets). Furthermore, in 2015, the licence holder of the Gösgen NPP decided 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. Measures within this project ensure residual heat removal from the core and the spent fuel pool for at least 72 h, including extended DC power supply. The construction work for the new special emergency feedwater storage tanks at Gösgen NPP was finished in 2021. These two enlarged storage tanks, which are protected against air plane crash and other extreme hazards, ensure residual heat removal from the steam generators for an extended period of time. In 2018, a seismic shut-down system was installed at Gösgen NPP. The system is intended to shut down the reactor very quickly should very small peak ground accelerations (0.02 g) occur, thus allowing a safe reactor shutdown before higher accelerations hit the core internals. Further measures at Gösgen are ongoing for the next few years and comprise new ventilation systems at the bunkered special emergency building taking into account new extreme temperatures, and improved isolation of venting systems should radioactive and hazardous gases occur in the plant area.
The assumption of a 10,000-year flood as a 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 Swiss NPPs. Nevertheless, Leibstadt NPP is strengthening the existing FCVS in order to increase the existing margins. Gösgen NPP enhanced the existing FCVS in 2018 with an additional filter device, aiming at reducing the release of organic iodine as required in Guideline ENSI-G02 after severe accidents. In 2014, all plants conducted a re-evaluation of the hydrogen hazard. In two plants additional passive autocatalytic recombiners (PAR) have been installed, so that all Swiss NPPs have passive measures (inertisation or PAR) to protect against hydrogen combustion.
The measures regarding SFP cooling and SFP instrumentation, namely 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, ENSI conducted several inspections to assess the situation in the Swiss NPPs in respect of issues that resulted from the accident management actions performed at Fukushima. ENSI 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 radiologically 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 in-situ, or by passive actuation by a rupture disk at a defined opening pressure. The condition of the venting filters was also inspected. In another inspection, the suitability and habitability of the emergency operations centres were checked.

Furthermore, ENSI 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 has 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 manually opening valves, 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, in 2013, ENSI decided to further strengthen the safety of the Swiss NPPs by increasing the safety margins for 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 licence holders conducted the required analyses in 2014. As a result of these investigations, the 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 were improved.

In 2013, ENSI ordered the licence holders to conduct studies related to extreme weather conditions. ENSI 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, as well as for the analyses regarding earthquakes, 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) or by the Nuclear Safety Standards Commission (KTA) and by the requirements of IAEA NS-R-1. These standards and requirements were also taken as a basis for the relevant ENSI guidelines. 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 relevant for safety functions. This means that the design-basis range of the components for ambient conditions is proven for normal operation as well as under adverse pressure, humidity and radiation conditions in the event of an accident. Additionally, the components must withstand the earthquake loads 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. 0E-classified electrical equipment 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.

Where the safety importance of a reliable and diversified electrical power supply for NPPs is concerned for the prevention of an SBO, it should be highlighted that the Swiss NPPs have enhanced protection against the loss of electrical power. In addition to the emergency power supply that is usually provided by diesel generators, an independent special emergency power supply provided by dedicated special emergency power diesel generators that are protected against external events is also in place. These supplies, which ensure operation of the systems required for safety purposes, can be operated autonomously for several days (exclusively using equipment stored on 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 chapter as safety layers of the electrical energy supply.

The following safety layers are in place:

- **First Safety Layer:** external main grid that 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 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 an 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 in accordance with Guideline ENSI-G01, which is based on IEC 61226. 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.

In general, analogue technology will be replaced step-by-step by digital control systems. Beznau NPP has already replaced the protection system, and the control system of the reactor and turbine. Gösgen NPP has replaced the reactor control and the emergency diesel control system. The replacement of the reactor protection system at Gösgen NPP is in progress and it has also been started at Leibstadt.

Seismic design of nuclear buildings

The nuclear buildings of the Swiss NPPs are divided into structural classes I and II, dependent on 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 previous practice, half of the SSE spectral accelerations were 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 or an exceedance probability of 0.4 % in 40 years must be considered. This led to seismic requalification and backfitting of the first generation NPPs Mühleberg and Beznau in the eighties assuming 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 g at the bedrock level.

Since construction, the buildings of the Swiss NPPs have undergone continual backfitting. In all NPPs, the masonry walls, which can endanger safety-relevant equipment, were secured with steel structures. In addition, the reinforced concrete structures of different buildings have been strengthened. Examples are the building of the emergency feedwater system of Gösgen NPP in 2008 or the strengthening of auxiliary buildings and of the SFP storage building of Beznau NPP in 2009 and 2015. In all three 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 original 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 building of NPP Gösgen, the diesel generator buildings of the new emergency power supply in NPP Beznau, and the new storage building for low level radioactive waste in NPP Leibstadt.

After the Fukushima event, ENSI ordered that the seismic safety of the Swiss NPPs must be verified. In their analyses, the licence holders 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 nonlinear calculation methods. The analyses as well as the review by ENSI confirmed that the nuclear buildings can withstand the 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 a low damage level is to be expected.

The PRP was completed and submitted to ENSI at the end of 2013. At the end of 2015,

	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

Table 7: Comparison of representative earthquake hazards parameters

ENSI defined a new seismic hazard, based on the PRP, called ENSI-2015. The following table compares the maximum earthquake accelerations applied in the past to the accelerations of the new hazard.

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 ENSI in 2016. The verification of the nuclear safety consists of four phases. In the first phase the licence holders worked out and submitted the general concept of a safety assessment. ENSI approved the concepts in 2017. The following verifications (update of post-Fukushima verification, probabilistic safety assessment) were finished with positive results and the deterministic verification phase is in progress.

The topics related to the seismic safety assessment of the existing NPPs have also been discussed in depth and the adequate methodology has been developed.

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 ENSI, 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 such as 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 improvement and regular testing to ensure and 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 ENSI and/or its technical support organisations TSOs.

In Switzerland, the US ASME Code is applied for the original design and construction of safety-relevant SSCs as well as for backfitting projects. Recognised non-nuclear codes and standards are used for some SSCs of safety classes 3 and 4. ENSI has implemented guidelines for the approval of design specifications that are applied in the event 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 SSCs are classified in accordance with internationally recognised Nuclear Safety Classes. These classifications reflect their relevance for 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 arisen 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, contrary to earlier experience, this material suffered from stress corrosion cracking in the LWR coolant environment. It was for this reason that the steam generators of Beznau NPP I and II were replaced in 1993 and 1999 respectively.
- It is known that Alloy 600 welding material at the penetration tubes of control rod drive mechanisms is susceptible to stress corrosion cracking under certain material and operational conditions. Therefore, based on international operating experience, Beznau NPP decided to replace the reactor pressure vessel closure heads of units 1 and 2, the replacement being successfully completed in 2015. To improve the resistance to stress corrosion cracking in Gösgen NPP, the Alloy 182/82 welding material at some pressuriser 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 Mühleberg NPP was replaced in 1986. A project to replace the recirculation system at Leibstadt NPP was completed in 2021.
- 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 licence holders. 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 inspections performed on 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 large number of indications were found. The individual UT indications were considerably smaller than the ones detected in Doel-3 and Tihange-2 but nevertheless required justification and a detailed assessment. The safety case (SC) for the RPV of Beznau I submitted by Beznau NPP in November 2016 was reviewed by ENSI and by a group of internationally recognised experts, the International Review Panel (IRP), appointed by ENSI. The reviews concluded that the SC contained insufficient supporting data on the effect on material properties as well as incomplete validation of the UT testing method. This resulted in ENSI requesting an extended materials characterisation programme and an updated SC. For the detailed investigations, a rep-

lica of the forged ring was produced based on original specifications for the fabrication process, aimed at reproducing in sufficient quantity the same type of UT indications in the same ingot zone as observed in the Beznau RPV shell. The additional assessments and review of the UT validation and the updated SC was completed early in 2018. The IRP and ENSI came to the conclusion that the UT indications are caused by agglomerates of alumina inclusions, formed during manufacturing, which do not significantly affect the material properties relevant for the structural integrity or the irradiation sensitivity. It could be confirmed that the applied ultrasonic testing procedures are reliable and able to detect all relevant flaws. A fracture mechanics assessment of the flaws, using highly conservative assumptions, demonstrated that the case is robust. After ENSI accepted the Beznau unit 1 RPV SC, the unit returned to operation in March 2018. ENSI has issued the requirement to repeat the UT inspection in 2022 of the base material of the RPV shell C where the indications with the highest UT amplitudes are located.

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.

Nevertheless, in the NPP control rooms, the most important element of the human-machine interface, all Swiss NPPs have made improvements compared to the original design. They have introduced computerised process visualisation techniques to facilitate operational control under 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 to 10 hours in the case of an external event.

ENSI pays particular attention to the consideration of human factors in the design of modifications of existing nuclear installations. Since 2007, ENSI has required a human factors engineering programme (HFE programme) from the licence holders together with the initial concept for a modernisation project that concerns 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 ENSI is closely monitoring the human factors engineering process applied by the licence holders:

- In the 1990s, 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 have been modernised. In 2015, they were validated using the full-scope simulator of the Beznau NPP.
- In 2015, 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. As a result, changes to the computerised EOPs were necessary. These changes were

also validated using the Beznau NPP full-scope simulator.

- In 2009, Gösgen NPP announced that it planned to replace all instrumentation and control systems. This modification has a major impact on the working conditions of the control room operators as well as on the maintenance personnel. The project is being carried out in several steps. For each step, a HFE programme is defined and implemented in order to address the specific human factors related aspects of the project. Depending on the impact, a graded approach is applied. During the reporting period, several further projects with HFE related issues were carried out or have been planned for the coming years (e.g. implementation of adaptive power density control, extension of emergency systems, and replacement of fire dampers).
- In 2011, the Leibstadt NPP installed the new operational information system ANIS. With the modernisation of the systems, a new computerised human-machine interface was created. Oversight performed by ENSI included close monitoring of the human factors engineering process and consideration of the impact of the new interfaces on the work of the operators deployed by the licence holder. Since the implementation, Leibstadt NPP has made stepwise changes to the instrumentation in order to use it for operational systems control. This process is still on-going with close oversight on the part of ENSI.

Developments and Conclusion

The carrying out of further backfitting measures depends on the assessments and analysis that are still to be performed as a consequence of the Fukushima accidents (see Article 14). Proof of the seismic robustness of the Swiss NPPs, which is based on the new ENSI-2015 hazard specification, will probably lead to further enhancements. Further improvements will also be made by implementing the requirements from ENSI regarding long-term operation. The safety requirements for equipment used in design basis and extended design conditions have been implemented in a new guideline (ENSI-G02) in which updated design rules for existing NPPs will be laid down.

Switzerland complies with the obligations of Article 18.

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 four Swiss NPPs in operation 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 Annexes 3 and 4 of the Nuclear Energy Ordinance and submitted by the applicant with the formal application;
- a safety evaluation report by ENSI;
- proof of insurance;
- report that the plant conforms with the general licence and construction licence.

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

The operating licence includes authorisation for commissioning. The commissioning programme must be approved by ENSI and consists of pre-operating and start-up tests as well as procedures for testing all equipment important for safety. The licence holder 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 because permits are required from ENSI.

As part of the operating licence, ENSI 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 ENSI'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

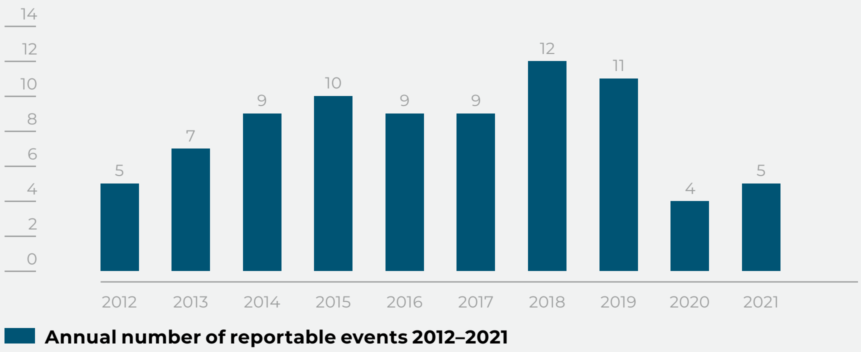
Clause 3: Each Contracting Party shall take the appropriate steps to ensure that operation, maintenance, inspection and testing of a nuclear installation are conducted in accordance with approved procedures.

This Clause is closely linked to Clause 2 and so they are covered together in the following paragraphs.

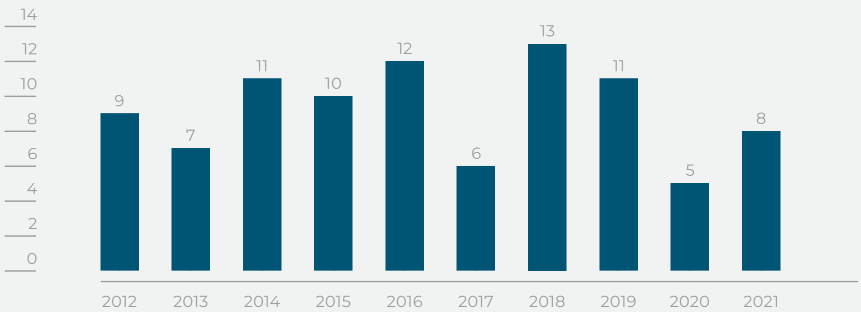
The operation of each NPP must comply with an appropriate set of limiting conditions for operation (LCO) approved by ENSI. The LCO constitute boundary conditions for procedures and the instructions for normal operation. They are derived from safety analyses and test results, and are included in the Technical 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 ENSI. Modifications are required as a result of plant modifications, operating experience and new knowledge. The Technical Specifications must conform with Chapter 6.3 of Guideline ENSI-G09. Additional procedures implemented by the licence holders 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

Table 8: Annual number of reportable events in Swiss NPPs.

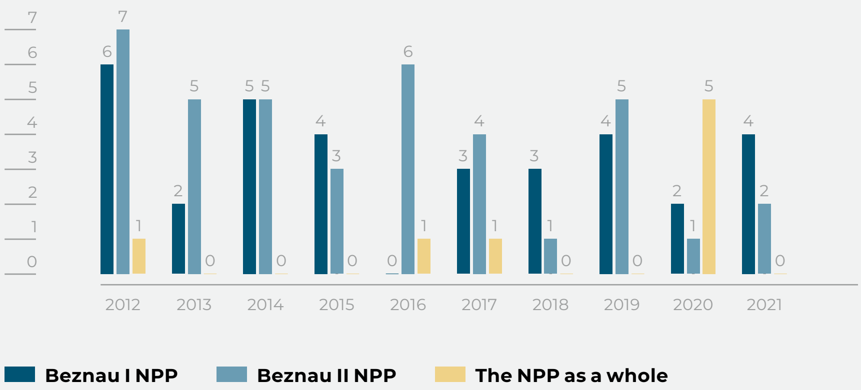
Leibstadt NPP



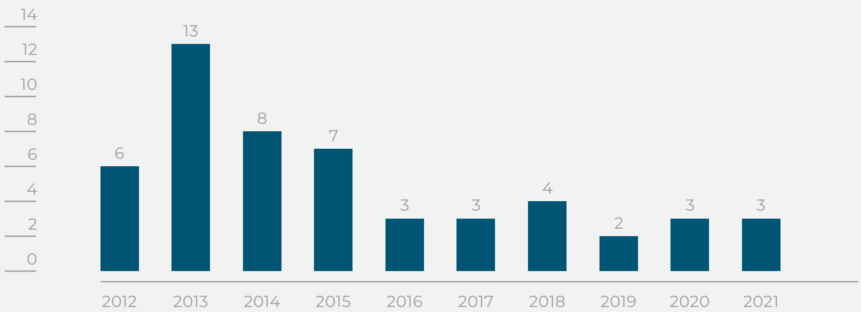
Gösgen NPP



Beznau NPP



Mühleberg NPP



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 comply with Guideline ENSI-B07.

The regulatory surveillance of plant operation relies on information obtained from the reports submitted by the operating organisations (in accordance with Guideline ENSI-B02 and Guideline ENSI-B03), on information collected during ENSI's inspections and on its own measurements. Since the INES classification was introduced in Switzerland in 1992, there have been 19 events in Swiss NPPs rated at Level 1 on the INES event scale and 2 events at Level 2. The annual number of reportable events as specified in Guideline ENSI-B03 (in effect since 2009) is shown in Table 8 above. Most of the reportable events were rated level 0 on the INES event scale.

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. Particular emphasis is placed on event reporting and investigation. Lessons learned and event feedback are essential elements of operating experience. In addition, the threshold for event reporting in Switzerland is low and so ENSI receives comprehensive reports on even minor events of relevance to safety. The analysis of incidents by both the utility and ENSI 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.

Each NPP has dedicated procedures for operational anomalies and emergency conditions as required by the Nuclear Energy Ordinance.

As top-level organisational documents, the emergency preparedness regulations reflect the policy of the operating organisation. They 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 ENSI if an event requires immediate reporting. The regulations also define the on-site criteria for alerts and alarms (see Article 16).

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 specify the measures required to manage incidents and accidents prior to core damage. Modifications to EOPs are reviewed 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. 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.

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 using exercise scenarios, for which SAMG plays the major role in managing the accident (see Article 16). SAMG is updated by the licence holder according to the state of the art. ENSI reviews the SAMG by means of inspections, as part of emergency exercises and as part of the periodic safety review.

All plants have fulfilled 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.

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 below) 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 location (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) 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.

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, alternative measures for reclosing large containment openings are prepared and guided.

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

ENSI regularly carries out inspections on the availability of AM means and to ensure that the procedures reflect the state of the art.

The Nuclear Energy Ordinance concerning the regulation of the content of the emergency preparedness regulations, the EOPs and the SAMG is embodied in guidelines published by ENSI (ENSI-B12, ENSI-G09). Changes in the content of the EOPs and the SAMG must be reported to ENSI. Where necessary, plant modifications, operating and training experience, scientific and technological developments and lessons from events in NPPs trigger such changes.

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, operating 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 licence holder'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 licence holder 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. ENSI is aware of this and the issue is discussed at the regular management meetings between ENSI and the 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 ENSI'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 ENSI's emergency organisation and other authorities;
- notification of events of public interest to allow ENSI to make an independent assessment and quickly inform the public.

The Nuclear Energy Act obliges licence holders to notify the regulatory authorities within a specified period 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. ENSI 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, Guideline ENSI-B03 contains criteria defining the reporting obligation threshold for events. The licence holder is responsible for giving a preliminary rating to each reportable event or finding based on INES, whereas ENSI 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 requiring immediate reporting, even if there is no significance for nuclear safety. A press release by the NPP implies public interest in the event. ENSI uses the written confirmation by the licence holder 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 General Emergency, Site Area Emergency or Alert or if there is public interest, ENSI's special emergency team meets as required by its own internal rules on emergency preparedness. General Emergency, Site Area Emergency and Alert are defined in Appendix 6 of the Nuclear Energy Ordinance (NEO).

To ensure that nuclear installations apply ENSI'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), ENSI 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 ENSI. The results are communicated to the licence holder and entered in the systematic safety assessment database. For several years, it has been ENSI's practice to include a summary of reported events and their classification in ENSI'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 relevant for safety, the non-conformance must be reported to ENSI. 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 its significance and applicability to an individual plant, the information is evaluated in detail and modifications are implemented as necessary. ENSI periodically inspects this process. Furthermore, plants must provide a monthly report to ENSI 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 operating experience, information from abroad, and 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.

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

ENSI 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 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 Leibstadt NPP;
- Indications for dryout at first cycle fuel assemblies in Leibstadt NPP;
- Installation deviation in respect of the shock absorbers for emergency diesel generators.

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

- Based on the Generic Letter 89-10 of the US-NRC, ENSI required all Swiss licence holders 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, ENSI 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. Nevertheless, one licence holder 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 ENSI 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. ENSI 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 ENSI. ENSI 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 ENSI'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, ENSI 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 by ENSI with the objective of understanding the event sequence, its causes and to be able to draw conclusions for the safety of Swiss NPPs. The Swiss National Assessment Report for the CNS Second Extraordinary Meeting contains more details on lessons identified, analyses performed and measures adopted. ENSI 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 that 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 licence holders 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 ENSI 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 operation of such installations, ENSI's oversight activities ensure compliance.

Each NPP stores the spent fuel discharged from the reactor on site for several years. The Nuclear Energy Act prohibits the export of spent nuclear fuel for the purpose of reprocessing. In the past, NPP operators have exported a total of some 1,139 tonnes of spent fuel to La Hague (F) and Sellafield (UK). All of this spent fuel has finally been reprocessed. All of the waste which had been allocated on the basis of the reprocessing contracts had been returned to Switzerland by end of 2016 and is currently stored at the central interim storage facility ZZL awaiting final disposal.

All separated Pu products from the 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 Gösgen sites. Even a part of the attributed U products has already been reused in the form of U(rep)oxide fuel elements in Swiss reactors.

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 dual-purpose casks (DPC). The Beznau NPP operates its own dry storage facility on site, while the Gösgen NPP started on site operation of a separate wet storage facility for spent fuel in May 2008. However even Gösgen NPP will have to transfer spent fuel elements into DPC in the late 20s due to a licensing condition of the wet storage facility.

While in earlier years foreign DPC designs were used for storage, the specific properties of Swiss spent fuel assemblies initiated several design and licensing projects for dedicated DPC designs, specifically addressing the issues of high burnup MOX elements and elements from reprocessed U. In establishing these projects Switzerland initiated and is leading international discussions on ageing management of dry spent fuel storage systems. All Swiss utilities are requested to establish comprehensive ageing management programmes addressing ageing of the storage facility components, the DPCs and their contents.

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 ENSI. The conditions required for clearance are included in Annex 2 of the Radiological Protection Ordinance. The associated procedures are detailed in Guideline ENSI-B04 which is equally applicable to any other (institutional) radioactive waste in Switzerland.

Radioactive waste in the form of resins, sludges or activated components is conditioned on site as soon as practicable at the NPPs. Incinerable waste, however, is conditioned externally at the Central Interim Storage Facility (ZZL), which is successfully operating the world's first plasma incinerator for radioactive waste. The previously used "conventional" incineration facility at the Paul Scherrer Institute is currently being decommissioned. The installations at the ZZL also provide services for decontamination, segregation, handling of bulky items and, more recently, the processing of radioactive waste containing asbestos.

According to the Nuclear Energy Ordinance, any procedure for the conditioning of radioactive waste must be approved by ENSI. 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 Guideline ENSI-B05. The utilities have continuously re-documented and finally also reconditioned "historic" waste packages which had originally been conditioned for sea dumping but remained in Switzerland after this disposal technique was no longer used. All waste packages are included in a nationwide registration and documentation system run by NAGRA and controlled by an independent register held by ENSI. This also applies to the PSI research

institute in charge of the central waste collection facility for institutional waste.
Specific requirements for interim storage facility operations are detailed in Guideline ENSI-B17, which came into force in 2021.
ENSI's up-to-date regulatory guidelines in addition to the relevant articles of the NEA and NEO comprehensively cover all pre-disposal aspects of the Swiss national waste management system. This also includes the requirements of the corresponding WENRA reports, the safety reference levels (SRLs) for the storage of waste and spent fuel, for decommissioning, and for disposal. The SRLs for processing waste as described in the WENRA processing report are only partly covered. Regulatory Guideline ENSI G-23: Design Requirements for Nuclear Installations other than Power Reactors, which covers the missing requirements including interim storage facility design, came into force in 2021.

Developments and Conclusion

Switzerland complies with the obligations of Article 19.

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 Eartquake
OECD	Organization 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 Grund 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 2022

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-G02	Design Principles for Operating Nuclear Power Plants	2019/08
ENSI-G03	Deep Geological Repositories	2020/12
ENSI-G05	Design and Manufacture of Transport and Storage Casks (Dual Purpose Casks) for Interim Storage	2021/10
ENSI-G07	The Organisation of Nuclear Installations	2013/07
ENSI-G08	Systematic Safety Evaluations for the Operation of Nuclear Installations	2015/06
ENSI-G09	Operational Documentation	2014/06
ENSI-G11	Safety Classified Vessels and Pipework: Engineering, Manufacture and Installation	2013/06
ENSI-G12	Radiation Protection in Nuclear Installations	2021/09
ENSI-G13	Measuring Instrumentation for Ionising Radiation	2015/10
ENSI-G14	Calculation of Radiation Exposure in the Vicinity due to Emission of Radioactive Substances from Nuclear Installations	2008/02
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 Rods: Design and Operation	2015/02
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ENSI-B06	Safety Classified Vessels and Pipework: Maintenance	2013/06
ENSI-B07	Safety Classified Vessels and Pipework: Qualification of Non-Destructive Testing	2008/09
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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	2019/08

Guideline	Title of guideline	Date of current issue
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
ENSI-B17	Operation of Interim Storage Facilities for Radioactive Waste	2020/01
HSK-R-08	Safety of Structures for Nuclear Installations, Federal Test Procedures for the Construction of Structures	1976/05
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-102	Design Criteria for the Protection of Safety-Relevant Equipment in Nuclear Power Plants against the Consequences of Aircraft Crashes	1986/12

Imprint:
Implementation of the Obligations of the Convention on Nuclear Safety

Switzerland's ninth National Report on Compliance with the Obligations of the Convention on Nuclear Safety

Publisher:
Swiss Federal Nuclear Safety Inspectorate ENSI
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