CONVENTION ON NUCLEAR SAFETY 2025

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

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August 2025

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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), *2023* 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 *tenth* 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 *2025.* 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 *joint eighth and ninth* 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.

Important updates made since the previous report are written in italic in the document.

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 km², more than half of which is mountainous, and a population of *about 9 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. At each level, a significant number of political rights are guaranteed to the people. The federal authorities are responsible under the Constitution for certain central functions. 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 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 2023, Gross Domestic Product per capita was approximately CHF 90,000 (EUR 96,300). 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, Italy, China, and France.

Total energy consumption in Switzerland was about 767,450 TJ in 2023. Electricity consumption accounts for about 26 % of energy consumption. The main sources of electricity in Switzerland are *hydroelectric (2023: 57 %)* and *nuclear power (32 %).*

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.

In March 2024, the federal popular initiative "Electricity for all at all times (Stop the blackout)" was launched. The aim of the initiative is to introduce a provision into the Swiss Constitution requiring that electricity supplies be always guaranteed. The initiative emphasizes that electricity production should be environmentally and climate-friendly. The Federal Council has spoken out against the initiative and instead launched its indirect counter-proposal that is a change in law removing the ban on new nuclear power plants from the law in order to increase technological openness in electricity generation. Parliamentary deliberations will take place in 2025/2026 and the popular vote is expected to take place in late 2027/early 2028.

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 contributed to civil engineering, buildings and mechanical and electrical engineering equipment. One NPP, Mühleberg, was permanently shutdown 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. *In November 2021 the DETEC released the installation from nuclear legislation*. 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) and at Gösgen NPP (wet storage). Both facilities started operation in spring 2008.

In addition to the on-site facilities, there is a centralised storage and conditioning facility (Zentrales Zwischenlager), 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

Introduction

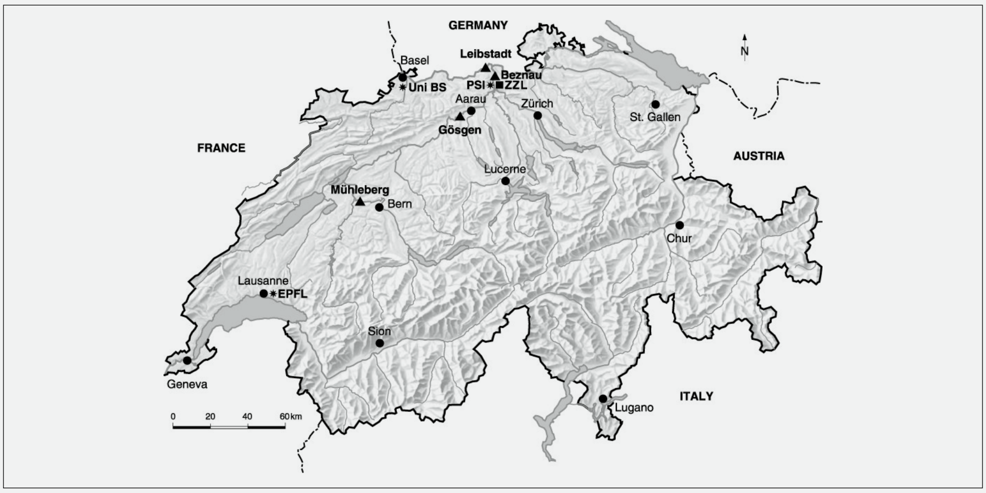


Figure 1: Geographic location of Swiss nuclear facilities. Triangles mark the NPP sites. Asterisks mark experimental and research installations. Squares mark facilities for nuclear waste management. The dots are major cities.

Table 1: Main technical characteristics of the Swiss NPPs (as of March 2025)

	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	*1233*
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**

waste. The Central Interim Storage Facility began operations in April 2000.

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 procedure for deep geological repositories for radioactive waste in Switzerland is described in detail in the 8th 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 (ENSI 2024, pages 18–25). The Swiss site selection procedure started in 2008 and is led by the Swiss Federal Office of Energy (SFOE). The process is divided into three stages, which lead to a stepwise reduction from entire Switzerland down to a or two final site(s), either one for low- and intermediate-level waste (LILW) and one for high-level waste (HLW) and spent fuel (SF) or a combined disposal facility for all waste in the same siting area.

The third and final stage of the site selection procedure started in 2018 with three remaining geological siting areas (Jura Ost, Nördlich Lägern, Zürich Nordost). Geoscientific investigations on all siting areas were executed by Nagra, the Swiss implementer responsible for deep geological disposal, Site investigations were designed to gather sufficient information for a final siting decision. They included 3D-seismic measurements and the drilling of a total of 9 deep (800–1400 m) and 11 shallow boreholes (40–300 m) in or close to all remaining siting areas. All borehole reports are available from the webpage of Nagra (https://nagra.ch/downloads/).

In September 2022, Nagra decided to focus future activities on the Nördlich Lägern site, for which it announced to prepare a general licence application for a final disposal facility. A second general licence application was announced to be submitted for a facility for the encapsulation of spent fuel and high-level waste at a site next to the existing central interim storage facility (Zwilag). Both general licence applications were submitted in November 2024 and are currently assessed by the national authority, (ENSI). In a first step, the submitted documents (230 reports, approximately 30,000 pages) have been screened for completeness. In February 2025, ENSI reported back to SFOE that the reports submitted by Nagra are well structured and of good scientific quality, but both the general licence applications for the encapsulation plant and for the final disposal facility will need complementary information. The detailed assessment of the general licence application will start as soon as Nagra has submitted the additional information.

According to current planning, the review by the federal authorities (ENSI) shall be completed early in 2027 (taking into account the evaluation of ENSI's assessment report by the Federal Nuclear Safety Commission (NSC) and the assessment of the Nagra documents by an international NEA review team) and will be followed by a 3-months public consultation phase. 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 number of 50,000 signatures or more from Swiss Citizens will require such a vote.

Summary and Conclusions

Developments in national nuclear policy

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. *Due to ongoing geopolitical and international challenges related also to electricity supply, on 20 December 2024, the Swiss Federal Council submitted a proposal to amend the Nuclear Energy Act and repeal the provisions banning the construction of new nuclear power plants. The aim is for Swiss energy policy to be technology-neutral, including nuclear energy. However, the expansion of renewable energies remains the priority. Lifting the ban on new nuclear power plants would give Switzerland the option of resorting to nuclear power in the future if renewable energy production were insufficient to meet electricity demand. The draft amendment is in consultation until April 2025, after which it will be debated in Parliament and later most likely subject to a public referendum.*

Currently, Copenhagen Atomics is planning to build a research reactor (a nuclear test facility for a "Molten Salt Experiment, MSE") on the PSI site. A full-scale molten salt test reactor with a reduced power of 1 MWth (equivalent to 1 % of nominal power) is to be built and tested at PSI. ENSI expects the applicant to submit an application for a facility with "low hazard potential" according to Art. 22 of the nuclear energy ordinance.

Meanwhile ENSI is developing its knowledge base in the field of molten salt reactor technologies and ramping up its international activities and cooperation agreements with regard to SMRs and advanced reactor technologies. This includes intensified bilateral and multilateral cooperation in this area.

In 2024 the Swiss Federal Administrative Court decided on an appeal against an ENSI ruling, by which a permit procedure was required for the backfitting of a decontamination facility in view of an obligatory upgrade to the state-of-the-art from the radiological point of view. The Swiss Federal Administrative Court rejected the appeal and clarified that radiation protection, which also includes occupational radiation safety, is part of nuclear safety in the legal sense. This judgement strengthens the occupational radiation protection in nuclear facilities as being part of nuclear safety and confirms ENSI's supervisory practice in radiation protection for future cases and for subsequent decommissioning projects.

In December 2024, Axpo, the operator of the Beznau nuclear power plant, announced that Block 2 of the nuclear power plant will remain on the grid until 2032 and Block 1 until 2033. They will then be decommissioned and shut down. This decision was made in consideration of social responsibility as well as technical, organizational, regulatory, and economic aspects. ENSI takes note of Axpo's decision to operate the Beznau 1 NPP until 2033 and the Beznau 2 NPP until 2032. Like all Swiss NPPs, the Beznau NPP has an unlimited operating license. Provided that safety is guaranteed, it is up to the operator to decide how long it wishes to operate the plant. The safety of the Beznau NPP is a top priority for ENSI and is continuously monitored as part of its supervisory activities. An important instrument for the comprehensive safety assessment of a nuclear power plant is the periodic safety review (PSR). The PSR must be carried out every 10 years and includes a safety case for long-term operation after 40 years of operation. The documents for the next PSR must be submitted to ENSI by KKB by the end of 2027.

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 maintaining and building competence of the parties responsible for nuclear 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.

After the IRRS mission, ENSI drafted an action plan to plan and monitor the implementation of the findings. *The action plan is public on the ENSI website. ENSI is currently well under way with implementing 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 of the 2021 IRRS mission is available on ENSI's website.

Furthermore, Switzerland also voluntarily participated in the EU Stress Tests and the 2017 European Topical Peer Review (TPR) on ageing management *and the second TPR on fire protection in 2023. The corresponding reports are available on the ENSI website* An IPPAS mission was conducted in Switzerland in 2018. The IPPAS Follow-up Mission in Switzerland was conducted in 2023.

In November 2024, Switzerland hosted a Country Specific Safety Culture Forum (CSSCF), organised by the Nuclear Energy Agency (NEA) and the World Association of Nuclear Operators (WANO). The CSSCF provided an opportunity for the key nuclear institutions and organisations in Switzerland to reflect on national characteristics and to engage in exercises to assess the impact that these characteristics might have on the overall nuclear safety culture. The results of the forum will be summarised in a report, which will be published.

Post Fukushima Daiichi Actions

Following the accident in Fukushima Daiichi, ENSI undertook a series of actions to understand the event sequence in Fukushima Daiichi and its causes. The knowledge obtained from analysing the events of the accident at Fukushima Daiichi was reviewed to determine its applicability to Switzerland, and a summary of insights was compiled in an ENSI report entitled "Lessons Learned" in the form of a series of checkpoints. Further points were added on completion of the analyses for the EU stress tests. The processing and implementation of the identified points were updated 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. The full reporting on the Swiss Fukushima activities can be found on the ENSI website.

Strategies and plans for crisis management in extraordinary events

ENSI's risk management is based on various legal requirements. Article 6, paragraph 6, letter i of the ENSI Act assigns responsibility for adequate quality assurance and operational risk management to the ENSI Board. ENSI's risk management includes both external and internal risks as well as crisis and continuity management. ENSI has created a designated crisis organisation designed to cope with events that could impair or prevent ENSI itself or its ability to fulfil its tasks. By contrast, the ENSI emergency preparedness organisation is designed to cope with events in Swiss nuclear plants (see Article 16). The composition of the crisis organisation varies depending on the type of event.

In 2024, the Business Impact Analysis (BIA) was updated, and the critical business processes were analysed. Based on the BIA, several measures are currently being implemented. As part of the continuous improvement process, ENSI will update its crisis organisation in 2025 and re-evaluate the *possible scenarios and crisis plans to constantly improve and increase resilience.*

Challenges from the joint eighth and ninth Review Meeting

The following challenge was identified for Switzerland during the joint eighth and ninth Review Meeting of the CNS:

Challenge 1: A shortage of qualified staff (for operators, sub-contractors and nuclear safety regulators) which, due to the ban on nuclear new build and the increased demand from decommissioning activities, is a serious challenge to maintaining competence in the medium to long-term.

Activities performed in this regard:

Governmental level:

The Swiss federal government has currently no overarching strategy for maintaining the skills of qualified specialists in the field of nuclear energy. In Switzerland, further development and maintenance of skills is primarily the responsibility of the nuclear industry. However, awareness of the issue has increased at the government level, and the ENSI-Board and the NSC have taken up the matter. According to the assessment of the SFOE (in 2021), the need for qualified specialists can be covered for the next five to ten years. However, for a meaningful analysis of longer-term development, an overarching evaluation of the need for the near and more distant future should be carried out.

Regulatory body:

To maintain the necessary number 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. In addition to those, a strategic workforce planning is done one regular basis. This specifically with regard to the retirements of employees and the associated drain of knowledge. In the past few years, ENSI has also established so called "tandem positions" for those positions in which employees retire within the next few years. Those positions are filled twice over a longer period of time in order to ensure the transfer of knowledge. As part of this concept, ENSI has increased its workforce plan by around 20 FTEs since 2022.

Licensees:

The Swiss nuclear power plant (NPP) operators and the entities responsible for waste management and intermediate storage closely monitor the needs of nuclear competence and workforce for the near to mid-future. In addition to the detailed workforce planning by the nuclear facilities, swissnuclear produces regularly an overview of the status of the nuclear workforce and a 5-year forecasts of needs for recruitment by the industry and by the authorities as well, in combination with an overview of the education providers and institutions. This provides a basis for identifying potential risk of competence loss early and in return to develop adequate measures to mitigate the risk. Both swissnuclear and the NPPs are involved in training and education of future workforce through several programs. From self-managing the School of Nuclear Technology (Nukleartechnikerschule), which offers the education of the nuclear operators, to financing several education and research programs at an academic level, the nuclear energy-specific education in Switzerland is supported to a significant degree by the NPP operators themselves. In addition, the operators have established traineeships programs to help freshly graduated students to enter the world of nuclear industry. Several nuclear-specific training programs are also offered to the workforce. Having the result of the last IRRS in mind, the project "Situation assessment and good practice in maintaining of competence in the Swiss nuclear energy sector" was initiated, in which the management of the nuclear competence in Switzerland was assessed by *a former IAEA expert. The conclusions in this study show that the nuclear competence is well managed in Switzerland and the risk of competence loss at a short to mid-term is low. The challenges are recognized at all level of the organizations and effective measures have been put into places. On a longer term, the expert suggests to better integrate the supply chain in the activities concerning the management of the nuclear competence. Overarching strategies on a national level may be needed regarding the future direction and responsibilities of maintaining nuclear energy competence in general in Switzerland, which is however beyond the responsibility of the NPP operators.*

Changes in legal and regulatory framework related to nuclear energy

The following relevant legal documents relating to nuclear energy have been revised since the ninth Swiss CNS National Report.

- *Nuclear Energy Ordinance (SR 732.11)*
- *Radiological Protection Act (814.50)*
- *Nuclear Energy Liability Act (732.44)*
- *Nuclear Energy Liability Ordinance (732.441)*

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 (Western European Nuclear Regulators' Association) and IAEA (International Atomic Energy Agency) requirements. (See Introduction, Articles 7 and 8.)

Major Common Issues from the joint eighth and ninth Review Meeting

During the peer review of the *joint eighth and ninth review meeting*, several common issues were identified and listed in the Summary Report (para 45–52). The issues identified have been dealt with in the corresponding chapters mentioned in the table below.

Issue	Reported
Contingency plans in managing extraordinary circumstances	Summary
Strengthening national regulatory capabilities taking into account new and innovative technologies	Summary
Fostering international cooperation	Article 8
International peer review missions	Summary
Impact of climate change	Article 17
Supply chains and NCSFI	Article 13
Implementation of ageing management strategies	Article 14
Cross border cooperation in relation to EPR	Article 16

Table 2: Major Common Issues from the joint eighth and ninth review meeting

Outlook

Long term operation (LTO) is a focus of ENSI's regulatory activities and will remain a challenge for the years to come both for the regulatory authority and operators. All Swiss NPPs have now been in commercial operation for more than 40 years, with NPPs Beznau I and II planned to shut down by respectively 2033 and 2032.

While aging management, maintenance and backfitting activities, notably in the course of periodic safety review, will continue, new challenges, specific to LTO need to be tackled. These challenges encompass both technical, operational, human and economic dimensions, especially as the industry transitions towards phasing out nuclear energy, in line with the Energy Strategy 2050.

Operators and the regulator adapt constantly in order to identify new areas to monitor or where special attention is needed. Factors such as the introduction of new technologies or generational shifts are carefully considered to prevent instabilities. Moreover, the replacement of outdated components is becoming increasingly challenging, particularly for those that are deemed technically or economically unfeasible to replace. Supply chain challenges are also of rising concerns and may pose further obstacles in the future. New approaches might need be brought forward to meet high level quality standards while mitigating supply chain risks.

The planned shutdown of the Beznau nuclear power plant by its operator poses an additional challenge on top of the long-term operation of the two reactors. Decommissioning activities will be planned and executed alongside ongoing operations. The experience gained during the decommissioning of the Mühleberg nuclear power plant, although it concerns a different type of reactor and a different operator, will contribute to successfully advancing the decommissioning of Beznau.

Intrinsically linked to LTO is the issue of knowledge retention and competence management, another critical issue for the future of the Swiss nuclear industry. The aging workforce, along with a decreasing interest from younger generations in joining an industry with limited future prospects due to the phase-out policy, poses a significant challenge in regard to the maintenance of a skilled workforce. This has also been identified by the IRRS Mission of 2021 to Switzerland. The reliance on tacit knowledge, which is difficult to transfer, makes knowledge management crucial to ensure long-term operational excellence, particularly as many experienced workers approach retirement.

In addition to transferring knowledge to the new generation, retaining critical nuclear knowledge within the Swiss nuclear industry involves the systematic capture and preservation of expertise from retiring personnel. This includes documenting knowledge through processes such as mentoring, internal knowledge databases, and collaborative platforms, which ensure that invaluable operational insights and best practices are not lost.

These challenges are well recognised by all those involved in the industry, who have put in place and continue to actively develop measures to ensure that Swiss nuclear power plants continue to operate safely in the years to come. In recent years, energy policy discussions in Switzerland have gained significant momentum, driven by increasing concerns over energy security and sustainability due to recent international and geopolitical events. A key focus of the current debate is a legislative proposal put forward by the Federal Council, which seeks to address the country's long-term energy needs while balancing environmental and economic factors, notably through allowing for the construction of new nuclear power plants. This proposal will have to be discussed in the next few months in the Swiss Parliament *and will then most probably be subject to a popular referendum.*

These policy debates, alongside developments in the industrial landscape, have the potential to introduce a new dynamic into the Swiss nuclear industry. As such, the company Copenhagen Atomics is considering Switzerland as the location for a molten salt research reactor. Such projects bring a breath of fresh air, sparking the interest of young professionals who view them as exciting opportunities for the future. These developments could play a role in making nuclear energy more appealing to younger generations, who may view it through a more innovative, forward-looking vision. This could then have a positive influence in attracting new professionals to the nuclear industry, which could help address the challenge identified by the IRRS Mission 2021 (difficulty in attracting and retaining professionals into the nuclear industry in view of a phase-out background).

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 a 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 with 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, *version of 1 October 2024)*. 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.**

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 *and Leibstadt NPP* by a modern digital system is in progress. A significant part of the old control technology of *Gösgen NPP* has already been replaced. Further project stages are being planned. *The control system modernisation of the first emergency cooling water division Leibstadt NPP was installed in 2024, followed by the other two in 2025. Further project stages are being planned.* 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. *To this end, the deionisation basin was removed from the emergency building as an initial measure and housed in a larger new building. The rooms thus freed up in the emergency building will be used for the backfitting measures.*

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. *At the end of 2022 KKL submitted a PSR including the evaluation for a long-term operation. ENSI plans to publish its review report in late 2025.*

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 review report was published in December 2023.*

In 1993, all five plants were backfitted 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.

After the shutdown of power operation on December 20, 2019, the fuel elements were unloaded from the reactor core and transferred to the fuel element storage pool. At that time, there were a total of 418 fuel elements with a total activity of 2.84E+18 Bq and an additional 108 control rods in the fuel element storage pool. The fuel elements were gradually transported to the Swiss central interim storage in Würenlingen (Zwilag) through numerous transport campaigns. The last transport took place in September 2023. Since then, the Mühleberg site has been fuel-free.

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. After the preparatory assembly work for cutting, packaging and removal of the RPV internals was completed, dismantling started. *The dismantling and packaging of the core internals in the reactor building was interrupted in March 2022 due to the start of the removal of the fuel elements in April 2022, which was completed in September 2023. Before resuming dismantling and packaging of core internals in October 2023, a new sealing bulkhead was installed at the equipment pool, and both dismantling techniques and operational workflows were technically refined.*

In 2022, the segment-by-segment dismantling of the inner torus in the reactor building began and has largely been completed in 2023. The remaining dismantling is planned for 2025. In the turbine hall, asbestos remediation was initially carried out in condensation and in the area of the feedwater system before the dismantling of systems and components continued in these areas. A new wet decontamination system was put into operation in the turbine hall in order to optimize logistical pathways, four construction elevators were installed – two in the reactor building and two in the turbine hall. As part of the preparation for the dismantling of systems and components in the turbine hall and the reactor building, asbestos findings required additional renovations. At the beginning of 2024, following the planned decommissioning, the dismantling of the core internals in the core pool in the reactor building resumed. Simultaneously, the reactor pit was equipped and commissioned with auxiliary systems necessary for dismantling the core internals, initiating the dismantling process. Parallel to this the existing fuel element channels, control rods and other core scrap were completely dismantled by an external *service provider in the fuel element storage pool. In the drywell Systems and components were dismantled on a large scale. In addition, various systems and components for residual heat removal were dismantled in the reactor building. In the turbine building, dismantling activities in the condensation is well advanced. All systems and components have been removed, except for the condensers.*

In 2024, numerous operational system modifications and measures were implemented specially to reduce fire loads and adapt fire protection measures. Furthermore, systems no longer required were taken out of service on a large scale.

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[1]

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 Nuclear Energy Act is a so-called "lex specialis" to the Radiological Protection Act.*

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-

[1] 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[2]

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[3];
- Radiological Protection Ordinance[4] (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;

[2] 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).

[3] 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).

[4] 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 also available on ENSI's website.[5]

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 re-

[5] **https://ensi.admin.ch/de/dokumente/document-category/richtlinien/**

quirements and guides as well as the relevant WENRA Safety Reference Levels. Once the draft guideline including the explanatory report has undergone an internal hearing, it is subject to an external consultation round. All interested parties, to which belong 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 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, *99 %* 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 *Swiss assessment for the* Radioactive Waste Treatment and Conditioning *SRLs has also shown a high degree of compliance. The minor remaining issues in this field are related to the periodic safety review of this type of installations, and its compliance requires a small change in the Swiss Nuclear Energy Ordinance, which has already been initiated.* Given the revision and publication of several safety guidelines in this field *over the past years (e.g.* ENSI-B17, ENSI-G05, *ENSI-G18* and ENSI-G23), a high degree of compliance could be achieved.

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. *As of 2018, the granting of general licences for the construction of nuclear power plants is prohibited according to the Nuclear Energy Act.*

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, not only have the Nuclear Energy Act and the Nuclear Energy Ordinance been subject to specific changes but also 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 *73* 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 6 million Swiss Francs: some 2 million Swiss Francs come from public funds and *around 4* million Swiss Francs come from the licensees.

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.

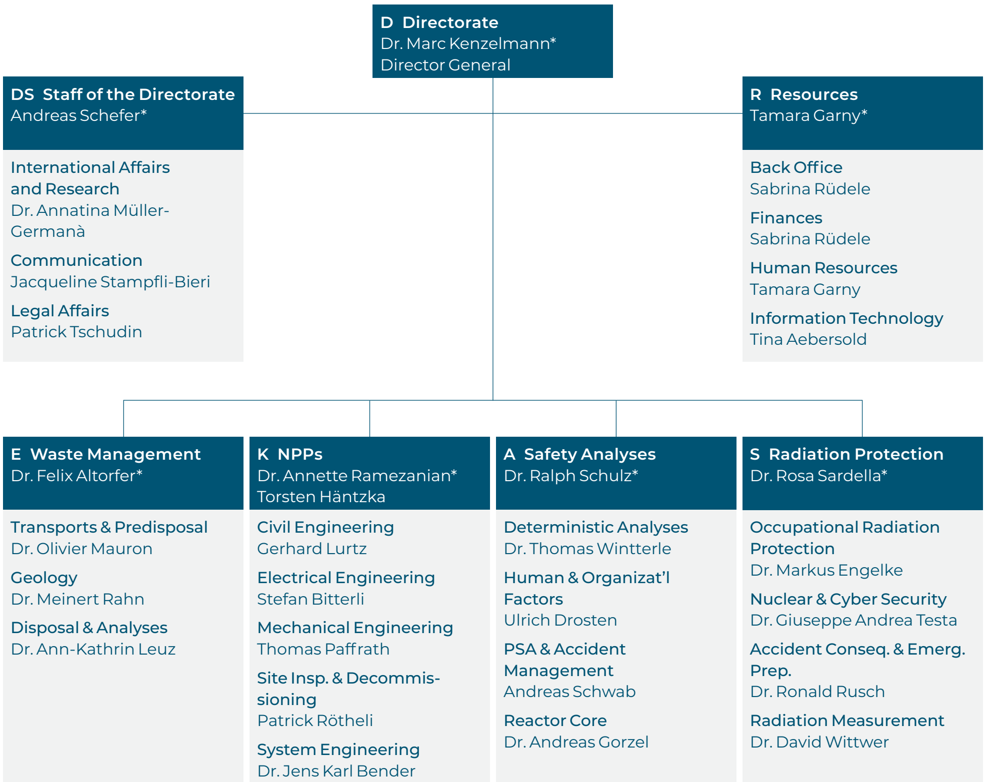
ENSI currently has a staff of *175* specialists covering the following fields:

- **Directorate D:** Director General, assistant *(2)*
- **Division K (Nuclear Power Plants):** oversight of nuclear power plants, including decommissioning and dismantling aspects, reactor safety, site inspection *(46);*
- **Division S (Radiation Protection):** occupational radiation protection, accident consequences and emergency preparedness, radiation measurement, nuclear and cyber security *(33);*
- **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 *(22)*
- **Division R (Resources):** human resources, IT and infrastructure, finances and back office *(25).*

The number of employees has *increased* in the recent years *due to the strategic workforce planning, which is done on regular basis.* In March *2025,* ENSI had *172* employees representing *162.9* 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

Figure 3: ENSI Organisational Chart March 2025 – Source ENSI



*** Members of the executive board**

become more and more important as several 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 number 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. *In addition to those, a strategic workforce planning is done one regular basis. This specifically with regard to the retirements of employees and the associated drain of knowledge. In the past few years, ENSI has also established so called "tandem positions" for those positions in which employees retire within the next few years. Those positions are filled twice over a longer period of time in order to ensure the transfer of knowledge. As part of this concept, ENSI has increased its workforce plan by around 20 FTEs since 2022.*

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 *2025*. Taking into consideration the costs and benefits, the certification of the environmental management system was abandoned in 2017. 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 accreditation for the laboratory for radiation measurement and the inspection body will be renewed for another five years in 2025. In 2024, ENSI established a compliance management system, which came into force in 2025. The compliance management system is based on ISO 27001, however there are no plans to certify it.*

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 by all staff members by 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 *14* 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 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, compliance, 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.
- 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 PWC. 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 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 *and implemented* several projects relating to human resources management *in the past few years*. The projects concern several topics including Knowledge and Skills Management, Employer Branding, Personnel Development and training, Workplace-Health-Management, modernisation of the terms of employment and digitalisation of HR-workflows.

ENSI has increased its involvement and participation in nuclear safety assistance programmes at many levels. This includes par-

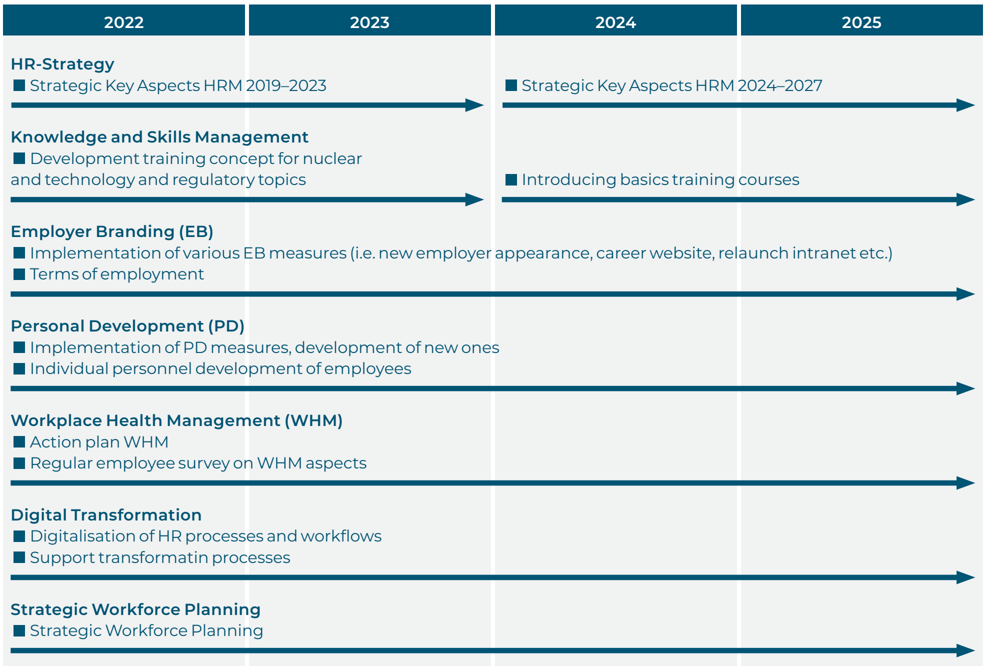


Figure 4: ENSI Key Aspects of Human Resources Strategy and Personnel Development – Source ENSI

ticipation in international working groups and IAEA services, such as the IRRS and *ARTEMIS* 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).

International cooperation

International cooperation is of central importance to the oversight of nuclear installations. Therefore, in 2024, ENSI updated its "Strategy International Activities 2024", which defines the extent of ENSI's international commitment, the topics to be addressed and the impact to be achieved. ENSI is currently developing a time- and content-related operational implementation plan. ENSI is actively involved in international cooperation to enhance nuclear safety and security. It participates in key organizations such as the IAEA, WENRA, and OECD-NEA. ENSI plays a role in developing international safety standards, exchanging regulatory expertise, and tracking global scientific and technological advancements (see more in Article 7). These efforts aim to reinforce nuclear oversight in Switzerland and foster global nuclear safety. ENSI's involvement spans more than 70 bodies, including international governmental organizations, bilateral commissions with neighbouring countries, professional associations, and EU institutions where ENSI participates as observer. With regard to international peer reviews, ENSI actively and regularly participates in the Review Conferences of the Convention on Nuclear Safety (CNS) and the Joint Convention. Switzerland also regularly hosts international peer review missions (see Chapter "Summary") and ENSI regularly sends experts to participate in international peer review missions.

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.

As a federal authority, ENSI has a statutory information mandate. It keeps the public informed about the condition of nuclear facilities and issues related to nuclear goods and radioactive waste. ENSI's website (www.ensi.ch) is an important communication tool for publishing aspects of nuclear safety and security in Switzerland that are relevant to the public in the national languages of German and French, and, to a lesser degree, in Italian and English. ENSI regularly provides information about incidents and overhauls at nuclear power plants, updates to the regulations, safety-related statements on the periodic safety reviews of nuclear power plants, contributions to safety cases in connection with earthquake and flood hazards, projects and events, research activities, and the disposal of radioactive waste. In addition to issuing technical publications, ENSI also publishes four annual reports: the Regulatory Oversight Report, the Radiation Protection Report, the Research and Experience Report and the Business Report of the ENSI Board. The reporting on the website is accompanied by social media activities and a regular newsletter. Other communication activities include responding to parliamentary procedural requests, 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, interviews, background discussions and answering questions about nuclear safety, which are the subject of current media discussions.

ENSI conducts two series of events to involve the public and various stakeholders in the current discourse on national safety and security of nuclear facilities and on deep geological repositories, and to provide information in an open and transparent manner: the Technical Forum on Nuclear Power Plants (TFK) and the Technical Forum on Safety (TFS).

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 operators and authorities. The responses from both forums are public and can be viewed on the ENSI website.

In the autumn of 2022, ENSI adopted the new communication strategy. The key objectives are to position ENSI as a recognised center of excellence for nuclear safety and security in Switzerland, and to proactively inform the dialog groups about the decisions that are relevant to them in a fact-based, quality-assured manner. Compared to the previous strategy, the new strategy is characterised by a more specific definition of the different dialogue groups and the corresponding communication objectives, as well as by the solution principle for achieving the objectives. The operational measures for implementing the strategy will be implemented step by step and aligned more specifically with the respective dialogue groups and their communication objectives.

In addition, the ENSI Communication Section, which currently employs seven staff members, participates as part of the core team in the ENSI Emergency Organisation, that is integrated in the national emergency organisation. In the autumn of 2022 and 2024, it took part in the overall emergency exercise of the Federal Office for Civil Protection (FOCP) and practiced and reviewed its own procedures. In addition to the national emergency exercises that take place every two years, the communications department also participates in all annual power plant emergency exercises.

Since Switzerland's nuclear power plants continue to make a significant contribution to the energy supply and the construction and operation of new nuclear power plants in Switzerland is prohibited by law, the focus of ENSI's supervisory activities and, consequently, of its communications activities, is increasingly on the long-term safe operation of the power plants. Other topics relevant to the public that will become increasingly important for ENSI's communications activities in the future include the decommissioning of nuclear power plants, the deep geological repository and planned research project for a nuclear facility with low hazard potential.

Oversight culture

ENSI uses the term "oversight culture" to refer to all characteristics and attitudes within ENSI that are related to, and focused on, continuous improvement and professional development in the execution of its core legal mission: the oversight of Swiss nuclear installations. *ENSI's approach to oversight culture is based on the belief that a regulatory authority has an influence on how the licensees think and act regarding safety in their daily work routine. Following this belief, the authority is aware that it naturally influences both the safety and the safety culture of the supervised organizations.*

ENSI started its engagement by launching a project to examine ENSI oversight culture in 2012. In the following years of this project, additional actions are initiated to promote ENSI's oversight culture. For example, feedback was requested and obtained from licensees on oversight activities.

All efforts to continuously improve the oversight activities were recognised as "Good Practice" by the 2021 IRRS Mission to Switzerland. Following this mission, ENSI launched new initiatives in the area of oversight culture. These also included a deeper understanding of the term "oversight culture", which is reflected in Figure 1 below, and the creation of a new position to coordinate oversight culture activities.

ENSI's understanding of oversight culture (see Figure 5) is based on two perspectives: An inner and an outer perspective. The inward perspective refers to the cooperation and work organization within ENSI, while the outward perspective refers to its supervisory strategy and method. *The consideration of both perspectives aims to strengthen ENSI's organization internally, which leads to a lasting impact externally, resulting in a reinforcement of the safety culture of the licensee's organisation. Furthermore, it also reflects the belief, that a regulatory authority inherently influences the licensees' safety culture.*

The continued development of the oversight culture thus involves the improvement of both perspectives. ENSI employees are

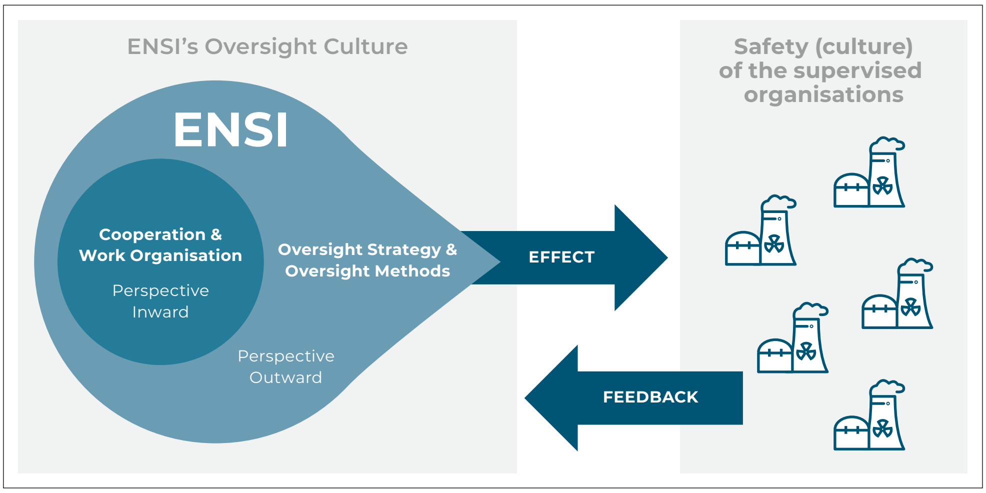


Figure 5: ENSI's oversight culture

involved in this improvement process, and already existing meeting and information forums as well as processes will also be used for this purpose.

In the report, ENSI focused particularly on the inward perspective. For example, focus groups were conducted in which randomly selected ENSI staff members discussed the topic of learning from experience, and ENSI's entire executive board held a seminar on the same topic. Similarly, ENSI began to improve feedback learning within project management and supports the adoption of agile project management methods, where learning from experience plays a crucial role.

In the fall of 2024 Switzerland invited NEA to hold a Country Specific Safety Culture Forum (CSSCF). Following this forum, ENSI took the opportunity to exchange on insights gained during the forum internally. This exchange will continue once the NEA report is available, which is expected in 2025.

As part of its efforts to promote its oversight culture following the 2021 IRRS Mission to Switzerland, ENSI created the position "Coordination of oversight culture activities". The aim of this position is to coordinate and initiate oversight culture activities. The holder of the position is a member of ENSI's Organisational Health Management / Oversight Culture steering group. Due to the cross-organizational nature of the role, the jobholder is a member of ENSI's Organisational Health Management / Oversight Culture steering group and reports directly to ENSI's executive board.

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

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

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. 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.

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[6];
- 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 since the years following the Fukushima accident in 2011. 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 losing nuclear expertise. *Further, according to forecasts, the shortage of skilled workers will be clearly noticeable in the future, and it will become more difficult to fill vacancies. The unemployment rate has been at a historically low level in the report period, making it even more difficult to recruit skilled workers. Filling vacancies with qualified specialists was challenging in the reporting period, particularly as the supervisory authority and the supply industry were*

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

also trying to recruit such specialists. For the most part, however, the vacancies were filled on time. ENSI is closely monitoring the personnel situation and the assumption of responsibility by the NPPs in times of a shortage of skilled workers. The nuclear industry also underwent changes due to the liberalisation of the European electricity market, which in previous reporting periods resulted in cost pressure and unprecedented austerity measures (see Leibstadt and Beznau NPP below). *During the reporting period, there has been a paradigm shift, and NPPs have started to increase their workforce. The increase in personnel is related to the selective strengthening of the organization, but also to investments in long-term operation (Leibstadt and Gösgen NPP), the securing of personnel resources until decommissioning (Beznau NPP) as well as strategic initiatives, such as the development of projects around digitalization or IT security (Leibstadt and Beznau NPP). The increase in personnel is also related to securing enough licensed personnel until the end of operating lifetime of the NPPs. However, the increase of workforce also has to do with double staffing in the context of retirements or job transfers. This is a forward-looking way of preserving expertise in connection with the generational change and ensuring the availability of experienced and qualified personnel to guarantee the continued safe operation of plants.* 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 reporting period, there were several personnel changes at management level at the power plants due to retirements. At Beznau NPP, it was necessary to replace almost the entire senior management team. These departures and replacements were already planned for the long term. There was also the departure of the power plant manager, who took over the management of the energy company's nuclear business, which includes the two nuclear power plants Beznau and Leibstadt. The power plant manager function was replaced by a "senior nuclear expert" who had been hired by NPP Beznau sixteen months earlier as part of the "strategic hire" program. A "strategic hire" is the employment of a younger, highly competent person who is being prepared to take on "senior" management functions. The new power plant manager received an intensive training and introduction program at the plant with a focus on operations and the technical departments as well as relevant committees, such as the Internal Safety Commission. 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, in addition, reports to the plant CEO of the energy company's nuclear business. The safety controller's mandate lasts for about 3 years. *Another voluntarily initiative is the creation of an independent supervisory body at the level of the energy company's nuclear business, called "Nuclear Safety Council". This council advises the management on nuclear safety issues. In addition, the energy company has also appointed a "Nuclear Safety Officer". He is a member of the "Nuclear Safety Council" and has a supervisory function at the level of the energy company.*

During the reporting period, the "Nuclear Advisory Board" was created to support the Executive Board of NPP Gösgen and provide advice on nuclear expertise with the involvement of external nuclear energy experts. "Corporate Independent Oversight" (CIO) and "Plant Independent Oversight" (PIO). The former is an external and independent review/assessment of safety, the latter an internal plant review/assessment, which further expands and strengthens the aspects of nuclear safety and plant availability.

At the start of the nuclear industry in Switzerland, the Swiss NPPs founded the "Group of Swiss NPP Managers" (power plant managers). 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.

In 2022–2025, the following WANO peer reviews, WANO follow-up missions and IAEA Safety Culture Self Assessments took place in Switzerland:

- ***2022:*** *WANO peer review in Beznau NPP*
- ***2022:*** *WANO peer review in Leibstadt NPP*
- ***2023:*** *WANO peer review in Gösgen NPP*
- ***2024:*** *WANO follow-up mission in Beznau NPP*
- ***2024:*** *WANO follow-up mission in Leibstadt NPP*

In addition to activities organised by WANO, the Swiss NPPs also conducted the following IAEA missions:

- ***2022:*** *IAEA Safety Culture Self-Assessment in Gösgen NPP*
- ***2022:*** *IAEA Safety Culture Self-Assessment in Leibstadt 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. *On the one hand, for specific functions (licensed operating, radiation protection and security personnel) there are requirements for the minimum number of staff and, on the other hand, for licensed operating personnel a presence requirement. The minimum staffing levels apply to service operations. The minimum staffing level is an organizational criterion that relates to the number of staff employed. It applies due to dismissals and retirements, not due to on-site absences due to e.g., illness. The presence regulations specify the minimum number of operating personnel and their presence in the control room according to the respective operating mode. A departing shift may only go home at the end of its shift if it can hand over the installation to a shift group that fulfils the presence regulations.*

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 relevant ordinances. The ordinance governing the requirements for personnel in nuclear installations also stipulates that NPP personnel must be medically and psychologically fit for their functions.

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 2024, the twin-unit Beznau NPP had a workforce of 530, Gösgen NPP had a workforce of 614 and Leibstadt NPP had a workforce of 538*.

All Swiss plants have 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. *Overall, staff turnover at Swiss NPPs is low. These measures must be seen primarily as accompanying measures to compensate for the changes of social developments, such as a generally higher mobility of (younger) workers or a partially decreasing attractiveness of the nuclear industry as an employer, low dynamics of nuclear technology due to the high density of regulation or the decreasing attractiveness of shift work.* 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.

In addition to the full-scope simulators, the NPP Beznau and Gösgen have field simulators on site. NPP Leibstadt trains its personnel in the KKB's field simulator. A field simulator is a facility that replicates the physical environment of a nuclear power plant. It thus creates a realistic environment where operators can practice and train on real equipment and in real scenarios. This allows them to experience situations as they would encounter them in the plant, promoting hands-on learning. The NPP use the field simulators e.g. to teach error avoiding techniques and standards for safe working.

NPP Gösgen has a High Reliability Organisation (HRO) centre, where its field simulator and further training facilities are installed The courses held at the HRO Centre are designed to efficiently convey the tools of professional action and behaviour through theoretical learning events and practical exercises. For this purpose, actions comparable to the ones in the power plant are carried out on the so-called human performance optimisation tracks (HPO). This makes the transferability of good and improvable actions clear to the participants and an open feedback culture makes it possible to reinforce good behaviour and learn from human errors. In the workshops, participants are divided into mixed groups across departments and hierarchical levels. These workshops are continuously developed further. The content is adapted to current internal and external developments and events. This also includes current trends that are identified from the analyses of deviation reports, as well as findings from WANO peer reviews. This also includes an annual safety day. The deviation reports are also evaluated at the HRO Centre. This evaluation is continuously developed in order to better identify the strengths and weaknesses of NPP Gösgen.

NPP Leibstadt launched a safety culture program in 2019. This program was completed and evaluated in 2022. The evaluation was carried out using the "IAEA Safety Cul-

ture Self-Assessment" program. Accordingly, the topics "Leadership", "Maintaining competence", "Attitude and behaviour", "Organization & processes" and "Communication" were examined. The development of the safety culture is of great importance even after the end of the project and will continue to be actively promoted.

The general training for new employees at NPP Beznau includes several lessons on safety culture and safety topics. Training on operational decision-making (FOORDEC) with the aim of ensuring that a large number of employees have in-depth FOORDEC training. In 2020, KKB launched the introduction of the "5-Why Cause Mapping" incident evaluation method, a tool for developing root cause analyses (RCA). Around a dozen specialists have already been trained as RCA specialists during the reporting period. For many years, the NPP Beznau has been working with weekly "5' for safety" lectures. These lectures provide information on current safety-related topics with reference to the expected standards of conduct. These lectures were successfully continued in the reporting period. The "Learning among colleagues" concept was also continued and became established during the reporting period. It pursues the retention of knowledge and promotes cross-departmental learning and cooperation. NPP Beznau also continued to promote the topic of "dealing fairly with mistakes" (Just Culture). In collaboration with the NPP Leibstadt, an explanatory video was produced on this topic, which supports instructors in communicating the topic via various training channels.

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 and demographic changes). The challenges associated with these changes requires nuclear facilities to adapt to these changes. This adaptive performance of an organization is denoted by organisational resilience. Organizational resilience is the ability of an organization 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 organizational resilience, it is not enough in an organization 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 organization 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 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 to incorporate 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 and finally 2021 – on the occasion of the 10th anniversary of the Fukushima accident – the third part was published.

Furthermore, the revised edition of ENSI guideline G07 came into force in November 2023. In this guideline, requirements for organisational resilience have now been formulated. It describes skills that an organisation must promote in order to foster organisational resilience:

- *The ability to observe and monitor (to know what to look for). This refers to the ability to observe what influences the organisation's performance or could influence it positively or negatively soon. Monitoring encompasses both the organisation's own performance and what is going on in its environment.*
- *The ability to react (to know what to do). This refers to the ability to respond to normal or abnormal events, disturbances and opportunities by activating prepared actions, by adapting current functioning or by inventing or creating new ways of doing things.*
- *The ability to learn (to know what has happened). This refers to the ability to learn from experience, in particular to draw the right lessons from the right experiences. This includes both the small circle of learning from specific experiences and the large circle of learning that is used to achieve goals.*
- *The ability to anticipate (to know what to expect). This refers to the ability to anticipate developments that lie further in the future, such as potential disruptions, new requirements or obstacles, new opportunities or changing conditions.*

In 2023, the Institute of Social Ethics at the University of Lucerne (Switzerland) launched a research project on the topic of responsibility with the aim of investigating responsi-

ble decision-making in nuclear safety. This is ENSI's first collaboration with a research group from the field of ethics of responsibility. Art. 9 describes the changes to which the nuclear industry is exposed. Experience with these changes shows that decisions and actions can no longer be made exclusively based on pre-established rules (such as guideline requirements, process flows). Instead, they also require the organization to adopt an approach that is adapted to the situation and therefore requires organizational resilience. The topics of responsibility and organisational resilience are therefore also integrated into the Guideline ENSI-G07. To maintain and further develop organizational resilience in a nuclear installation, the current practice of improving safety by focusing in particular on errors and defects and their elimination and on avoiding the same or similar events in the future (Safety-I approach) is not sufficient. This approach must be combined with a second perspective. This includes learning from the positive or normal functioning and thus observing and analysing how and why things go right and not wrong (Safety-II approach). ENSI considers the combination of both approaches to be essential for the supervision of organizational resilience and thus for the continuous improvement of safety. The Safety-II approach stands for a dynamic – and therefore not exclusively predetermined and fixed – pursuit of safety by employees. It places people, i.e., their actions and decisions, at the centre of safety efforts. This presupposes that employees are perceived as subjects of responsibility, i.e., as bearers of responsibility (cf. ENSI, 2023), who must provide answers for their actions. This demonstrates the need to combine organizational resilience with the principle of responsibility. The realization that organizational resilience and the principle of responsibility belong together leads to questions that the Safety II approach raises regarding responsibility:

- *What specific skills and characteristics qualify employees for their central role in the Safety-II approach and for fulfilling the responsibility assigned to them in this context?*
- *How are conflicts of responsibility handled in the practical implementation of Safety-II?*
- *What specific guidance is available for employees in dynamic and changing environments as part of the Safety-II approach?*

These questions are to be investigated as part of the three-year research project.
In 2025, the University of Applied Sciences and Arts Northwestern Switzerland launched the research project "Safety – Security – Information Security: Promoting Integrative Safety". In the nuclear field, safety, security, and information security have often been considered separately over the last few decades. Such an approach, as evidenced by experiences in the transportation and healthcare sectors, such an approach can lead to conflicts of objectives and conflict of measures that only become apparent in the case of an event, potentially having a detrimental effect on safety. The increasing interconnectivity of modern systems (digitalized systems) means that areas of safety, security and information security are becoming increasingly interdependent and must therefore be considered comprehensively (integratively) already during planning and implementation stages. The two-year research project examines these three areas integratively, aiming to develop supportive tools to identify and evaluate potential conflicts between them.

Organisation and Safety Culture

The obligation of the licensee to establish a suitable organisation is firmly embedded at several places in the Swiss legislative framework. The Nuclear Energy Ordinance sets out requirements concerning the organisation that are specified in detail in the guideline "Organisation of Nuclear Power Installations" (ENSI-G07). In 2020 ENSI started to revise this guideline. The revised guideline meets the requirements of the IAEA (i.e., GSR Part 2) as well as several WENRA reference levels and will consider new safety concepts like «Organisational Resilience» and «Safety-II». *In November 2023 the revised guideline ENSI-G07 came into force.*

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

In 2025, ENSI will conduct such a discussion on the subject" Safety culture programs: impact, experiences and perspectives of actions". Swiss NPPs have been implementing safety culture programs for many years. ENSI has overseen each single program and now wants to review the effect on safety culture of these programs in everyday work life and decided to proceed such a specialist discussion to reflect on how these programs have impacted the fostering of safety cultures in each NPP.

All Swiss nuclear power plants have pandemic plans since the end of the noughties of this century. These plans have been further developed in recent years and updated for the COVID-19 outbreak. The pandemic plans contain measures to prevent contagion from and between employees and to maintain a safe and reliable electricity production. They should ensure that the number of staff for safe operation does not fall below a critical threshold and that the greatest possible redundancy of staff is maintained.

Human Factors Engineering

The Nuclear Energy Ordinance lays down a series of design principles for NPPs, including a principle relating to human factors engineering: "Workstations 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. It requires a human factors engineering programme in conjunction with the initial concept of modernisation projects. *The guideline ENSI-G07 specifies the requirements of such programmes. In principle, these programmes should be aligned with the IAEA Specific Safety Guide No. SSG-51 "Human Factors Engineering in the Design of Nuclear Power Plants"*. Further, the programme should also adopt a graded approach. This ensures that appropriate resources are allocated in accordance with requirement 7 "Application of the grades 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, who receive adequate education and training on a regular basis.

During the reporting period, NPP Beznau established a new "Event Analysis" group. This organisational change resulted from the findings of the WANO peer review. The recruitment of the necessary specialist staff was completed during the reporting period.

Developments and Conclusion

The revised guideline on organisation of nuclear power installations came into force. This guideline, for the first time, establishes requirements for organisational resilience and human factors engineering in plant modernisation projects. Additionally, two research projects have been launched in the field of human and organisational factors. ENSI has continued its effort to oversee

these factors in both, plant modernisation projects and event analysis. It also maintained its ongoing efforts to oversee safety culture issues in the Swiss nuclear installations.
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. *This including the use of internal and external (supplier) audits.* Major changes in the management system require notification to ENSI.

ENSI concentrates its supervisory activities on the aspects of the licensee'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 in the frame of different oversight activities like in the event analysis process, the outage management, and the process for plant modifications.

The aging issues and plant life extension cause a continuing need for plant modifications to keep the plant state-of-the-art according to the Swiss regulatory requirement. All NPP activities other than normal operation and relevant to safety, e.g. backfitting, replacement and modifications to systems and components, need a permit. To achieve the regulatory approval, ENSI assesses the quality assurance program with special attention to the performance of an independently verification of all safety relevant information in the frame 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 verified if the management system of the NPPs have the appropriate processes in place to capture, analyse and learn from minor deviations and near-miss events. Within the framework of the continuous improvement cycle (PDCA cycle) the control of the effectiveness of the measures derived from the lessons learnt was verified. Another inspection series was performed on the configuration management. The operating organisation of a nuclear installation had to demonstrate the application of an effective configuration management for plant modifications which ensures that planning, realisation, and documentation are coordinated at all times and correspond to the actual designs in the plant. In the frame of a team inspection ENSI carried out a focus inspection of chillers and the associated management system processes. They should ensure that changes in legal requirements, e.g., for refrigerants, are anticipated in an early stage and the impact on the own systems in operation is analysed. In this respect, all licensee organisations have processes in place to monitor and timely react on regulatory changes for refrigeration systems.*

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.

In the frame of the continuous improvement of the management systems, ENSI paid particular attention to capture, analyse and learn from minor deviations and near-miss events and the application of an effective configuration management for plant modifications.

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. *Since June 2017, an additional LTO safety proof must be submitted as part of the PSR for the period following the fourth operating decade. The licence holder must 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 (see section below).*

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 *(revised version of January 2025).*

The above safety analyses are explicitly specified in the Nuclear Energy Ordinance as the requirements. *Decommissioning requires, among other things, a systematic safety assessment and a review of the safety analysis, which is specified in the NEO, too.* 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.

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, the corresponding update of the probabilistic safety analyses (case b)), *and recently in 2023 and 2024* the refined deterministic safety analyses *(case c)). Requested additional refinements of the deterministic analyses of the seismic hazard are progressing. In addition, the earthquake hazard ENSI-2015 is also progressively applied to the nuclear installations of Zwilag and PSI.*

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 *of the Swiss NPPs and the nuclear installations of PSI and the Central Interim Storage Facility (Zwilag) in November 2021* to perform a new safety assessment that also includes the morphological effects *by the end of 2022. The formal request comprised of a detailed and refined deterministic safety analysis and to assess possible strengthening of riverbank reinforcement. In addition, for the NPPs in operation (Beznau KKB, Gösgen KKG, Leibstadt KKL) ENSI requested an update of the external flooding probabilistic safety assessment for power operation. The operators of the Swiss NPPs, the PSI and Zwilag have updated their external flooding safety assessment accordingly and submitted their analyses on time. At PSI improvement measures were derived from the project based on the morphological effects. At the NPPs in operation as well as at Zwilag the detailed recording of the soil and/or the riverbank structures and the comparison of the determined resistance values with the modelled loads showed that no safety-relevant buildings are at risk from erosion.*

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. 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. *Building on this, in October 2022 ENSI requested that the license holders of the NPPs in operation update their extreme weather safety assessments for an exceedance frequency of 10^{-4} per year. The updated and by the operators in the second half of 2024 submitted assessments are currently under scrutiny. Part of the submission is phased for Gösgen NPP to the second half of 2026.*

Furthermore, Switzerland voluntarily participated in the second European Topical Peer Review (TPR) on fire protection. In the first phase of the review, national self-assessments on the fire safety analyses, the fire protection concepts and its implementation, as well as the national regulatory framework were assessed, and the results were published in October 2023. The results of the Swiss NPPs in operation, Mühleberg NPP (under decommissioning), and the spent fuel storage facilities (interim dry storage ZWIBEZ at KKB, interim wet storage at KKG, central interim dry storage Zwilag) were documented in the National Assess-

ment Reports (NARs). The second phase started in the beginning of 2024 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 June 2024. Once the final results have been published by ENSREG, ENSI will set up a national action plan to resolve possible areas for improvement.

The 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, *see section on deterministic analysis. Furthermore, the recent detailing of the Guidelines on Fire Protection in the new ENSI-G18 (October 2024) that substituted the former HSK-R-50 stipulated the update of the respective rules in the ENSI-A01.*

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 revised ENSI-B08 (October 2022).* 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 was submitted with the PSR in 2022 and is currently under review by ENSI. Results of the ENSI review are described in the LTO safety evaluation reports dated November 2010 and November 2021 for Beznau NPP, December 2012 for Mühle-*

berg NPP and December 2023 for Gösgen NPP. 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.

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 *for the NPPs in operation* 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 *(revised in April 2025)*. 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 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 *was* 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. *During the reporting period, the requirements for deterministic fire analyses were also updated as part of the preparation of the fire protection guideline ENSI-G18 (Revised October 2024).*

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 main-

tenance 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 start-up 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.

PSR & *LTO*

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. *Additional LTO safety proof must be submitted as part of the PSR for the period following the fourth operating decade (see section above).* 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.
A complete summary of the backfittings initiated after Fukushima is given in Article 18.

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.

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 *requirements* for AMPs in Switzerland are provided within the cur-

rent 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). *The Guideline is currently under revision and is planned to be published in 2026. The requirements of the IAEA Specific Safety Guide SSG-48 as well as the outcome of the Topical Peer Review conducted in 2017 (see further below) are considered for the revision.*
Information from manufacturers, knowledge gained from *inspection and* 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 *based on generic catalogues of 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 *and inspection* 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 factsheets 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). The TPR report confirmed that the Swiss NPPs have implemented effective AMPs. In addition, challenges which are common to many, or all countries were identified. *Also,* Switzerland was issued a number of good practices *(see ENSI CNS report 2022).*
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 *or*

are currently being implemented in the Guidelines ENSI-B01 and ENSI-B02.

Guideline ENSI-B02 was revised in 2020 and issued in February 2021 *(recent amendments in September 2023)*. 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.

Due to administrative restructuring the revision of Guideline ENSI-B01 is delayed and will be published in 2026. The following additions are considered in the draft version:

- *Requirements for the ageing management of concealed pipework,*
- *Consideration of technological obsolescence in the AMPs for mechanical and electrical SSCs,*
- *Definition of maintenance measures during prolonged shutdown periods,*
- *Enlargement of the scope of mechanical SSCs to be considered in the AMPs.*

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.

For each NPP, *safety assessment* 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.

Table 3: Safety Assessment Table

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

Levels of Defence in Depth:
Level 1: Prevention of abnormal operation and failures;
Level 2: Control of abnormal operation and detection of failures;
Level 3: Control of accidents within the design basis;
Level 4: Control of severe plant conditions, including prevention of accident progression and mitigation of the consequences of severe accidents;
Level 5: Mitigation of radiological consequences of significant releases of radioactive material.

Table 4: Safety Assessment Table – *Primary* Safety Functions

Goals \ Subject		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				

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 of 1991 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 issued in 2017 (came into force in 2018). The Ordinance's contents are now arranged 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 issued in 2017:

- 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

ENSI has issued, revised or is in the process of revising and adapting all of its other guidelines relevant for radiation protection. *Since the last Review Meeting two Guidelines have been revised and newly issued:*

- **ENSI-B04:** Clearance of materials and zones from controlled areas (issued in November 2018);
- ***ENSI-B09:*** Determining and reporting of doses from occupationally radiation-exposed personnel (revised and issued in November 2024);

In 2024, ENSI published the new edition of the ENSI-B09 guideline, thereby achieving harmonization with current international standards and including adjustments derived from supervisory practices. Regarding the harmonization to IAEA GSR Part 3 several updates were introduced. Dose limits for the organ-equivalent dose for occupationally exposed individuals aged 16 to 18 are now set in the ENSI-B09 guideline, specifically regarding the lens of the eye, as well as the skin, hands, and feet. For this group of persons, access to the controlled zone is only permitted under supervision and solely for training purposes. Furthermore, the obligation of license holders to inform occupationally exposed women and those who, according to Article 142 of the Radiation Protection Ordinance (RPO), are designated for emergency response, has now been formally introduced. It is essential that women are made aware of their rights, which they may exercise once they inform their employer of a pregnancy or a breastfeeding. The primary *focus is the protection of the unborn child or infant. This measure implements a recommendation from the IAEA's IRRS mission to Switzerland in 2021, at least at the guideline level. It is nonetheless planned within the ongoing revision of the Radiation Protection Ordinance that all the above-mentioned points are explicitly introduced in the legislation.*

- ***ENSI-G12:** Nuclear Facility internal Radiation Protection Measures (issued in 2021)*
- **ENSI-G13:** Radiation protection measuring instruments in nuclear facilities, basic concepts, standards and testing (issued in July 2018);
- ***ENSI-G14:** Calculation of the radiation exposure in the vicinity of nuclear installations as a result of emitted radioactive substances and direct radiation* (revised and issued in 2025);

The Guideline ENSI-G14 has been thoroughly revised adopting the definition of exposure situations of the new RPO. Implementing a suggestion from the IAEA's IRRS mission to Switzerland in 2021, it has been brought up in line with the international requirements for dose calculations along ICRP 101 and ICRP 103. In particular the model of the representative person has been adopted.

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 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

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.

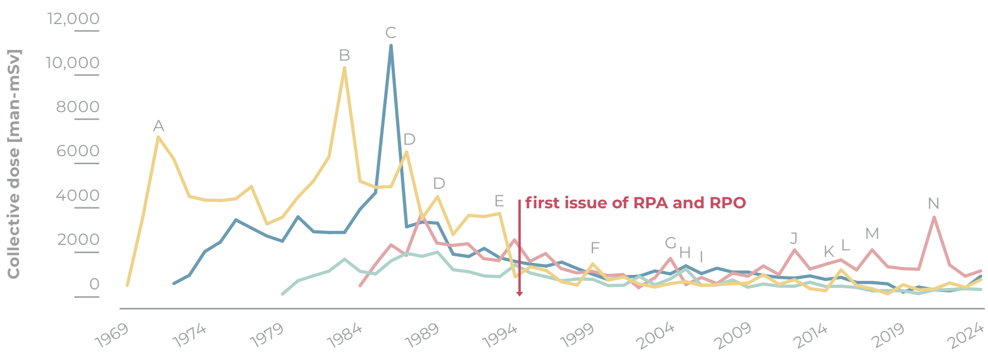
Observation of dose limits and main results for doses to exposed workers

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 power plants is around 6000. The annual collective doses of the last 20 years are presented 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 2024



Annual collective doses for the personnel in Swiss NPPs. All peaks relate to extraordinary work performed. (note 1: the Beznau NPP consists of two units, both located on the same site; note 2: the Mühleberg NPP has permanently ceased operation and is in decommissioning since 2020).

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

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

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-G14 at a maximum value of 0.3 mSv per year per person.
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 not exceed 0.3 mSv per year, for failures with

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 ■ 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 ■ *using drones and robots for inspections in high-dose rate areas*
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 radiological 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 interventions 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

Table 5: Main dose reduction measures in Swiss NPPs.

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 disposition regulating 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 to check compliance with the relevant legal and regulatory requirements 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").

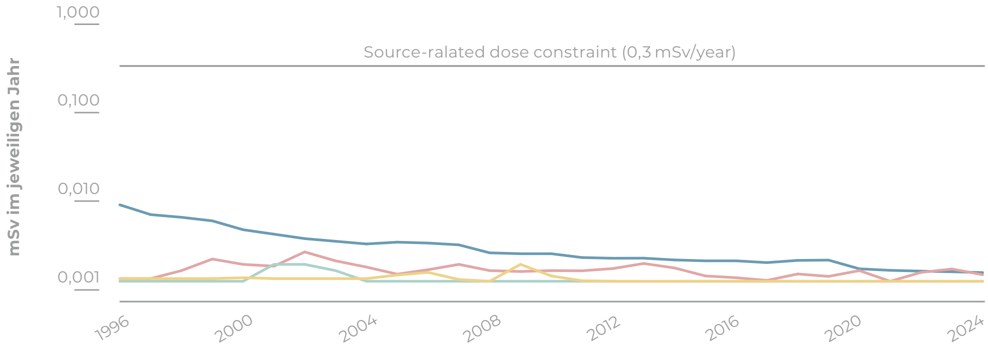
The dose calculations are performed for the representative person according to ICRP recommendations 101 and 103. The following pathways are considered: submersion from the plume, inhalation, ground radiation and ingestion of fruits, vegetables, milk, meat, fish, and drinking water from the river downstream 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 wastewater is collected and treated in batches. However, each plant applies customised reduction techniques for the treatment of this wastewater. In Beznau NPP, the radioactivity in the wastewater is reduced by nanofiltration and/or, if necessary, chemical precipitation. In Gösgen NPP, an evaporation technique is used to reduce the amount of contaminated wastewater and produce a concentrated slurry. Leibstadt NPP employs a centrifugation or evaporation technique sometimes combined with ion-exchange to treat their contaminated wastewater, 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 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 0.3 mSv/year is also shown. (note 1: the Beznau NPP consists of two units, both located on the same site; note 2: the Mühleberg NPP has permanently ceased operation and is in decommissioning since 2020)

Beznau I + II NPP **Gösgen NPP** **Leibstadt NPP** **Mühleberg NPP**

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 1 GBq/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 other national federal laboratories (in particular PSI, Swiss Federal Institute of Aquatic Science and Technology, Spiez Laboratory) are required to cooperate to the monitoring program. 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, on-site and off-site emergency plans must be established and approved by ENSI. The general requirements for emergency preparedness are based on the following acts, ordinances, Inspectorate's guidelines and concepts:

Acts
- Nuclear Energy Act;
- *Civil Protection and Defense 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 Civil Protection;
- Ordinance on the Federal Civil Protection Crisis Management Board;
- Ordinance on Iodine Prophylactics in the Case of a Nuclear Accident;
- *Ordinance on the Crisis Organisation of the Federal Administration;*
- 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 an accident in a nuclear facility in Switzerland, Federal Office for Civil Protection FOCP (2024).
- National Planning and Measures Concept: Large-scale evacuation in case of a nuclear power plant accident (2016)

Following the accident in Fukushima, a working group was set up by the Federal Council (IDA NOMEX)[7] in May 2011 to review emergency preparedness measures in case of extreme events in Switzerland. The group's report "Review of Emergency Preparedness Measures in Switzerland", which is available on the ENSI website, was adopted by the Federal Council in July 2012 and describes a series of organisational and legislative measures which have proven to be necessary as a result of the review conducted. These include, for example, measures in the field of equipment and material, emergency planning zones, scenarios for emergency planning and large-scale evacuations. As a consequence of IDA NOMEX, the legal basis as well as concepts pertinent to emergency preparedness and response were revised. *Recently, the Civil Protection and Defense Act, the Civil Protection Ordinance as well as the Emergency Protection Concept in Case of an Accident in a Nuclear Facility in Switzerland were updated. The Civil Protection Ordinance regulates the cooperation of authorities involved in civil defense, the*

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

alerting and information in the event of an incident. Drawing lessons from the Covid-19 pandemic, the Federal Government issued a new ordinance on the Crisis Organisation of the Federal Administration. The new ordinance came into force in February 2025 and has established new structures for crisis management in Switzerland in order to create the necessary conditions for a rapid and systematic deployment of interdepartmental crisis teams. A national crisis in this context can be a pandemic episode but also a nuclear emergency. The new ordinance should organize the processes of crisis management at the top level of the Federal Administration including the political decision makers. The implementation of the new structures including the interface with the existing federal and cantonal emergency organisations is ongoing.

Since the accident in Japan, the scenario used for emergency planning purposes is characterized by an unfiltered, substantially higher source term than previously assumed. Consequently, awareness for emergency preparedness and response beyond the outer radius of Zone 2 (i.e., 20 km) have been raised, which is reflected in the revised concept for the emergency protection in case of an accident at a nuclear power plant. All nuclear facilities under the supervision of ENSI are using an IAEA-compatible emergency classification system for emergency declaration to ENSI. The scope of inspections with regard to emergency preparedness and response at the NPP sites has been extended and the redundancy of emergency communication means has been improved. *Following a suggestion from the IRRS mission in October 2021, ENSI is in the process of clarification of the requirements for the notification of emergencies to ENSI by licensees.* A national nuclear and radiation emergency plan is still to be finalized under the lead of the Federal Office for Civil Protection (FOCP).

On-site emergency organisation

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

- operating procedures for abnormal situations
- emergency operating procedures
- severe accident management guidance (SAMG)
- procedures for reporting to ENSI and to the National Emergency Operations Centre
- procedure for reporting to cantonal police for 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 were extended. As a result, additional emergency equipment has been installed or stored at the plant site and the existing accident management procedures have been adapted.

Further equipment is 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 are available and can be delivered from Reitnau to the affected NPP within eight hours of the request. For situations where transport to the power plant by road is impossible, an option exists for transport by air via military helicopter. The operators test the severe accident equipment stored at Reitnau on a regular basis and during their emergency exercises. To ensure communication in an emergency, redundant and diverse communication systems between the NPPs, ENSI and the National Emergency Operations Centre are available. These communication systems are tested once a month. ENSI and all NPPs have the possibility to relocate emergency staff to one or more alternate emergency facilities. Assessing the operability and habitability of emergency infrastructure during nuclear accidents is part of ENSI's inspection programme.

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 firefighting 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 immediate 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 the radioactivity in the environment and about the consequences of such dispersion. ENSI also 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 surrounding of all NPPs in Switzerland. The system monitors dose rates continuously at 12 to 17 locations in the vicinity of each NPP. The data are transmitted online to ENSI and the National Emergency Operations Centre. The Ministry of the Environment of Baden-Württemberg (Germany) receives online data from the dose rate monitors in the vicinity of the Beznau NPP and Leibstadt NPP. All data is also available on the ENSI website in real time. For further information on MADUK, please refer to Article 15. A second automatic network (NADAM) monitors dose rates on the whole national territory. The data is available on the NEOC's website. Every hour Switzerland transmits the dose rate hourly mean values of all its stations to EURDEP which are then transmitted to IRMIS. The ANPA system also provides ENSI with online access to measurement data for 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 (**S**ource **T**erm **E**stimation **P**rogram), which allows a source term estimation considering actual plant parameters. ENSI uses an automated system for radiological forecasting: Calculations are performed hourly by means of JRODOS (Java-based real-time online decision support system) in combination with LASAT (Lagrangian Simulation of Aerosol-Transport) as

the dispersion engine, using forecast meteorological data. ENSI operates a redundant IT infrastructure at its alternate emergency premises, thus ensuring a full redundancy of its systems for emergency management. Yet another JRODOS-system is operated at the National Emergency Operations Centre.

■ 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 after the initial phase of an emergency during an accident. The NEOC is also responsible for the overall assessment of an emergency situation and for the transmission of warnings to the cantonal and federal authorities. It must decide on initial protective actions to protect the population and to transmit the alarms (sirens) together with the behavioural instructions disseminated by radio broadcast. The NEOC is responsible for coordinating measurement teams, data processing and evaluation, assessing the radiological situation and sharing these results with other emergency related information with all the relevant response organisations on a secured electronic platform. It is also responsible for information exchange and communicating with international partners (neighbouring countries and international organisations).

■ The Federal Civil Protection Crisis Management Board is responsible for the 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 so-called cantonal government conferences. Within their area of responsibility, the members take the necessary precautions for coping with radiological emergency events.

■ *According to the new ordinance on the Crisis Organisation of the Federal Administration, the interdepartmental crisis organisation of the Federal Administration consists of a strategic policy crisis management team and an operational crisis management team. The two crisis teams are supported by a permanent, professional crisis management organization. The Federal Council appoints the strategic policy crisis management team when there is an immediate and serious threat to the state, society or economy that cannot be dealt with by existing structures. It assesses the strategic/political aspects, coordinates the crisis management of the Federal Administration at the strategic/political level and develops options for action and bases for decision-making for the attention of the Federal Council. The operational crisis team compiles the information relevant for the development of decision-making bases and prepares them for the attention of the strategic policy crisis management team. It also coordinates the activities of the special task forces, expert teams and groups, and crisis teams of the administrative units and other affected bodies that are deployed. The ordinance on the Crisis Organisation of the Federal Administration being new, the interfaces of the new structures with the Federal Civil Protection Crisis Management Board are yet to be clarified.*

■ 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 are more precisely described in the 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.

Protective measures	Dose	Dose intervention level	Integration time
Sheltering (house, cellar, shelter)	Effective dose from external radiation and inhalation (outdoors)	10 mSv	7 days
Precautionary evacuation or sheltering	Effective dose from external radiation and inhalation (outdoors)	100 mSv	7 days
Taking iodine tablets	Thyroidal dose from inhalation of radioactive iodine	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	–	

Table 6: Intervention levels

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 to 5 km.
- Zone 2 envelops Zone 1 and encloses an area with an outer radius of about 20 km. Zone 2 is divided in broad overlapping sectors and the public can be alerted in individual sectors as appropriate.

The area outside the Zones 1 and 2 encompasses the rest of Switzerland. As a basis for 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 to be considered in the event of an immediate risk to the population as well as their intervention levels are part of the Dose-Measures Concept defined in the Ordinance on Civil Protection (see Table 6). The concept also includes measures 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. According to the concept, children, adolescents and pregnant women will be further advised to shelter when doses exceed 1 mSv.
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 activity in foodstuffs. The limits correspond to a large extent to the maximum activity levels as set in the EU-legislation.
The protective measures applied during the acute phase must be planned so that they can be implemented as a preventive measure in the initial phase of an accident. During the release, 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 by 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 cloud shine in the cloud phase of an accident by shelter in houses, cellars or shelters. Therefore, this is considered as the most important protective action. In order to prevent infiltration of radioactive material, windows and outside doors should be closed and air-conditioning systems turned off.

■ Iodine (KI) tablets are distributed to all houses, schools, and companies within a radius of about 50 km around the NPPs. Outside of this 50 km radius, KI 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 an accident in a nuclear facility in Switzerland, a precautionary evacuation of zone 1 and affected sectors of zone 2 is to be prepared. Such precautionary evacuations will be ordered by the NEOC. 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 include remaining indoors, evacuation after the cloud passage, restricted access to certain areas, restrictions on certain foodstuffs, countermeasures for agriculture, decontamination, and medical support. The Emergency Preparedness Ordinance also assigns duties in preparedness and response for cantons outside of the zones 1 and 2.

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 the emergency class “Site Area Emergency” is reached. 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 (emergency class “General Emergency”). 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. Alarms are also sent via push notification to mobile phones (AlertSwiss App).

■ Further **alarms** by sirens are issued if necessary, in order to instruct 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: sirens will alert the public located in Emergency Planning Zone 1 and 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 emergency exercise under the observation of ENSI every year. The outcomes of an exercise may lead to new measures to improve the functioning of the emergency organisation. Such measures are implemented into the training programmes of the members of the emergency organisation. According to ENSI's Guideline ENSI-B11, different types of emergency exercises need to be performed regularly, e.g., staff emergency exercises lasting up to 24 hours in order to check the adequacy of the Severe Accident Management procedures and organisational measures especially for long-duration events. A full-scale, so-called general emergency exercise is conducted every two years in Switzerland. Regular participants of the general emergency exercise are at least one NPP, ENSI, NEOC, the Federal Civil Protection Crisis Management Board, the FOCP, the 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 (s. Alert procedures).

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 a nuclear facility, reporting is the responsibility of ENSI. For other radiological incidents, reporting obligations are the responsibility of FOPH.

Because the Leibstadt and Beznau NPPs are close to the German 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. Redundant and diverse communication systems 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 is represented within the "Commission locale d'information" of the Bugey NPP (France) since spring 2016.

Emergency plans are not only tested at the national level. For example, German authorities at both the local and federal level take part in exercises at the Leibstadt and Beznau NPPs. Switzerland intermittently participates in exercises at the French NPPs of Bugey, 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 participates in working groups of HERCA and WENRA on emergency preparedness, as well as in the EPReSC safety standard committee of the IAEA. Furthermore, 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 prearation 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

The emergency protection concept in case of an accident in a nuclear facility in Switzerland has been updated in 2024 and tested during a general emergency exercise the same year. The exercise has shown that questions and challenges remain e.g., with regards to the planning, preparation and implementation of evacuation as a protective measure. A systematic analysis of the existing legal and conceptual foundations with regard to evacuation is needed, the responsibilities at the federal and cantonal level as well as the relevant processes should be recorded. Open questions remain also with regards to the handling of vulnerable persons. At the legislative level, a new ordinance on the Crisis Organisation of the Federal Administration entered into force in February 2025: the implementation of the interfaces with the Federal Civil Protection Crisis Management Board is an ongoing process.

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 in 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). *According to these assessments that have been reviewed by ENSI, earthquakes are dominating the core damage frequency for all NPP. The deterministic assessment was proofed and accepted by ENSI. Minor open points and additional refinements of the deterministic analyses of the seismic hazard are progressing.*

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. *According to these safety assessments of the licence holders that have been reviewed by ENSI, the deterministic and probabilistic requirements are met.*

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 defined new *provisional* hazard assumptions concerning extreme weather conditions *in 2022. Furthermore, ENSI has requested the licence holders to perform a new safety assessment for these values.*

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 *(under decommissioning)*, 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.
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.

In conclusion, Beznau NPP completed a comprehensive analysis and backfitting programme, and substantial improvements have been made. Mühleberg NPP was shut down in December 2019.

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 m² to about 110 m².

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 m² were replaced with strainers of 15 m². 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 airplane 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 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 is in *progress at Gösgen and under consideration at Leibstadt NPP.*

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).

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 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 pow-

Table 7: Comparison of representative earthquake hazards parameters

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

er 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 non-linear 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, 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 and deterministic safety assessment) were finished with positive results.

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 replica 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.

Developments and Conclusion

The implementation of further backfitting measures depends on the assessments and analysis that is continuously performed according to the *Swiss legal and regulatory framework* (see Article 14). Proof of the seismic robustness of the Swiss NPPs, which is based on the new ENSI-2015 hazard specification *led to* further enhancements, *which are tracked by ENSI*. Further improvements *are ongoing* by implementing the requirements from ENSI regarding long-term operation. The safety requirements for equipment used in design basis and design extended conditions have been implemented in the regulatory guideline (ENSI-G02) in which the design rules for existing NPPs are 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 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 Figure 8 below. 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).

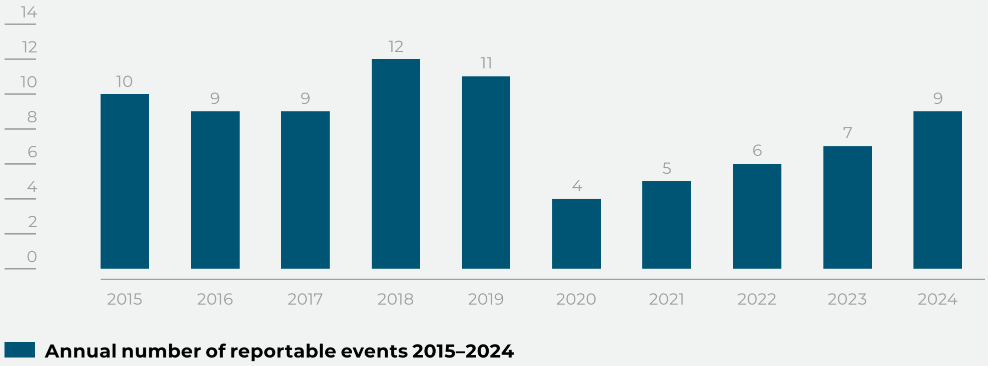
As means for supporting the response to emergencies, emergency operation procedures (EOPs) are designed to bring the plant into a safe operational state, while the Severe Accident Management Guidance (SAMG) is designed to mitigate the consequences of accidents leading to fuel damage.

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.

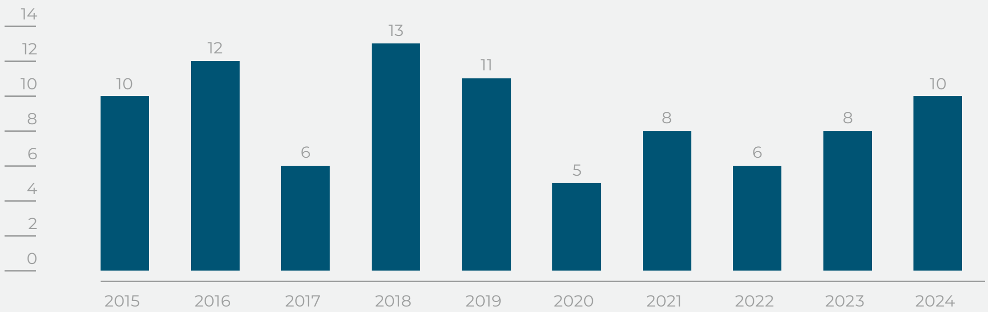
In all plants, SAMG is implemented covering all relevant operational states. Two NPPs closely followed (Beznau) or adapted (Leibstadt) the SAMG concept of the owners' group, Westinghouse PWR or WOG/BWROG, respectively. The Mühleberg NPP (GE BWR) and the Gösgen NPP (Siemens KWU PWR) developed plant-specific con-

Figure 8: Reportable events in Swiss NPPs from 2015–2024

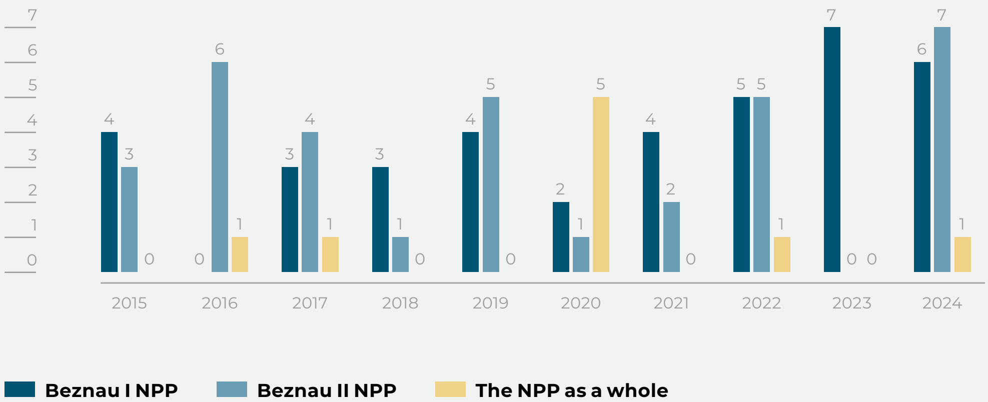
Leibstadt NPP



Gösgen NPP



Beznau NPP



cepts. 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 head-

quarters 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 Zwilag 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 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 reuse or conventional disposal under the supervision of ENSI. The conditions required for clearance are included in Annex *3* 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 (Zwilag), which is successfully operating the world's first plasma incinerator for radioactive waste. The previously used incineration facility at the Paul Scherrer Institute is currently being decommissioned. The installations at Zwilag also provide services for decontamination, segregation, handling of bulky items and 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. 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.

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

Appendix 2: List of ENSI's guidelines currently in force

Status: *April 2025*

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 (amdt. of 2024/10)
ENSI-G03	Deep Geological Repositories	2020/12 (amdt. of 2023/11)
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	2023/11
ENSI-G08	Systematic Safety Evaluations for the Operation of Nuclear Installations	2015/06 (amdt. of 2021/12)
ENSI-G09	Construction and Operational Documentation	2022/10 (amdt. of 2024/10)
ENSI-G11	Safety Classified Vessels and Piping: Engineering, Manufacture and Installation	2009/02 (rev. 2 of 2013/06)
ENSI-G12	Radiation Protection in Nuclear Installations	2021/09
ENSI-G13	Measuring Instrumentation for Ionising Radiation	2015/10 (amdt. of 2021/10)
ENSI-G14	Calculation of the Radiation Exposure in the Vicinity of Nuclear Installations as a Result of Emitted Radioactive Substances and Direct Radiation	2025/04
ENSI-G17	Decommissioning of Nuclear Installations	2014/04 (amdt. of 2023/11)
ENSI-G18	Fire Protection	2024/10
ENSI-G20	Reactor Core, Fuel Assemblies and Control Rods: Design and Operation	2015/02
ENSI-G23	Design Principles for other Nuclear Installations	2021/10 (amdt. of 2024/10)
ENSI-A01	Technical Safety Analysis for Existing Nuclear Installations: Scope, Methodology and Boundary Conditions	2018/09 (amdt. of 2024/10)
ENSI-A03	Periodic Safety Review for Nuclear Power Plants	2014/10 (amdt. of 2018/10)
ENSI-A04	Application Documents for Modifications to Nuclear Installations Requiring a Permit	2008/07 (rev. 1 of 2009/09; amdt. of 2024/10)
ENSI-A05	Probabilistic Safety Analysis (PSA): Quality and Scope	2018/01 (amdt. of 2024/10)
ENSI-A06	Probabilistic Safety Analysis (PSA): Applications	2015/11 (rev. 1 of 2025/01)
ENSI-A08	Source Terms Analysis: Scope, Methodology and Boundary Conditions	2010/02
ENSI-B01	Ageing Management	2011/08

Guideline	Title of guideline	Date of current issue
ENSI-B02	Periodic Reporting by the Nuclear Installations	2008/09 (rev. 5 of 2015/06; amdt. of 2023/09)
ENSI-B03	Reports by the Nuclear Installations	2021/07 (rev. 1 of 2023/02; amdt. of 2023/11)
ENSI-B04	Clearance of Controlled and Supervised Areas and of Materials from Mandatory Licensing and Supervision	2018/11
ENSI-B05	Requirements for the Conditioning of Radioactive Waste	2007/02 (amdt. of 2023/03)
ENSI-B06	Safety Classified Vessels and Piping: Maintenance	2009/04 (rev. 2 of 2013/06)
ENSI-B07	Safety Classified Vessels and Piping: Qualification of Non-Destructive Testing	2008/09
ENSI-B08	Safety Classified Vessels and Piping: Periodic Non-Destructive Testing	2022/10
ENSI-B09	Determination and Recording of the Doses of Persons Exposed to Radiation	2024/11
ENSI-B10	Basic Training, Recurrent Training and Continuing Education of Personnel in Nuclear Installations	2010/10
ENSI-B11	Emergency Exercises	2007/11 (rev. 1 of 2013/01; amdt. of 2020/12)
ENSI-B12	Emergency Preparedness in Nuclear Installations	2019/08 (amdt. of 2024/10)
ENSI-B13	Training and Continuing Education of the Radiation Protection Personnel	2010/11
ENSI-B14	Maintenance of Electrical and Instrumentation and Control Equipment Classified as Important to Safety	2010/12
ENSI-B17	Operation of Interim Storage Facilities for Radioactive Waste	2020/01 (amdt. of 2021/10)
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-102	Design Criteria for the Protection of Safety-Relevant Equipment in Nuclear Power Plants against the Consequences of Aircraft Crashes	1986/12

Imprint:
Convention on
Nuclear Safety 2025

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

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Swiss Federal Nuclear
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