SWISS NATIONAL ASSESSMENT REPORT FOR THE TOPICAL PEER REVIEW 2023

Fire Protection

October 2023

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

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

Swiss National Assessment Report for the

Topical Peer Review 2023

Fire protection

October 2023

Executive summary

At the end of 2021 the Swiss Federal Nuclear Safety Inspectorate (ENSI) decided that Switzerland would take part in the second Topical Peer Review (TPR 2023) of the European Union on 'Fire Protection in nuclear facilities'. In accordance with the ENSREG terms of reference, licencees are expected to carry out independent assessments of the fire protection measures taken. The licensees of the Swiss nuclear facilities were therefore required to submit reports with the information specified in the WENRA Technical Specification. The Swiss nuclear facility licensees submitted the required reports to ENSI on time.

Switzerland has five nuclear power plants at four different locations. These are the Beznau nuclear power plant (KKB) with units 1 and 2, Gösgen (KKG) and Leibstadt (KKL), which are in operation. The Mühleberg nuclear power plant (KKM) has been decommissioned and is being dismantled.

In addition, there are also several research reactors at three other sites. Of these, only the research reactor at the University of Lausanne is still in operation. Two research reactors at the Paul Scherrer Institute (PSI) have been almost completely dismantled. A third research reactor at the PSI has finally been decommissioned and is being dismantled. The dismantling of the research reactor at the University of Basel has been completed.

Interim storage facilities for spent fuel elements are located firstly near the PSI site, the central interim storage facility in Switzerland, and at the Beznau and Gösgen nuclear power plant sites. Two of the interim storage facilities also serve to receive radioactive waste.

Chapter 1 of the National Assessment Report (NAR) justifies the scope of the nuclear facilities included in the TPR 2023 and describes the national regulations applicable to the topic 'Fire Protection'. The assessments focus on the fire protection precautions taken and fire analyses performed at the Swiss nuclear power plants and interim storage facilities.

ENSI has integrated the information and statements from the licensee`s reports into Chapter 2 'Fire Safety Analysis' and Chapter 3 'Fire Protection Concept and its Implementation' of the NAR and provided an assessment in each case. Chapter 4 of the NAR provides an overall assessment of the fire analyses carried out and of the fire protection concept implemented in the Swiss nuclear facilities and draws conclusions.

Notwithstanding the following general conclusions, ENSI has identified potential areas for improvement within the framework of the TPR 2023, which are summarised in ChapterChapter 4 of the NAR.

Fire Safety Analyses

Nuclear power plants in operation

Overall, from ENSI's point of view, the probabilistic and deterministic fire analyses performed by the Swiss nuclear power plants in operation fulfil the requirements specified in WENRA SRL SV 6.1 and E 6.1. The analyses show the high level of protection of Swiss nuclear power plants against internally and seismically triggered fires by demonstrating the shutdown to a safe state with the safety or emergency systems even under conservative boundary conditions. The findings from the analyses of fire effects resulting from an aircraft crash have not been dealt with in the NAR for reasons of information protection.

Manual fire extinguishing by the fire brigade has only been considered in a few fire scenarios in the fire analyses of the Swiss nuclear power plants since the critical fire Chapters are mostly protected by automatic extinguishing systems. In accordance with regulatory requirements, manual fire extinguishing was also only taken into account if there was sufficient time available for intervention on the basis of the fire spread simulations. WENRA SRL SV 6.2 is thus also fulfilled.

From ENSI's point of view, it has been possible to derive specific measures for improving fire protection in Swiss nuclear power plants from the fire analyses carried out to date.

Dedicated spent fuel storage facilities

Overall, from ENSI's point of view, the deterministic fire analyses carried out for the Swiss interim storage facilities meet the requirements specified in WENRA SRL S-30 and E 6.1. Due to the existing specific protective measures against fires resulting from earthquakes and aircraft crashes, there is no need for detailed fire analyses for the repositories with high-level waste.

Fire scenarios covering internal fires and externally triggered fires were analysed for the storage facilities with low- and intermediate-level waste. The fire analyses show that no inadmissible releases of activity occur due to the existing fire protection measures. The permissible dose values according to the regulatory requirements are clearly undercut.

Facilities under decommissioning

Overall, from ENSI's point of view, the deterministic fire analyses carried out for the Mühleberg nuclear power plant (KKM), which is currently being decommissioned, meet the requirements set out in WENRA SRL S-30 and E 6.1.

The fire analyses show that there are no inadmissible releases of activity due to the existing fire protection measures. The permissible dose values according to the regulatory requirements are clearly undercut.

Due to the continuous changes in plant configurations during decommissioning, the fire protection measures implemented in the original plant design can no longer be fully complied with. From ENSI's point of view, the fire analyses carried out show that comprehensive protective measures against internal fires are still being maintained at the KKM, or that alternative measures have been taken.

Fire Protection Concept and Its Implementation

Overall, from ENSI's point of view, the concept of staged fire protection precautions, which includes the prevention and control of fires and the mitigation of the consequences of fires, is being consistently pursued in all Swiss nuclear facilities. The requirements set out in the WENRA Safety Reference Levels are met.

The following fire protection principles are implemented in all Swiss nuclear facilities:

- The facilities have a fire protection concept that contains the most important principles of fire protection. The associated documentation is reviewed regularly and adapted if necessary.
- The facilities have a fire load management tool with which the existing fire loads are systematically recorded and evaluated.
- The facilities have a fire alarm system whose monitoring scope is designed as full monitoring in accordance with national fire protection regulations. The fire alarm systems have been upgraded to state-of-the-art technology in recent years or the projects are currently being implemented.

- Fire protection equipment in the plants is regularly checked using internal processes.
- The principle of forming fire compartments is consistently applied in the facilities, which is based on national fire protection regulations.
- In the facilities, the ventilation systems are designed so that each fire compartment can be separated in the event of a fire by the targeted closing of fire dampers.
- In the plants, the fire protection officer has a commissioning function, which is linked to sound training.

From ENSI's point of view, the particular challenge in fire protection is to bring the current state of the art into line with the existing design of nuclear facilities, some of which are already over 50 years old in Switzerland. The design criteria that corresponded to the state of the art 50 years ago are no longer up to date today, but in some cases cannot be adapted either.

Contents

1 General Information

1.1 Nuclear installations identification

1.1.1 Qualifying nuclear installations

Switzerland has five nuclear power plants at four different locations. These are the Beznau nuclear power plant (KKB) with units 1 and 2, Gösgen (KKG) and Leibstadt (KKL), which are in operation. The Mühleberg nuclear power plant (KKM) has been decommissioned and is being dismantled.

Three units of the Swiss nuclear power plants are pressurised water reactors, two of which are of American design (KKB I and II) and one of which is of German design (KKG). The Leibstadt nuclear power plant is an American boiling water reactor. The units of the Beznau nuclear power plant have more than 50 years of operation and the unit of the Gösgen nuclear power plant has more than 40 years of operation. The Leibstadt nuclear power plant has been in operation for 39 years.

Switzerland also has several research reactors at three other sites. Of these, only the research reactor at the University of Lausanne is still in operation. Two research reactors at the Paul Scherrer Institute (PSI) have been almost completely dismantled. A third research reactor at the PSI has finally been decommissioned and is being dismantled. The dismantling of the research reactor at the University of Basel has been completed.

Interim storage facilities for spent fuel elements are located, firstly, near the PSI site and at the Beznau and Gösgen nuclear power plant sites. Two of the interim storage facilities also serve to receive radioactive waste.

The locations of the nuclear facilities described are shown in Figure 1.1.

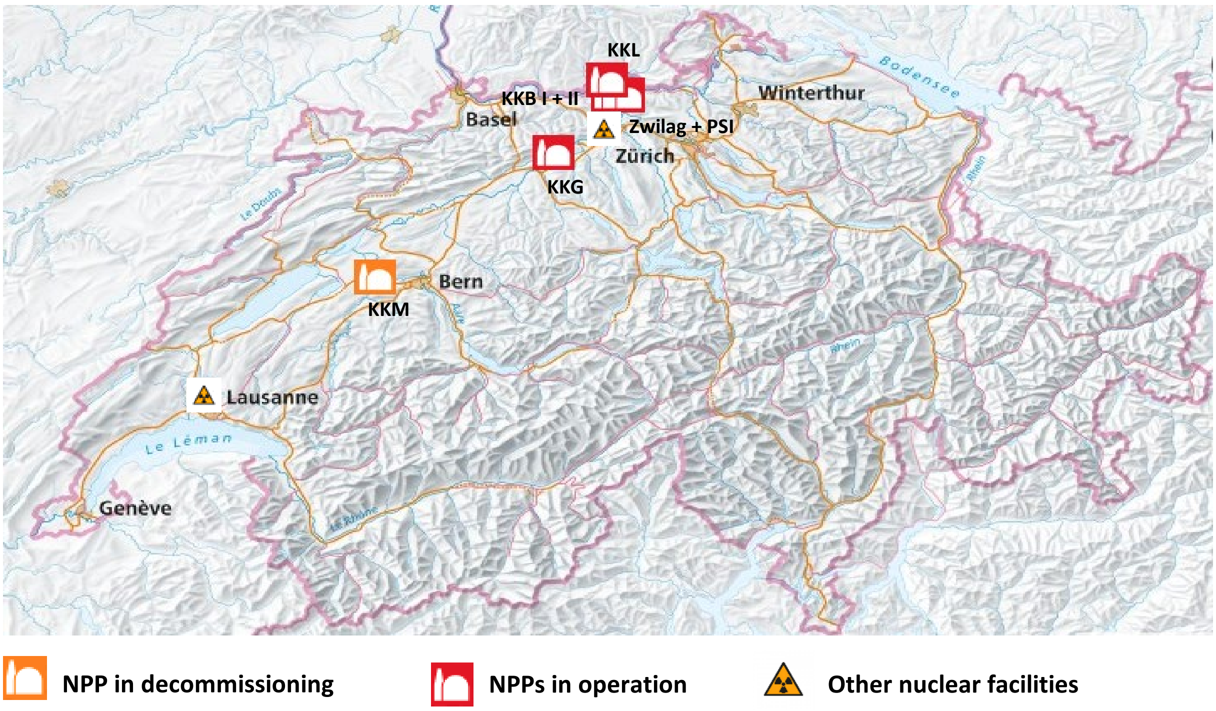

Figure 1.1: Swiss Nuclear Installations

1.1.2 National selection of installations

The nuclear facilities in Switzerland included in the Topical Peer Review (TPR) 2023 were selected based on the criteria set out in the Technical Specification of the Western European Nuclear Regulators Association (WENRA) /1/. The overview in Table 1.1 shows which nuclear facilities in Switzerland were included in the TPR 2023 and which were excluded.

TPR Fire Safety: Swiss nuclear installations to be considered (scope)

Installation	In scope	Justification
NPPs		
4 units in operation	Yes	-
Beznau I & II		Operating PWR
Gösgen		Operating PWR
Leibstadt		Operating BWR
1 unit in decommissioning	Yes	-
Mühleberg		BWR under decommissioning
Research Reactors		
1 unit in operation	No	
CROCUS Reactor (Swiss Federal Institute of Technology Lausanne)		Experimental zero-power (100 W) reactor; low risk/rad. inventory; less than 1 mSv dose in case of total release of activity.
3 units in decommissioning	No	Fuel removed to storage facility ; only minor rad. inventory left for a short time.
Spent fuel storage facilities		
3 units in operation	Yes	-
Zwilag		Central interim storage facility
Zwibez		Dry storage building at Beznau NPP
Nasslager		Wet storage facility at Gösgen NPP

Table 1.1: Swiss candidate nuclear installations

According to this, all nuclear power plants in Switzerland and the three interim storage facilities mentioned in Chapter 1.1.1 are included in the TPR 2023. The research reactors in Switzerland are not being included in accordance with the criteria in the WENRA Technical Specification /1/ as they have a very low hazard potential either due to their very low power or due to their decommissioning status.

1.1.3 Key parameters per installation

Nuclear Power Plants

In table 1.2, the parameters according to the Technical Specification /1/ shows the main technical data required for the Swiss nuclear power plants Beznau (KKB 1 and 2), Gösgen (KKG) and Leibstadt (KKL) that are in operation, as well as for the Mühleberg nuclear power plant (KKM) that is being dismantled.

	KKB 1	**KKB 2**	**KKG**	**KKL**	**KKM**
Thermal output [MW]	1130	1130	3002	3600	1097
Gross electric output [MW]	380	380	1060	1285	390
Net electric output [MW]	365	365	1010	1233	373
Reactor type	Pressurised water	Pressurised water	Pressurised water	Boiling water	Boiling water
Reactor supplier	W	W	KWU	GE	GE
Turbine supplier	BBC	BBC	SIEMENS	BBC	BBC
Generator data [MVA]	2 x 228	2 x 228	1140	1318	2 x 214
Main heat sink	River water	River water	Cooling tower	Cooling tower	River water
Commenced commercial operation	1969	1972	1979	1984	1972
Licensee	Axpo AG	Axpo AG	Nuclear Power Plant Gösgen-Däniken AG	Leibstadt AG Nuclear Power Plant	BKW FMB Energy Ltd
Final shutdown date	Not specified	Not specified	Not specified	Not specified	2019

Table 1.2: Key Data for Swiss Nuclear Power Plants

In the following Chapter, special design features of Swiss nuclear power plants are described that are considered important with respect to the assessment of protection against internal and external fires. In view of the now significantly lower activity inventory of the Mühleberg nuclear power plant (KKM), which is being dismantled, a distinction is made between nuclear power plants in operation and those being dismantled.

Nuclear Power Plants in Operation

Beznau Nuclear Power Plant (KKB)

The KKB is located in the lower valley of the river Aare on an island. The island site is bounded to the west by the natural course of the Aare and to the east by the artificially constructed channel. The shore zones are heavily overgrown with bushes and trees and belong to the protection zone. Units 1 and 2 are located in the southern part of the island and the Beznau interim storage facility (ZWIBEZ) is located in the northern part of the island.

The power plant site is accessible from both sides of the Aare. Due to the insular location of the Beznau nuclear power plant, only indirect impacts as a result of a forest fire are to be expected. In this case, it is assumed that only one side to the Aare is affected and that access to the power plant site is guaranteed from the unaffected side.

In the original design of the Beznau nuclear power plant, the requirements for protection against internal, system-wide impacts and against external impacts in particular were not comparable with the design requirements that have increased over time. To improve protection, it was decided at the beginning of the 1990s to retrofit both units with an emergency system that largely covers the safety functions of the original safety systems, is spatially separate and largely independent of the original safety systems and offers special protection against external events. Among other things, this significantly improved protection against internal fires. Consistent fire protection separation of the original safety systems could not be implemented due to space constraints, so the focus at the Beznau nuclear power plant is on fire protection separation of the emergency systems from the original safety systems.

The structure and the existing operating and safety systems are basically identical in both units of the Beznau nuclear power plant. It follows that fire protection concepts and fire safety analyses are applicable to both units. Existing differences between the two units are considered when preparing and updating the fire protection concepts and fire safety analyses.

Gösgen Nuclear Power Plant (KKG)

The KKG is also located on the Aare. There are no wooded areas on the power plant site itself, only two narrow strips of forest border the power plant site. The river Aare runs between the narrow forest strips and thus forms a natural barrier. This results, on the one hand, in protection against ignition of the adjacent forest strips and, on the other hand, in sufficient waiting time for firefighting. The risk of a forest fire is considered to be very low.

Leibstadt Nuclear Power Plant (KKL)

The KKL is located on the south bank of the river Rhine below the confluence with the Aare. There are no extensive forested areas in the immediate vicinity of the nuclear power plant.

In the newer Gösgen and Leibstadt nuclear power plants, protection against internal, system-wide impacts and against external impacts was already given high priority during the design phase, in contrast to the Beznau nuclear power plant. Since the beginning of operation, both nuclear power plants have had emergency systems that are spatially separate and largely independent of the safety systems and offer special protection against external impacts. Independently of this, the individual strands of the safety systems are spatially separated so that consistent fire protection separation is ensured by fire compartments except for the reactor building.

Analyses of the sites of the Swiss nuclear power plants in operation have shown that there are no hazards to the sites from industrial plants, fuel storage facilities or natural gas pipelines that could trigger an external fire.

Nuclear Power Plant in Decommissioning

Mühleberg Nuclear Power Plant (KKM)

The KKM is also located on the river Aare. The surrounding agricultural areas are fields, meadows and pastures. To the south-east of the site is a slope with semi-natural mixed forest. A potential hazard in the event of a forest fire would only be conceivable through the intake of smoke into the ventilation systems or into emergency power generators. The ventilation systems of the safety-relevant buildings are designed in such a way that an intake of smoke can be detected and appropriate countermeasures can be initiated.

After final decommissioning, the Mühleberg nuclear power plant was transferred to decommissioning phase 1 in September 2020. The number of decommissioning phases was chosen for safety and security reasons and is based on the activity inventory and the hazard potential. This is dominated by the presence of nuclear fuel and activated components and decreases continuously while decommissioning.

As of 30 June 2022, according to the Technical Specification /1/ the plant was still in decommissioning phase 1 and the fuel assemblies were stored in the storage pool inside the containment. Since September 2023, decommissioning phase 1 has been completed, the plant is free of nuclear fuel and has been transferred to decommissioning phase 2.

Obsolete systems were largely taken out of service and in some cases already dismantled. The remaining systems were still subjected to the operational tests and periodic inspections required by the technical specifications, as well as the necessary maintenance work.

Dedicated spent fuel storage facilities

In table 1.3, the parameters according to the Technical Specification /1/ shows the main technical data required for the Swiss interim storage facilities in operation. These are the interim storage facilities (ZWIBEZ) at the Beznau nuclear power plant site, the wet storage facility at the Gösgen nuclear power plant site and the central interim storage facility (Zwilag) near the PSI site.

The radiological inventory and the associated hazard potential of the Swiss interim storage facilities are described below regarding the assessment of protection against internal and external fires.

	Dry storage ZWIBEZ	Wet storage KKG	Dry storage Zwilag
Type	Interim storage facility for radioactive waste	Interim storage facility for spent fuel elements	Interim storage facility for radioactive waste
Supplier		AREVA	
Commercial commissioning	1994 (Low-level waste storage) 1997 (High-level waste storage)	2010	2000
Operator	Axpo Power AG	NPP Gösgen-Däniken Ltd.	Interim Storage AG Würenlingen
Decommissioning date	Not specified	Not specified	Not specified

Table 1.3: Key Data for Swiss spent fuel storage facilities

Interim storage facility ZWIBEZ at KKB

The ZWIBEZ is used by the Beznau nuclear power plant for the interim storage of radioactive waste from both reactor units and is located on the site of the nuclear power plant. It is organisationally subordinate to the nuclear power plant and is operated by the power plant staff but is considered a separate nuclear facility due to its independent licence.

The ZWIBEZ consists of a storage facility for low-level waste (LAW) and a storage facility for high-level waste (HAW). These include:

- Low-level waste from the operation and decommissioning of the Beznau nuclear power plant and from the now discontinued reprocessing of irradiated fuel elements. In addition, raw waste from the Beznau nuclear power plant that is destined for final conditioning in the incineration and melting plant (plasma plant) at Zwilag is also stored temporarily.
- High-level waste, in particular irradiated fuel elements or vitrified high-level waste from the reprocessing of irradiated fuel elements at that time, which is delivered in transport and storage casks (T/L casks).

In the low-level waste storage facility, the waste packages are stacked in storage containers in a high-bay storage. Most of the waste packages are 200-litre packages containing final-conditioned radioactive waste. The final-conditioned waste does not represent a fire load because it is cemented in steel drums or concrete containers.

Temporarily, raw waste intended for later conditioning is also stored in the low-level waste storage facility. For combustible raw waste, the storage quantity and thus the resulting fire load is administratively limited.

In the first phase of operation until 2008, the storage facility for high-level waste served only to store the original steam generators from the Beznau nuclear power plant, which had previously been replaced. Since the final operating licence for high-level waste was granted in 2008, T/L casks loaded with fuel elements have also been stored. The T/L casks are designed to withstand the effects of fire and also do not represent a fire load.

Intermediate-level waste (ILW) from the Beznau nuclear power plant or from reprocessing is not stored at the ZWIBEZ, but at Zwilag and the nuclear power plant's residue storage facility.

Interim storage facility at KKG

The total storage capacity of the wet storage facility at the Gösgen nuclear power plant site is 1008 fuel assemblies. The wet storage facility will be continuously loaded with fuel assemblies from power plant operations after a decay period of approximately three to five years, so that the heat output in the storage pool will increase continuously until the last operating cycle of the NPP and will reach its maximum with the emplacement of the last core. As important boundary conditions, only defect-free fuel assemblies are stored in the wet storage facility.

Depending on the ambient temperatures and pool occupancy, the fuel assemblies are cooled passively via water/air heat exchangers installed in cooling towers or additionally actively via fans. The fire loads in the wet storage facility are mainly limited to the electrical equipment required for operation and accident management.

Central interim storage facility Zwilag

The Zwilag essentially comprises nuclear integrated waste interim storage and handling facilities (conditioning and incineration and melting) which can handle all categories of wastes, including decommissioning wastes and spent fuel. The wastes stored on site are:

- Operational waste and spent fuel elements from the nuclear power plants.
- Waste of all categories from the reprocessing of spent fuel elements from Swiss sources in foreign reprocessing plants.
- Waste for which the Confederation is responsible, i.e. radioactive medical, industrial and research waste.

The facility consists of the following main units where differerent categories of waste are treated:

- <u>Conditioning plant (Building K):</u> Technical equipment for treating the waste delivered to the facility - mainly packaged goods and large components from the nuclear power plants. Packaging and weight, mechanical separation methods and abrasive treatment methods are supplemented by other processes, such as electrolytic and chemical leaning processes. The residue is either packed in concrete or in standard waste containers and sent to the plasma plant for further treatment. The radioactive wastewater generated during the cleaning process are processed further in the internal waste water treatment plant or in the plasma plant. Large volumes of raw waste barrels can be stored in a high-rack storage until they can be treated in the plasma plant.
- <u>Plasma plant (Building V):</u> The radioactive waste is thermally decomposed or melted in a plasma plant at temperatures of up to 20'000° C. With the plasma process, all organic fractions of the waste are burnt, so that the non-combustible fractions are vitrified together with the fusible parts. The release of radioactive substances and the formation of dioxides is prevented by the flue gas cleaning system. During a campaign of about 12 weeks, the plasma plant is operated continuously. One or two campaigns are carried out per year, depending on demand.

- Cask storage hall (Building H): The cask storage hall is used to store vitrified high-level waste from the reprocessing and spent fuel assemblies from the Swiss NPPs. The highly radioactive vitrified waste and spent fuel assemblies are stored in tightly sealed transport and storage casks. At full capacity, this hall has room for 228 standing casks.
- Storage hall for medium-level waste (Building M): The storage hall for medium-level waste has a storage capacity for 384 twenty-foot storage containers. The storage containers are filled with conditioned waste ready for final storage and are stacked one on top of the other in the storage shafts by remote control. The individual storage shafts in the storage building are covered by solid concrete lids. The presence of a gas warning device installed in the exhaust air vents continuously monitors the concentration of gases such as hydrogen and methane as well as the temperature in the storage hall. Building M is the only place at the Zwilag where combustible solidified radioactive waste can be stored in a dedicated shaft (pit).
- Storage hall for low- and medium-level waste (Building S): The storage hall for low- and medium-level waste was built during a second construction phase in 2002 and started the nuclear operation in midst of 2020. This building has storage capacity for 1'144 twenty-foot storage containers. The storage hall is also used for the interim storage of decommissioning waste from the Swiss NPPs.
- Hot-Cells (Building Z): Storage casks can be checked and repaired in the hot cells. This area is also used for the inspection and unloading of spent fuel assemblies.

According to Figure 1.2, the highest radioactive inventory is located in the cask storage hall (building H). The total activity amounts up to 2.8E+19 Bq. The maximum activity of the hot cell is defined by the maximum activity of a single cask which is 1.40E+17 Bq. Most of the medium active waste (MAW) is stored in the building M. It amounts up to 1.20E+17 Bq.

A smaller part of the MAW and most of the low active waste is stored in the storage hall for low- and medium-level waste (building S). The maximum activity in the building S is limited to 1.0E+16 Bq.

Large volumes of 200-l-barrels of raw waste can be stored in a high-rack storage in the conditioning plant (building K). The maximum activity is around 1.05E+14 Bq of which more than 95.0 % is stored at the high-rack storage.

The maximum activity in the plasma plant is approx. 2.01E+12 Bq of which most of the activity (around 84 %) is stored at the high-rack storage of the plasma plant.

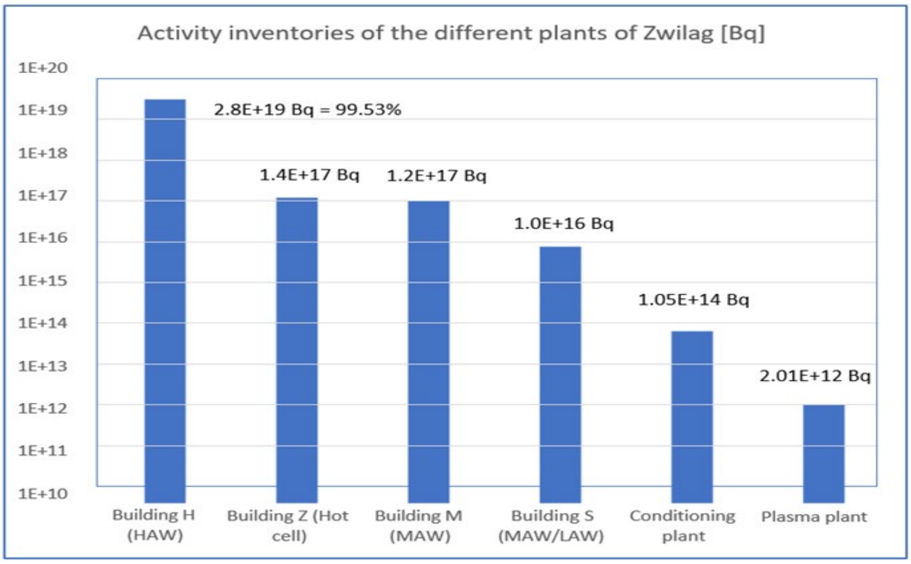

Figure 1.2: Activity inventories in the Zwilag buildings

In general, it can be stated that no radioactive fire loads are kept or temporarily stored at Zwilag. All radioactive waste that does not contain any spontaneously combustible or explosive substances according to the acceptance conditions is encapsulated and conditioned or, if necessary (in the case of raw waste), compressed and is located in areas of Zwilag that have an immobile fire load of significantly less than 90 MJ/m².

1.1.4 Approach for the development of the NAR

At the end of 2021 the Swiss Federal Nuclear Safety Inspectorate (ENSI) decided that Switzerland would take part in the second Topical Peer Review (TPR 2023) of the European Union on 'Fire Protection' in nuclear facilities. In accordance with the ENSREG terms of reference /2/, licencees are expected to carry out independent assessments of the fire protection measures taken. The licensees of the Swiss nuclear facilities were therefore required to submit reports with the information specified in the WENRA Technical Specification /1/.

The following aspects were discussed in technical meetings with the Swiss nuclear facility licensees:

- Coordination of the TPR and assignment of contact persons at ENSI and the licensees;
- Defining the scope of the nuclear facilities to be included in the National Assessment Report (NAR) based on the selection process in Annex 4 of the WENRA Technical Specification;
- Defining the structure and content of the reports to be submitted by the licensees based on the detailed content list in Annex 2 of the WENRA Technical Specification;
- Defining the deadline for submission of the licensee reports to ENSI.

The Swiss nuclear facility licensees submitted the required reports /3/ to /9/ to ENSI on time. ENSI has integrated the information and statements from these reports in Chapters 2 and 3 of the NAR and provided an assessment in each case. Chapter 4 of the NAR provides an overall assessment of the fire protection concept implemented in Swiss nuclear facilities and of the fire analyses performed and draws conclusions.

The interim storage facilities in Switzerland are only dealt with in Chapter 2.4 "Dedicated spent fuel storage facilities", even if radioactive waste is also treated and stored in the interim storage facilities ZWIBEZ and Zwilag. The reason for the joint treatment of the interim storage facilities is that, according to the WENRA Technical Specification /1/, the same Safety Reference Levels (S-30 and E 6.1) are used for their assessment. Chapter 2.5 "Waste storage facilities" is therefore covered in the NAR by Chapter 2.4.

Since there are no fuel cycle facilities in Switzerland (see Chapter 1.1.1) and the research reactors in Switzerland are all disregarded (see Chapter 1.1.2), these facilities are not the subject of the Swiss NAR. The Chapters 2.2 and 2.3 are therefore marked as "not applicable" in the NAR.

1.2 National regulatory framework

1.2.1 National regulatory requirements and standards

The principles of nuclear safety are laid down in Art. 4 and 5 of the Nuclear Energy Act (KEG). /10/. In particular, it states that the operator of a nuclear installation must take protective measures in accordance with internationally recognised principles during the design, construction and operation of the installation. Furthermore, the Nuclear Energy Ordinance (NEO) /11/ Art. 8 also states that a fire is to be regarded as a design basis accident. Annex 2 of the Nuclear Energy Ordinance requires operators to prepare a fire protection concept.

Fire protection requirements

In Switzerland, the implementation of fire protection in buildings is regulated by the Association of Cantonal Building Insurers and enforced by the cantonal building insurers. For the structural, technical and organisational specifications for fire protection, the relevant standard is the Association of Cantonal Fire Insurances (VKF) /12/ and its associated guidelines for the fire brigade, the cantonal fire brigade law and the associated ordinance are authoritative. Nuclear facilities must also implement these legal requirements as far as reasonably applicable.

It is the specific nuclear requirements that call for a supplement to the VKF and cantonal fire protection requirements and require a separate guideline on fire protection in ENSI's supervisory area.

The requirements for fire protection in Swiss nuclear facilities are currently still defined in guideline HSK-R-50 /13/. This guideline came into force in 2003 and will be replaced in 2024 by the new guideline ENSI-G18 /14/. The basic fire protection requirement in both guidelines is compliance with the nuclear and radiological protection goals in the event of a fire by means of staggered fire protection measures (Defence in Depth Principle).

Compared to the previous guideline, the new ENSI-G18 guideline contains more comprehensive and detailed fire protection requirements and is harmonised with the corresponding international requirements of the IAEA and WENRA. A comparison of the contents of the guidelines HSK-R-50 and ENSI-G18 can be found in Appendix 1 of this NAR.

The structure of the ENSI-G18 guideline is based on the regulations of the Association of Cantonal Building Insurers (VKF) and includes the following subsections:

- Basic fire protection requirements
- Structural fire protection
- Technical fire protection
- Organisational fire protection
- Review and changes to fire protection measures

In addition to guideline ENSI-A04 /15/, guideline ENSI-G18 specifies which modifications to fire protection installations require approval and which documents must be submitted in this context. Furthermore, guideline ENSI-G18 states that modifications to fire protection installations requiring approval may only be carried out under quality assurance.

Guideline ENSI-B10 /16/ specifies which office, functions must be available in a nuclear installation. Guideline ENSI-G18 specifies the requirements for the initial and further training of fire protection officers.

The ENSI-B12 guideline /17/ contains requirements for escape and rescue routes, which are specified in guideline ENSI-G18 according to the building category.

The guideline ENSI-G23 /18/ currently specifies general fire protection requirements for interim storage facilities and also specific criteria for when radioactive waste can be neglected as a fire hazard. These requirements are also included in guideline ENSI-G18.

Requirements for deterministic fire analyses

According to Art. 8 of the NEO /11/ the occurrence frequencies for incidents (including fires) are to be determined and recorded in accordance with the requirements of the Ordinance on Hazard Assumptions /19/ into three accident categories. The occurrence frequencies for design basis accidents range from 10E-1 to 10E-6 per year. Radiological acceptance criteria and technical acceptance criteria for compliance with protection goals are defined for each accident category.

The guideline ENSI-A01 /20/ regulates the scope, methodology and boundary conditions of the technical safety analysis for existing nuclear installations. Accordingly, the deterministic fire analysis for nuclear power plants comprises the following analytic steps:

- The identification and selection of relevant fire compartments as well as the determination of fire occurrence frequencies shall be carried out according to the specifications in guideline ENSI-A05. For the selection of the relevant fire compartments, the qualitative criteria mentioned there shall be used.
- The extent of damage resulting from the respective fire scenario shall be determined and documented taking into account the fire detection and fire fighting capabilities as well as the resistance of the fire barriers.
- If a detailed determination of the extent of damage is not made, all components of the affected fire compartment shall be assumed to have failed as a worst case effect and a fire spread analysis shall be used to show that the fire barriers will withstand.
- The fire scenarios shall be grouped according to their extent of damage and the resulting incident sequences determined.

- The control of the fires shall be demonstrated with the safety systems still available, taking into account a single fault and emergency power case.

In general, deterministic fire analyses must be periodically reviewed for nuclear power plants in accordance with guideline ENSI-A03 /21/.

For other nuclear installations, it has to be decided on a case-by-case basis, depending on the fire hazard potential, whether a detailed deterministic fire analysis has to be performed in accordance with the above-mentioned specifications.

The radiological effects of fires shall be analysed in accordance with the methodological specifications in guideline ENSI-A08 /22/.

As part of the preparation of the new guideline ENSI-G18, the requirements for deterministic fire analysis were specified as follows:

- In principle, the fire must only be assumed to have started in one fire compartment.
- The effects of fire such as smoke, temperature, flying sparks, ventilation conditions must be taken into account.
- Externally initiated fires on equipment shall be assumed if it has a fire load and cannot be shown to withstand the effect.
- A fire brigade operation may only be considered if there is sufficient time for fire brigade actions to be diagnosed and carried out.

These specifications will come into force in 2024 as part of an external amendment to Guideline ENSI-A01.

Requirements for probabilistic fire analyses

According to Art. 8 NEO /11/ it must be demonstrated by means of probabilistic methods that nuclear installations are adequately protected against beyond-design-basis accidents. According to the Ordinance on Hazard Assumptions /19/ this protection is given if:

- The frequency of core damage for existing nuclear power plants is less than 1E-04 per year.
- With a frequency of core damage between 1E-04 per year and 1E-05 per year for existing nuclear power plants, all reasonable precautions have been taken.
- the risk contributions of beyond-design-basis accidents are balanced.
- the frequency of releases of radioactive substances on a hazardous scale is significantly lower than the frequency of a core damage.

The guideline ENSI-A05 /23/ regulates the quality and scope of the plant-specific probabilistic safety analysis (PSA) of levels 1 and 2 for internal and external initiating events and all relevant operating states of nuclear power plants. Accordingly, the probabilistic fire analysis comprises the following analysis steps:

- The information required for the fire analysis (e.g. fire compartments, fire loads, ignition sources) shall be collected from the operational documentation and checked by means of inspections.

- The plant sections relevant for the analysis shall be identified. A fire compartment can be excluded from further analysis during the qualitative screening,
  - if it does not contain PSA components,
  - a fire there neither leads to a triggering event nor makes a manual shutdown of the reactor necessary, and
  - there are no PSA components in adjacent fire compartments or in fire compartments connected by ventilation systems.
- The fire occurrence frequencies shall be determined on the basis of plant-specific and generic operating experience using a Bayesian method.
- If no refined analysis is carried out, the failure of all components and cables of a fire compartment (including false excitations) is to be assumed.
- Refined analyses are preferably to be carried out by means of a fire event tree in which the availability of fire detection and fire fighting options as well as the fire barriers are queried.
- The effects of the fire scenario on the error probabilities of personnel actions due to, among other things, increased stress, impeded accessibility and instrumentation malfunctions shall be considered.
- Fire scenarios that do not contribute more than 10E-8 per year in total to the core damage frequency can be excluded from further analysis in the quantitative screening.

The probabilistic fire analyses are also carried out periodically in accordance with the requirement in guideline ENSI-A03 /21/. The principles to be observed are described in guideline ENSI-A06 /24/. If the risk contribution from fires exceeds 60 % of the mean CDF and if the contribution is greater than 6E-6 per year, measures to reduce this risk contribution shall be identified and - if appropriate - implemented.

Provided that it can be shown on the basis of the deterministic accident analyses that the cumulative frequency of all accidents with a resulting dose of more than 1 mSv is at most 1.0E-6 per year, no further probabilistic analyses are required for other nuclear installations.

1.2.2 Implementation/Application of international standards and guidance

For each of the ENSI guidelines mentioned in Chapter 1.2.1, there is an explanatory report that explains the extent to which the international requirements of WENRA and the IAEA (only at the level of safety requirements) are covered by the national guidelines. Based on this assessment, it can be stated that the fundamental international requirements are covered in the ENSI guidelines. Thus, the guidelines ENSI-A01 and ENSI-A05, in which, among other things, the requirements for the deterministic and probabilistic fire analyses are specified, cover the superordinate requirements from the IAEA Safety Requirements SSR-2/1 /25/ and SSR-2/2 /26/ from. Furthermore, within the scope of the self-assessment of the implementation of the revised WENRA Safety Reference Level (SRL) /27/ showed that both Directives fulfil the Implementation Status Category A (RLs considered to be fully implemented in national regulation).

The exception is the fire protection guideline HSK-R-50 due to its age. This guideline will shortly be replaced by the new fire protection guideline ENSI-G18. As part of the self-assessment of the implementation of the revised WENRA Safety Reference Level (SRL), ENSI came to the conclusion that the overriding requirements of the new Issue SV "Internal Hazards" are covered in particular by the legal requirements in Switzerland and the guidelines ENSI-A01 and ENSI-A05 (Implementation Status Category A). The additional, specific requirements for fire protection (SRL SV6) are covered with the publication of the new guideline ENSI-G18 (Implementation Status Category B).

ENSI's assessment in the following Chapters 2 to 4 focuses on the extent to which the requirements set out in WENRA's Technical Specification /1/ are implemented for internal fires in the Swiss nuclear facilities.

2 Fire Safety Analyses

2.1 Nuclear power plants in operation

2.1.1 Types and scope of the fire safety analyses

Beznau Nuclear Power Plant (KKB)

Both deterministic and probabilistic fire analyses are carried out at the KKB. The type and scope of the analyses follow the nationally valid guidelines ENSI-A01 /20/ for deterministic safety analyses and ENSI-A05 /23/ for probabilistic safety analyses.

Deterministic fire analysis

For the classification of fire events into incident categories, occurrence frequencies were used according to the fire occurrence frequencies from the probabilistic fire analysis with inclusion of the individual fault frequency.

To meet the regulatory requirements, the deterministic fire analyses are used to prove that in the event of fire, the system can be transferred from any initial state to a stable and safe state. In a further step, the consequences of fire effects on activity-carrying systems and components are systematically included in the assessment. This is done by demonstrating compliance with the technical and radiological criteria of the respective applicable accident category in accordance with the Ordinance on Hazard Assumptions /19/.

Fires are postulated that cause component failures, short circuits and faulty tripping caused by control systems. It is shown that despite failure of the equipment directly affected by the fire, at least two independent shutdown paths remain available in the fire compartment and thus the single fault criterion is fulfilled. A shutdown path is a combination of largely independent systems (original safety systems and emergency systems) and measures that can be used to bring the plant into a safe state. In addition, possible false tripping due to fire is postulated, which can cause a transient. In the deterministic fire analyses, it is demonstrated that these transients are controlled with the equipment that remains available.

Consequential fires after earthquakes or fires resulting from paraffin leakage in the event of an aircraft crash are also assessed in the corresponding accident analyses.

Probabilistic fire analysis

The probabilistic fire analysis of the KKB follows that of the EPRI and the USNRC in the NUREG/CR-6850 report. /28/. The focus is on determining the core damage frequency (CDF) in power operation, the fuel damage frequency (FDF) in non-power operation and the frequency of a subsequent release of more than 2E15 Bq to the environment (LERF) within 10 hours due to fires.

Gösgen Nuclear Power Plant (KKG)

Both deterministic and probabilistic fire analyses are carried out at the KKG. The type and scope of the analyses follow the nationally valid guidelines ENSI-A01 /20/ for deterministic safety analyses and ENSI-A05 /23/ for probabilistic safety analyses.

Deterministic fire analysis

The safety status analysis (SSA) of the KKG considers fires in safety-relevant buildings and their possible consequences. The SSA is a main document in which the events that determine the requirements for the safety systems are derived from the facility-specific event spectrum. With regard to possible safety-relevant fire events, the analysis aims to determine the effects on the safety systems and emergency systems and to show that the system functions required to ensure the safety functions are not impaired to an unacceptable extent.

Based on fundamental engineering considerations to limit the possible consequences of a fire incident, the SSA determines the scope of safety functions that are required in the event of a fire. Furthermore, irrespective of the existing fire protection measures in the safety-relevant buildings, the possible effects of fires on the individual components of the associated system functions are first identified and the guarantee of the respective safety function by alternative system functions is evaluated (e.g. the high-pressure safety feed of the emergency cooling system can be used instead of the auxiliary borating system to ensure subcriticality in the long term). These analyses take into account the various system states, such as power operation or outage. The results show which of the required system functions can be affected in the event of a fire in a specific building and which special fire protection measures take effect building-specifically to protect these system functions.

The fire protection concept was checked several times using deterministic fire analyses. Fire was assumed to occur wherever combustible material was present, regardless of the presence of an ignition source. Selected scenarios were investigated to obtain data on temperature and smoke development. The results were used to assess the feasibility of firefighting operations.

Specific fire analyses are then prepared (see Chapter 2.1.2), if potential weaknesses are identified with regard to ensuring the functionality of the safety systems in accordance with the design principle that the effect of a fire remains limited to a redundancy of the safety systems.

Probabilistic fire analysis

Probabilistic fire analysis (fire PSA) is used to assess the contributions of relevant fire scenarios to core damage frequency or release frequency.

Fire PSA essentially comprises the following sub-steps:

- By means of a qualitative and quantitative screening, the relevant spatial areas are identified.
- In some cases, brand-specific detailed analyses are carried out for these spatial areas.
- The influence of the relevant fire scenarios on the plant risk is evaluated in the PSA model with the help of event trees.

With regard to the scope of the fire events considered, a distinction is made between fires due to the usual fire loads located in the plant and fires of large components. Fires of large components (e.g. main coolant pumps, transformers, turbines) and explosions are each modelled as separate initiating events. The occurrence frequencies of the fire scenarios (fires in the relevant room areas) are determined per building. Both generic and plant-specific data are used to determine these fire occurrence frequencies.

For fire scenarios during plant shutdown, the differences to power operation, for example due to the introduction of temporary additional fire loads, are taken into account.

By modelling the relevant fire scenarios in both the power and shutdown models, the fire risk (CDF, FDF and LERF) is determined for all plant conditions.

Leibstadt Nuclear Power Plant (KKL)

Both deterministic and probabilistic fire analyses are carried out at KKL. The type and scope of the analyses follow the nationally valid guidelines ENSI-A01 /20/ for deterministic safety analyses and ENSI-A05 /23/ for probabilistic safety analyses.

Deterministic fire analysis

KKL carried out new deterministic and probabilistic fire analyses as part of the Periodic Safety Review in order to evaluate fire events within the plant and to keep the fire analysis up to date with the latest technology. Consistency between deterministic and probabilistic fire assessments was ensured in order to have a common basis for fire risk assessment.

The internal fires were analysed in accordance with the requirements of the guidelines ENSI-A01 /20/. The latest generic and plant-specific experience data from the fire PSA were taken into account for the deterministic fire analysis. All fire events are classified into the corresponding accident categories based on the expected occurrence frequencies, and evidence of compliance with the regulatory requirements is shown.

All safety-relevant buildings where a fire may have an impact on the operational and safety systems were investigated. Buildings where fires have no impact on the operation or safety of the plant were screened out. In addition, areas of the plant containing radioactive materials that could be released in a fire were investigated.

The deterministic fire analysis includes all system states (power, low-power and outage).

Probabilistic fire analysis

The effects of internal fires were assessed in accordance with the requirements of guideline ENSI-A05 /23/ and the latest international guidelines. The general methodological approach is based on the report NUREG/CR-6850 /27/.

The analysis of fires caused by earthquakes is based on the EPRI report 3002012980 /31/.

2.1.2 Key assumptions and methodologies

Beznau Nuclear Power Plant (KKB)

Deterministic fire analysis

For the determination of the occurrence frequencies of fire events, it was conservatively assumed that every incipient fire in a fire compartment can lead to a fire, regardless of whether sufficient fire loads are present. Temporary ignition sources were also taken into account in the occurrence of fires (e.g. due to hot work).

The KKB has several shutdown paths, to each of which the necessary systems and components were assigned. For this purpose, mechanical components as well as components of the power supply and control technology were considered, among others. When assessing the impact of a fire, the affected equipment is examined for each fire scenario to see whether it belongs to the shutdown paths.

The multiple spurios operations (MSO) identified in the probabilistic fire analysis serve as the basis for determining MSOs due to fire-related faults in circuits. MSOs with more than four fire-related faulty actuations were excluded from the deterministic fire analyses. Likewise, MSOs that require a faulty enable signal from the main command room were not considered, as the corresponding signalling is protected against faulty actuation. For all MSOs, it was checked whether they have an influence on a certain departure path and, if applicable, whether alternative departure paths remain available.

Probabilistic fire analysis

The methodology in the NUREG/CR-6850 report includes several technical analysis steps. In the first step, the spatial areas (fire Chapters) of the fire analysis are defined and, as far as possible, divided into analysis areas. This is followed by the identification of the components located in each analysis area and relevant for the shutdown of the plant. Based on this, the risk significance of the fire analysis areas is determined. Further steps include the development of a logic model that depicts the reaction of the plant after a fire, the determination of occurrence frequencies for individual fire Chapters and fire scenarios, and the analysis of the probability of fire-related faults in circuits. In addition, the consequences of a fire are taken into account, including, for example, the initial fire characteristics, the fire spread and the damage caused by heat and smoke. Furthermore, the reliability of actions by operating personnel after a fire and the interactions between seismic events and fires are analysed.

The methodology for determining MSOs is based on the NEI 00-01 /31/ report. For each relevant fire scenario, possible MSOs were investigated.

Gösgen Nuclear Power Plant (KKG)

Deterministic fire analysis

The fire analyses are carried out in such a way that fires are assumed in all safety-relevant room areas where there is sufficient fire potential (combustible materials and ignition sources). When determining fire loads, cables are conservatively considered as a whole, regardless of their fire properties (flame-retardant, fire-retardant).

In addition, earthquake-induced fires in systems not designed to withstand earthquakes in buildings or in other areas on the power plant site were assumed in the analysis. Possible fire locations in this respect are, for example, the turbine building or the unit transformers in the vicinity of the turbine building. Based on engineering assessments, a hazard to safety-related equipment is not assumed due to the structural separation and the separation by distance. No specific fire spread analyses were required for this aspect.

To check the fire protection concept by means of deterministic fire analyses, selected scenarios were analysed with the CFD code "FDS". The subject of the investigation was, among other things, the effects of an oil fire at a main coolant pump and cable fires in the reactor building as well as the effects of a systematic failure of fire dampers in the switchgear building.

As a result of anomalies in fire dampers during a function test in which some fire dampers in the switchgear building did not reach their CLOSED position, a re-evaluation of the occurrence was carried out by means of a detailed model calculation with the CFD code "FDS" on the basis of CAD room models. For this purpose, a building area was selected in which, assuming a systematic failure of fire dampers (failure to remain open in case of demand), an air connection between the rooms of different system redundancies would result.

Probabilistic fire analysis

The determination of the fire risk essentially follows the methodology described in the German PSA Guidelines /33/. The critical fire areas were determined by the following selection criteria:

- The room contains a fire load > 90 MJ/m^2.
- The room contains safety-related equipment or cables to this equipment.
- The room contains equipment for power operation or measurement devices of the limitation and protection systems or cables which have the potential to trigger a plant transient or an accident-triggering event by their failure. The triggering of a shutdown as a result of damage to more than one subsystem of the safety equipment is also considered.
- If a fire causes a safety valve to open incorrectly or a comparable triggering event (loss of coolant), this room or fire area is classified as particularly significant for the analysis. In addition, components whose failure both triggers a transient and affects a safety system are also classified as particularly significant.

Based on generically determined occurrence frequencies per building, the specific occurrence frequencies per building are determined using the Bayes method on the basis of the fire events that occurred in the KKG. The occurrence frequencies for the individual rooms are determined from this with the help of room properties using the method developed by Berry and described in the PSA guideline.

In a first screening step, the total failure of all components in a room fire is assumed. Due to the consistent redundancy separation in the KKG, such a scenario leads to negligible effects on the plant risk in most cases and is therefore not analysed in more detail.

Where appropriate, deterministic fire spread calculations were carried out using the "CFAST" software. To supplement and verify the CFAST results, detailed simulation calculations were carried out for selected fire scenarios using 3D building models with the "FDS" software.

Leibstadt Nuclear Power Plant (KKL)

Deterministic fire analysis

The deterministic and probabilistic fire safety analyses provide a common basis for evaluating fire safety in the KKL. The boundary conditions for the analyses and the definition of the fire compartments were based on the current plant documentation. The safety-relevant systems and components whose fire-related failure could lead to the triggering of events were identified with the help of the current technical database of KKL, as well as areas with radioactive materials that could be released in the event of a fire. Types and sources of potential fires in each plant area were identified and documented. Targeted plant inspections were carried out to verify the sources and loads of fire.

Compartments are defined largely based on the plant design fire zones. Fire zone layouts, spatial interaction analysis, and plant walkdowns were also used as inputs to identify relevant fire compartments. Out of 72 buildings in overall plant area, 34 buildings are identified as areas relevant for deterministic fire risk assessment.

At KKL, a distinction is made between covering and detailed deterministic fire analyses.

Within the bounding analysis, a single fire scenario is postulated in each fire compartment and all components and cables in the compartment are considered as failed due to fire damage conservatively. No credit is taken for fire protection systems and spatial separation of equipment. Regardless of fire frequency or event category, all fire events are treated as design basis events. The most limiting boundary conditions for deterministic safety analysis according to Guideline ENSI-A01 are applied. These include the following:

- Independent single failure
- One division under planned maintenance
- Total Loss of Offsite Power
- Credit for only safety systems within first 10 hours
- No credit for operator actions until 30 minutes.

The detailed fire analyses were carried out to reduce conservative assumptions and demonstrate the successful shutdown path. The analysis includes the findings from fire simulations and the plant's internal accident regulations.

Probabilistic fire analysis

The determination of fire occurrence frequencies is based on the latest generic data from the NUREG-2169 report. /29/. The Technical Database was compared with the list of generic ignition sources in the NUREG/CR-6850 report to ensure that all types of ignition sources are covered by the combination of generic and plant-specific data. At the same time, KKL-specific fire event data was evaluated and considered as plant-specific experience.

The fire PSA includes the identification and characterisation of potentially significant, fire-related incident scenarios and their effects with regard to the failure of plant safety equipment and operator actions, as well as the mapping of the reliability of the existing fire detection and fire extinguishing systems. Based on the results of the fire simulations, the reliability of manual fire fighting was modelled for different fire scenarios, taking into account the available time windows. The complex activities of the fire brigade in the event of a fire were not the subject of the modelling (conservative approach). The effects of the fire on the components and the resulting damage states as well as the actions of the operating personnel were analysed and the fire risk quantified in the form of core damage frequency (CDF) and fuel damage frequency (FDF).

With the help of the fire simulation programmes "CFAST and "FDS", detailed fire models were created for the analysis of fire spread. The existing fire alarm and fire extinguishing systems were taken into account.

In order to comply with the state of the art, an analysis of multiple false tripping (MSO) in circuits was performed according to report NEI 00-01 /32/ was carried out. Possible single and multiple component trips were assessed in detail, both within the system and between systems. An additional verification of the already integrated MSOs was performed to ensure that the generic MSOs and all critical MSOs were covered for their applicability in the KKL. The verification process was reviewed by external experts.

As part of the detailed refinement of the fire scenarios, a fire compartment-wide analysis (MCA) was carried out in accordance with NUREG/CR-6850 to assess the impact of a fire on other fire compartments.

The screening analysis for seismically induced fires involves the development of a comprehensive list of ignition sources and their screening based on a systematic, step-by-step process. A top-down approach was followed to eliminate ignition sources based on qualitative and quantitative criteria, facility-specific fire effects, walkover observations and seismic fragilities.

2.1.3 Fire phenomena analyses: overview of models, data and consequences

Beznau Nuclear Power Plant (KKB)

Deterministic fire analysis

At KKB, deterministic fire analyses are prepared for all safety-relevant buildings. The buildings of the facility are separated from each other in terms of fire protection, so that an interaction of a fire with several buildings is effectively prevented.

When determining the fire scenarios to be covered, the largest possible Chapter of the building that may be affected by a fire is determined for each building so that, assuming the failure of all the equipment in it, at least two exit paths are still available. The Chapter of the building determined in this way is referred to below as the event space.

This method is conservative because the event spaces determined in this way may also consist of several fire compartments, although the spread of fire over several fire compartments can be practically excluded by effective active and passive fire protection measures.

In the deterministic fire analysis, credit is taken for the fire scenarios determined in this way that no further spread of the fire has to be assumed due to the existing passive fire protection measures.

The effects of a fire from temporary fire loads (transient fire packages) are also assessed. These are standardised fire loads that can lead to a fire independently of other influences. The introduction of such fire loads, e.g. for maintenance purposes, is regulated in the KKB by administrative measures.

If several departure paths are affected by a fire within an event space, this is analysed in more detail and, if necessary, reduced to the decisive fire Chapter. In the case of a more detailed analysis within a fire compartment, specific fire scenarios are determined taking into account the existing mobile and immobile fire loads as well as the existing ignition sources.

During the detailed investigation of incident rooms, the possibility of fire spread is also checked. Fire spread and the resulting effects on components are assessed in accordance with NUREG-1805 /30/ or determined with the help of CFD codes. The selection of the methodology used is based on the fire scenario to be investigated, taking into account the local conditions.

The temperature in the hot gas layer, the temperature in the flame-induced convection plume (plume) and the thermal radiation density in safety-relevant components are evaluated as relevant effects. Fire-retardant properties of components are adequately taken into account when determining fire spread. For example, for non-combustible cables, the spread of fire due to spontaneous ignition is excluded; for non-ventilated, closed and qualified enclosures, the spread of fire outside the enclosure is excluded.

Furthermore, the possibility of oxygen supply from outside through ventilation openings is included in the analysis. When evaluating the results, the spatial distribution of components of the departure paths is taken into account. If a relevant component is exposed to a temperature that exceeds the design, this component is no longer credited in the associated departure path.

Probabilistic fire analysis

The fire PSA is strongly inspired by the methodology developed by EPRI and U.S.NRC, most notably in the NUREG/CR-6850 /28/ is recorded. The procedure consists of the following analysis steps:

- By listing the equipment present in the relevant plant areas and the initiating events considered in the PSA, the possible initiating events in the event of a fire there are assigned to the individual plant areas. Possible initiating events due to fire-related false activations are also checked and taken into account.
- Spaces in which fire damage can lead neither to the unavailability of equipment credited in the PSA for incident control nor to a reactor shutdown are not considered further in the analysis. Based on the potential fire impacts identified in the previous analysis step, the model for fire events is created from the risk model for internal events.
- The plant-specific fire frequencies are obtained from generic operating experience and the fire events that have occurred in the plant using the Bayesian method. The distribution to the individual rooms of the facility is carried out proportionally to the inventory of potential ignition sources and according to the volume of activities with possible fire occurrence.
- Spaces that result in only small contributions to the CDF, assuming complete burnout and initiation of the worst-case malfunctions, are excluded from further analysis, with the sum of the CDF contributions neglected in the process being less than 1E-8 per year. The impact of the fire on the reliability of the personnel actions for incident management is assessed quantitatively.
- In the subsequent rough fire spread analysis, ignition sources are neglected as a contribution to the fire frequency of the respective rooms, provided that the fire they start is too small to endanger several PSA-relevant components.
- Typical electrical circuits are examined for their behaviour in case of fire-induced short circuits to conductors of the same voltage level. Of interest are possibilities of faulty tripping of active equipment. The conditional probabilities of the various false trippings are evaluated based on the nature of the wiring harnesses.
- In the course of detailed fire modelling, selected fire compartments are divided into fire zones and the fire impacts are analysed, justifying the subdivision by fire spread calculations in a zone model. The final fire scenarios are inserted in the PSA model to quantify the risk contributions to CDF and LERF.

Gösgen Nuclear Power Plant (KKG)

Deterministic fire analysis

CAD room models in which the components with the leading fire loads are mapped individually were and can be used for detailed fire analyses that have been and may be carried out. The CFD code "FDS" used for the fire spread calculations provides detailed results on smoke spread and temperature distribution in the room areas affected by the fire. The modelled fire loads are based on a room-specific fire load list, which is periodically checked to ensure that it is up-to-date.

Existing fire loads that could ignite in the event of a fire are taken into account on a room-specific basis in accordance with the current fire load register. Administrative precautions are taken to ensure that no additional fire loads are introduced into safety-relevant rooms, except for the operationally necessary performance of maintenance activities.

Probabilistic fire analysis

All fire events are systematically recorded. During the periodic data update, in addition to generic data, the plant-specific data (according to the Bayesian method) are used to update the triggering events and the reliability parameters of the modelled fire protection systems.

Changes to the system are evaluated annually or during the project. For example, due to anomalies detected in the closing behaviour of the fire dampers in the switchgear building (see ChapterChapter 2.1.2), additional cross-redundancy fire events that had not previously been modelled were taken into account in the PSA model. After the replacement of all fire dampers in the switchgear building, these fire scenarios were removed from the PSA model.

The information in the fire load register and in the fire protection plans was checked and verified by systematic plant inspections. All specific data required for modelling the fire are collected and managed in a specially developed database.

Leibstadt Nuclear Power Plant (KKL)

Deterministic fire analysis

For the deterministic fire analysis, the fire occurrence frequencies determined in the fire PSA and, on a case-by-case basis (within the scope of the detailed analyses), the fire spread calculations carried out in the fire PSA were used.

Probabilistic fire analysis

The determination of fire occurrence frequencies is based on the latest generic data from report NUREG-2169 /28/. The Technical Database was compared with the list of generic ignition sources in the NUREG/CR-6850 report to ensure that all types of ignition sources are covered by the combination of generic and plant-specific data. At the same time, KKL-specific fire event data was evaluated and considered as plant-specific experience.

In a first step, non-relevant fire events were sorted out for the determination of fire occurrence frequencies and only significant fire events were considered. In a second step, it was investigated whether a particular fire event endangered or could have endangered the safety of the plant. The aim of this step is to identify the reported events that were a fire outbreak or explosion and had the potential to develop into a self-sustaining fire. Fire events without this potential were not considered when determining the fire occurrence frequency.

The data collected at KKL on plant-specific fire events was used as input for the Bayes update of the fire occurrence frequency. This data is used to estimate the plant-level fire occurrence frequency for each ignition source. The fire occurrence frequency for each fire compartment is the sum of the fire occurrence frequencies determined for each of the ignition sources present in the fire compartment. Both permanently existing ignition sources and additional temporary ignition sources during standstill are considered.

2.1.4 Main results / dominant events (licensee's experience)

Beznau Nuclear Power Plant (KKB)

Deterministic fire analysis

The safety systems in the KKB are designed in such a way that they are each assigned to one block or that they can supply both blocks simultaneously. Safety systems assigned to one block are spatially separated from the analogue systems of the other block. There are cross-connections between the two blocks which, if necessary, make it possible to transfer one block to a safe state by means of safety systems from the other block.

The retrofitted emergency standby systems and emergency feedwater systems are designed to cope with external impacts and are housed in different, bunkered buildings. Due to the fire protection separation of the emergency buildings and the emergency feedwater building from the other buildings and the spatial separation of the emergency and emergency feedwater systems from the safety systems of the original plant, at least two exit paths are always available in the event of a fire within the plant. Thus, even if an individual fault is assumed, the system can always be transferred to a safe and stable state. Exceptions with regard to spatial separation are the safety building, the live steam blow-off station and the emergency control room.

Within the safety building, a continuous spatial separation of the exit paths in separate fire compartments is not possible. Therefore, a more detailed consideration is carried out for the deterministic fire safety analysis of the security building. The occurrence frequency of fires in the containment building is low. In the event of a fire within the containment, the facility can always be brought to a safe state. Within the containment, systems for early fire detection and extinguishing systems are available to protect the reactor main pumps.

Transients that can be triggered by MSO are covered by the incident spectrum and do not lead to the unavailability of further exit paths. The fire analyses in the annular space show that a cable fire at a bushing both in the outer wall and in the steel pressure shell cannot spread to other bushings due to the fire protection upgrades that have been carried out. Due to the redundancy separation, a single-fault-proof shutdown is thus guaranteed at all times.

In the emergency building, the emergency functions are formed in two redundant, electrically and physically separated strings. In the fire scenarios considered, sufficient shutdown paths are available for single-fault safe shutdown. Since the outgoing emergency signals have priority over other signals, special attention was paid during the analysis to the I&C links of the components controlled by the emergency protection system, which are also part of the conventional safety systems.

In the course of the analysis, the control technology rooms of the two emergency control rooms as well as the emergency control room were identified as central, since several departure paths can be affected in the event of a fire. The effects of a fire in the two control rooms or in the emergency control room were investigated by means of fire spread calculations. It was shown that even in the event of a fire in one of the two control rooms, sufficient systems remain available to bring the plant to a safe state. The control rooms are equipped with a halon extinguishing system, which would additionally limit the spread of a fire. However, an extinguishing effect was not credited in the analyses. Even without considering the automatic halon extinguishing system, the spread of a potential fire can be ruled out due to the design characteristics of the control panels/control cabinets.

All cables used in the emergency system are flame-retardant, hardly combustible, self-extinguishing and halogen-free. Due to the low fire load and the short intervention times of the operators, it does not have to be assumed that any fire within individual components in the control desks/control cabinets will spread to neighbouring areas. It could be shown that in all cases of fire in individual control panels/control cabinets, sufficient equipment of the shutdown paths remains available to transfer and maintain the plant in a safe condition. Further transients that can be triggered by MSO are covered by the incident spectrum or do not lead to the unavailability of further shutdown paths.

The annexe contains, among other things, the main command room and the reactor protection system. Some rooms of special importance for the control and regulation of the plant are equipped with a halon extinguishing system. A fire of the entire building is assumed as the covering fire scenario, which destroys all components in the building. A fire-reducing effect through extinguishing systems or further fire-fighting measures is conservatively not credited. The fire would result in a loss of power supply and system control for various systems. However, sufficient shutdown paths remain available so that the plant can be shut down in a single-failure safe manner. Possible transients triggered by MSO are covered by the incident spectrum or do not lead to the unavailability of further shutdown paths. In this fire scenario, the operators can switch to the emergency control room, from where they can shut down the plant with single-fault protection.

In the event of a fire in other buildings of the plant, e.g. in the turbine building or in the supply ducts, sufficient shutdown paths remain available even in the event of complete failure of all components within the buildings, with which the plant can be shut down in a single-fault-proof manner.

Cooling of the fuel pools is ensured even in the event of a fire; at least two cooling lines are maintained in all fire scenarios investigated. Due to the large volume of water in the pools, an unacceptable increase in the pool water temperature is not to be expected even in the event of a brief interruption in cooling (several hours).

The deterministic fire analyses show that at least two departure paths are available for all fire events investigated. This also applies to any subsequent fires caused by earthquakes. This means that the transfer of the plant to a safe state is always guaranteed, even if a single fault is assumed. This result applies to every block.

In an additional analysis, interactions between the two units were examined. It was shown that the degree of redundancy of the plant is additionally increased by the existing cross-connections between the two units and that no relevant negative interactions result from this.

The new earthquake verifications to be provided show that the shutdown paths credited in the deterministic fire analyses are not affected by seismically induced fires, as the equipment of the shutdown paths is sufficiently seismically qualified and no ignition sources have been identified that would pose a fire hazard to the required equipment. An exception is the hydraulic system of the blow-off valves in the main steam station, for which a subsequent fire cannot be ruled out. Since the main steam quick-acting valves and the steam generator safety valves are not at risk in the event of a seismically induced oil fire in the main steam station, secondary heat dissipation is ensured.

The events that occurred in the course of operational experience only concern conventional fire protection (see ChapterChapter 3.1.3). There were no events that contradict the findings of the fire safety analyses.

Probabilistic fire analysis

The contribution of the fire risk to the core damage frequency is approx. 10 % (1.4E-06 per year). Fires of electrical equipment in the switchgear rooms and emergency buildings as well as fires in the reactor building and in the main steam blowdown station provide the largest risk contributions.

Seismically induced fires were also considered. They are of minor importance.

Gösgen Nuclear Power Plant (KKG)

Deterministic fire analysis

The following key findings can be derived from the deterministic fire analyses:

- In the annular space of the reactor building, separation of the individual safety redundancies is only possible to a limited extent. However, the redundant system areas are spatially far apart from each other and partly separated by massive radiation protection walls. In areas where there are insufficient distances (e.g. cable routes lying one above the other), sprinkler systems that respond independently in good time prevent an impermissible, cross-redundancy failure of safety systems.
- In the interior of the reactor building (containment), oil fires must always be considered. A leak or break in the return line of the oil supply of one of the main coolant pumps can cause oil to leak out, which ignites and spreads burning over a larger area or collects in the sump of the containment and ignites there. However, a fire in the containment can only affect the long-term feed of the auxiliary borating system. Alternatively, long-term borating can also be carried out with a high-pressure safety feed pump. This does not require any switching of fittings inside the containment, so that a fire there has no effect.
- In the switchgear building, an assumed systematic failure of fire dampers (non-closure in case of demand) does not affect the safety systems across redundancies. The principle that fire effects are limited to one safety redundancy is ensured by structural and spatial separation as well as effective limitation of fire loads.
- Fires as a result of earthquakes, which may lead to a hazard to safety systems or to a hazard to the integrity of activity-carrying components, are not to be assumed.
- The results of the fire simulations confirm the basic design concept of the KKG that, due to the structural and spatial separation in most plant areas, no more than one redundancy of the safety systems can be endangered by a fire.

Probabilistic fire analysis

The contribution of the fire risk to the core damage frequency is approx. 17% (1.6E-06 per year). This contribution is dominated by fires in the containment and the switchgear building. Seismically induced fires were also considered. They are of minor importance.

Leibstadt Nuclear Power Plant (KKL)

Deterministic fire analysis

With the deterministic fire analysis, it was demonstrated that the plant can be transferred from all operating states (power, low-power and shutdown operation) to a safe state. The robust design of the KKL, in particular the consistent spatial and electrical separation of the safety systems and emergency systems, demonstrates that the plant can be safely shut down in the event of an internal fire and that long-term core cooling is ensured.

In addition, it is demonstrated that there is no unacceptable release of radioactive substances in the event of a fire. In this context, the release potential of activity-carrying filters during fires was also analysed.

Probabilistic fire analysis

The contribution of fire risk to core damage frequency is approximately 1% (5.6E-08 per year). The dominant CDF and FDF contributions result from fires in the main command room and containment and drywell where equipment of more than one safety redundancy is present within a fire compartment. The contribution from fires in other buildings is low, as the individual safety redundancies are either consistently separated in terms of fire protection or there are no safety-relevant components there.

The risk of seismically induced fires at KKL is negligible compared to the overall seismic risk of the plant, as the ignition sources are either sufficiently seismically robust or these are located in fire Chapters with a low-risk contribution.

2.1.5 Periodic review and management of changes

2.1.5.1 Overview of actions

Beznau Nuclear Power Plant (KKB)

Based on changes and updates to the Swiss regulations, the deterministic and probabilistic fire analyses in the KKB are updated. In addition, the fire analyses are checked for up-to-dateness as part of the periodic safety review and revised if necessary. In this process, knowledge gained from operating experience during the period under review is incorporated via a defined process in which operational events or incidents with safety relevance are analysed and evaluated with regard to their impact on plant safety.

An analogous process is carried out for reported events or operating experience from other nuclear facilities. The focus here is on analysing whether a similar event could occur at the KKB and what measures exist to prevent negative effects on operational safety.

A probabilistic assessment of plant modifications is part of the safety assessment within the plant modification process. All plant modifications carried out are reviewed annually for their PSA relevance and taken into account in the periodic updating of the PSA model.

Gösgen Nuclear Power Plant (KKG)

The control of fire loads, recurring plant inspections that also take fire protection aspects into account, recurring inspections of fire protection systems and a maintenance programme in line with requirements (e.g. regular inspection and, if necessary, repair or replacement of fire doors) ensure that the assumptions made in the deterministic and probabilistic fire analyses remain valid and that the fire protection facilities meet the requirements placed on them.

The fire load inventory is reviewed periodically in accordance with the overarching fire protection concept, usually every ten years. If significant changes occur as a result of plant modifications, the fire load inventory is updated in a timely manner.

In the case of fire protection-related plant modifications, the process flows in the KKG ensure that these are also taken into account in the fire analyses. A probabilistic evaluation of plant modifications is part of the safety assessment within the framework of the internal KKG process for plant modifications. Plant modifications that have been carried out are reviewed annually for their PSA relevance. Risk-relevant changes are taken into account when updating the PSA model as part of the periodic safety review.

Leibstadt Nuclear Power Plant (KKL)

The current deterministic fire analysis was requested on the basis of new requirements in guideline ENSI-A01 as part of ENSI's safety statement on the periodic safety review in 2016 and submitted to ENSI at the end of 2022. Best practice methods from international standards and the latest generic and plant-specific fire data are used in the fire analyses.

The development of the probabilistic fire analyses of KKL dates back to the 1990s. The probabilistic fire analysis submitted to ENSI at the end of 2012 was comprehensively revised due to the changes in guideline ENSI-A05, the further development of international PSA methods and model changes. The risk-related influence of the plant modifications carried out at KKL in recent years was assessed as part of PSR 2022. The majority of the plant modifications were classified as not risk-relevant. The plant modifications classified as risk-relevant do not involve any fire protection measures.

The fire analyses are subject to continuous improvement and further development.

2.1.5.2 Implementation status of modifications

Beznau Nuclear Power Plant (KKB)

During the many years of operation of the KKB, the fire protection of the plant was continuously upgraded and adapted to the state of the art. Significant improvements in fire protection were achieved through the construction of the emergency standby and emergency feedwater buildings and the construction of two emergency diesel buildings.

In the safety building (Reactor Building), cable penetrations were separated from each other with fire stops. In the event of a fire within one feedthrough, this prevents the spread to other feedthroughs. Furthermore, the cabling was checked and replaced so that cables of redundant safety systems are not routed through the same bushing.

In its statement on PSR-2012, ENSI required the KKB to carry out deterministic fire analyses, taking into account the new requirements in guideline ENSI-A01. In the safety-related statement on PSR-2017, ENSI evaluated the analyses submitted by KKB and demanded a number of additions and improvements. Based on these demands, the following fire protection measures were initiated:

- The implementation of improvement measures in the live steam blow-off station to protect against internal fires.
- The specification of organisational measures in the administrative directives of the KKB to reduce mobile fire loads in the emergency buildings.

The first measure has not yet been completed, while the second measure has been implemented in the meantime.

The potential for improvement identified by ENSI in the review of the last periodic safety review with regard to the probabilistic fire analysis will be implemented by the end of 2023.

Gösgen Nuclear Power Plant (KKG)

For future fire analyses, the fire simulation software PYROSIM was procured. This couples the FDS programme with a graphical user interface. For optimised use, it is planned to use 3D models for certain buildings. The building models are based on building plans supplemented by data from 3D laser scans.

A retrofit project is currently being implemented in the KKG to expand the emergency systems and thus extend the controllable spectrum of beyond-design-basis events. This project also includes an improvement of the protection against external fires by retrofitting the ventilation systems in the emergency building with an automatic building closure in case of fire detection in the outside air.

A complete review and revision of the fire PSA was carried out as part of PSR-2018. The last adjustment of the model took place at the end of 2022. All plant changes with an influence on the fire PSA were taken into account in the model.

Leibstadt Nuclear Power Plant (KKL)

The available deterministic and probabilistic fire analyses did not reveal any need for fire protection improvements in the KKL.

In the past, some fire protection improvement measures were derived from the probabilistic fire analysis, in particular the definition of clear criteria for leaving the main command room in the event of a fire and the decentralised structure of the fire alarm control centres, as well as a more detailed analysis of the effects of false signals in the emergency control points (RSD). These measures have been implemented in the meantime.

2.1.6 Licensee's experience of fire safety analyses

2.1.6.1 Overview of strengths and weaknesses identified

Beznau Nuclear Power Plant (KKB)

The strength of the fire analyses carried out at KKB lies in the systematic investigation of the effects of fires in the safety-relevant plant areas. The determined parameters and results from the deterministic and probabilistic fire analyses provide an overall picture of the possible extent of damage as well as the associated risks in the event of a fire and enable an adequate assessment of the existing fire protection measures with regard to nuclear plant safety.

The potential for improvement identified by ENSI in the review of the last periodic safety review with regard to the probabilistic fire analysis will be implemented by the end of 2023.

Gösgen Nuclear Power Plant (KKG)

The deterministic fire analyses carried out confirm the basic system design of the KKG that cross-redundancy effects on the emergency and safety systems in the event of fire are largely avoided by the structural separation of the individual safety redundancies.

In the annular space of the reactor building in particular, however, consistent fire protection redundancy separation is only possible to a limited extent. In this area of the plant, on the one hand, the separation by distance of the safety redundancies takes effect, and on the other hand, in areas where no sufficient separation can be implemented, self-triggering sprinkler systems prevent an inadmissible redundancy-spanning failure from occurring. Model calculations for cable fire scenarios have shown that the resulting temperatures are so low that a cable fire is controlled either by the automatically triggering sprinkler system or by the deployment of the fire brigade.

The fire event with the greatest impact is an oil fire at a main coolant pump in the reactor building, as it can lead to a failure of both redundancies of the auxiliary borating system. In this case, the high-pressure safety feed would continue to ensure long-term subcriticality. In addition, self-triggering extinguishing devices (deluge spray systems) are installed in the plant area concerned to effectively counteract the spread of fire at an early stage.

The KKG-internal database was provided with various functional extensions as part of the update. The database contains all data required for fire modelling such as reliability values of fire protection equipment, fire compartments, inventory for all rooms incl. fire loads, cables and routes. In addition, three-dimensional data is available for all relevant buildings, created from extensive 3D laser scans.

As part of the new creation of the PSA model with a software change from Riskman to RiskSpectrum, the fire PSA model will also be updated. In future, the method according to NUREG/CR-6850 will be used for this purpose.

Leibstadt Nuclear Power Plant (KKL)

The probabilistic fire analysis of the KKL has been carried out, updated and continuously improved since 2006. In the period 2019-2022, a complete revision of the deterministic and probabilistic fire analyses was carried out to meet the partly new requirements in the ENSI-A01 and ENSI-A05 guidelines and, at the same time, to adapt the studies to international best practice and the state of the art in several areas. For the fire analyses, current and complete data on components and cable runs from the KKL technical database were used in all phases.

The consistency and common ground of the fire analyses was ensured by using the fire areas defined in the deterministic fire analysis as a starting point for defining the probabilistic fire analysis boundaries. A screening analysis of the internal fire hazards was performed to identify the fire hazards requiring detailed analysis. The differences between power, low-power and outages in terms of ignition sources, fuels, scenario analysis and fire spread were identified and considered in all phases of the fire analysis.

The main features of current deterministic and probabilistic fire analyses are:

- Consistent and common basis for fire risk assessment through the application of the design fire compartments;
- Comprehensive assessment of fire effects on components and cables using the latest/updated plant engineering databases;

- Plant-specific fire frequencies for fire sources by combining the latest generic data from NUREG-2169 and KKL operational experience;
- Event matrix for the representative events in the states power, low-power and outage;
- Fire simulations for risk-relevant fire Chapters with the "Consolidated Fire and Smoke Transport Model (CFAST)" and the "Fire Dynamics Simulator (FDS)";
- Consideration of fire detection and fire fighting in the fire scenarios;
- Analysis of multiple false tripping according to NeI-00-01 supported by an international expert panel with participation of KKL experts, PSA specialists and external experts;
- "Multi-compartment analysis according to NUREG/CR-6850 recommendations.

For the preparation of the fire analyses, extensive discussions were held with the technical and operational staff of the KKL in order to take into account the specific fire aspects.

2.1.6.2 Lessons learned from events, reviews, fire safety related missions

Beznau Nuclear Power Plant (KKB)

Since the commissioning of the emergency systems at the beginning of the 1990s, there have been no fire events at the KKB with relevance for nuclear safety. Nevertheless, it was possible to derive technical and organisational improvement measures from the results of the deterministic and probabilistic fire analyses, which significantly improved the degree of protection of the plant against fire events (see ChapterChapter 2.1.5.2).

In the area of organisational fire protection, new risk-based instruments were implemented at KKB, which regulate the handling of fire loads in a safety-oriented manner in the form of room-specific specifications and regular rounds.

Gösgen Nuclear Power Plant (KKG)

So far, no safety-relevant fire incidents have occurred in the KKG. This experience can be seen as proof that the fire protection principle of limiting fire loads to a necessary minimum is being adhered to and that the fire protection precautionary measures are effective when dealing with ignition sources, e.g. during hot work in the context of revision activities.

In 2019, a short circuit occurred on a transformer switch in a 10 kV switchgear. Neighbouring switches were not affected. This event is seen as evidence of the effective enclosure of the switchgear, which is an assumption in the safety analyses.

The KKG-specific operational experience (including occurrence frequencies of fire events, reliability of the fire protection equipment) is systematically evaluated and taken into account as part of the periodic update of the fire PSA. The abnormalities in the closing behaviour of the fire dampers in the switchgear building identified in 2016 during functional tests had a direct influence on the calculated plant risk and were taken into account in the PSA model accordingly in a timely manner.

Leibstadt Nuclear Power Plant (KKL)

External events are specifically evaluated by a working group at KKL. Events that are relevant to the plant are always forwarded to the specialist departments and their comments are obtained. During the review period of PSR-2022, there were no fire events that were classified as relevant for KKL.

At the end of 2022, a new, overall fire protection concept was submitted to ENSI as a document requiring approval.

The review and verification of the individual steps of the fire analyses took place in various internal and also external committees. The quantification and verification of the model were repeated after each significant development or improvement of various model elements.

An IAEA Peer Review Mission (IPSART) was organised to ensure that the KKL-PSA meets the international state of the art and quality assurance requirements. The IPSART mission highlighted the high quality of the analyses carried out. The results from the review have been incorporated into the subsequent revision of the fire analyses. The updated deterministic and probabilistic fire analyses were submitted to ENSI at the end of 2022 as part of the PSR for the long-term operation of KKL.

2.1.7 Regulator`s assessment and conclusions on fire safety analyses

2.1.7.1 Overview of strengths and weaknesses identified (by the regulator)

Beznau Nuclear Power Plant (KKB)

Deterministic fire analysis

The analysis methodology used by the KKB in the deterministic fire analysis largely complies with the requirements of guideline ENSI-A01. According to ENSI's assessment, the effects of fires in all safety-relevant buildings of the KKB have been analysed and the extent of damage of the individual fire scenarios has been determined in a largely comprehensible manner. Furthermore, the fire analysis takes into account the fire detection and firefighting options available at the KKB. The incident categorisation made on the basis of the fire occurrence frequencies determined in the probabilistic fire analysis is basically plausible.

In the course of the periodic safety review, however, ENSI found that the fire compartments defined in the fire analysis only partially corresponded to those in the fire protection plans and thus did not meet the requirements of the updated ENSI-A01 guideline. In addition, there was no consideration of the fire effects on radiologically relevant components. Although the spectrum of MSO-induced accidents identified by the KKB takes various scenarios into account, there is no assessment by the KKB of whether the corresponding acceptance criteria according to guideline ENSI-A01 are met. However, it is plausible for ENSI that the effects of the relevant MSOs are covered by the incident spectrum.

From this, the following need for improvement (National area for improvement) was derived:

- Determination of occurrence frequencies based on the fire compartments defined in the fire protection plans as well as proof of compliance with the acceptance criteria in MSO-induced incident scenarios for internal fires.
- Assessment of the radiological consequences of fire effects on activity-carrying systems and components.
- Investigation of the effects of fires in the building housing the boron water storage tanks (RWST) on the availability of the individual departure paths.

- Identification and implementation of improvement measures to increase fire protection in the live steam blow-off station.
- Implementation of organisational measures derived from the fire analyses.
- Analysis of the effects of fires on the emergency control room, taking into account the specifications in guideline ENSI-A01.

Its implementation is being pursued by ENSI in the ongoing supervisory process.

In addition, the KKB has analysed the effects of earthquake-induced fires as part of the new earthquake verification. This verification is currently being reviewed by ENSI. According to the current test stand, the plant can also be transferred to a safe state in the event of this combination of events.

Probabilistic fire analysis

The fire-PSA of the KKB essentially complies with the requirements of guideline ENSI-A05 /23/.

As part of a revision of the fire-PSA, it was found that for fires in the switchgear building, partially unrealistic effects on emergency standby, emergency cut-off water and emergency feed water systems were modelled. This was a consequence of simplified modelling, according to which the burning of some cables also led to the failure of components when these cables are not required for the operation of the components. This conservatism in the modelling has since been largely removed. In the course of detailed fire modelling, selected spaces are also subdivided into subChapters, each with a smaller amount of damaged equipment and possible initiating events, and the acceptability of the assumed separations between the subChapters is justified by fire spread calculations in a zone model. In some cases, further refinements of the fire effects are also made.

According to the current fire-PSA of the KKB, the fire CDF amounts to 1.4E-06 per year. The largest contribution to this is 5.3E-07 per year from a fire in a room of the emergency building, which thus accounts for 38% of the fire CDF and approx. 4% of the total CDF. For ENSI, the fire-PSA of the KKB is suitable for assessing the risk level and the balance of the risk profile.

Gösgen Nuclear Power Plant (KKG)

Deterministic fire analysis

From ENSI's point of view, the deterministic fire analysis carried out so far in the KKG shows that, due to the largely consistent spatial and functional separation of shutdown paths 1 (conventional safety systems) and 2 (emergency systems), shutdown of the plant to the cold shutdown state is ensured in the event of a fire with an assumed single fault. The lack of spatial separation of the safety and emergency systems in the annular space of the reactor building by passive fire barriers is compensated for by spatial distance and basic fire protection measures, such as minimisation of fire loads and ignition sources and the presence of extinguishing equipment.

However, the deterministic analyses carried out by the KKG do not fully meet the requirements of the updated guideline ENSI-A01 (National area for improvement). For example, the determination of the frequency of occurrence of the initiating events and an accident categorisation based on this is missing. Furthermore, the effects of a possible single fault as well as the effects on components that contain or may contain radioactive substances in a nonnegligible quantity have not been systematically analysed. ENSI will continue to pursue the implementation of this need for improvement in the ongoing supervisory process.

In addition, the KKG has analysed the effects of earthquake-induced fires as part of the new earthquake verification. This verification is currently being reviewed by ENSI. According to the current test stand, the plant can also be transferred to the "cold shutdown" state in the event of this combination of events, since the fire protection separation of the safety redundancies is guaranteed.

Probabilistic fire analysis

The fire-PSA of the KKG essentially complies with the requirements of guideline ENSI A05. However, from ENSI's point of view, the fire-PSA still shows the following need for improvement (National area for improvement):

- Various methods, especially for determining fire occurrence frequencies and for dealing with fire-induced short circuits, have undergone significant advances in the state of the art since the last revision of the study and require further adjustments.
- The assumptions used for the quantitative exclusion procedure regarding fire spread to further fire compartments are rather restrictive, possibly leading to optimistic results.
- There is no adaptation of the error probabilities of personnel actions to the specific conditions under which they are to be carried out in the case of fire.
- There is a lack of studies on consequential fires caused by fires with damage to electrical safety equipment and the possible effects of this fire damage on the control of the power supply.

ENSI will continue to pursue the implementation of this need for improvement in the ongoing supervisory process.

Leibstadt Nuclear Power Plant (KKL)

Deterministic fire analysis

In its 2019 statement on the periodic safety review, ENSI followed KKL's assessment that the systems required to reach and maintain the cold shutdown state are available in the event of an internal fire due to the multiple redundant safety systems, which are largely separated from each other functionally and spatially. However, since this purely qualitative justification did not meet the requirements of the updated guideline ENSI-A01, ENSI demanded that a deterministic fire analysis be carried out in accordance with the regulatory requirements.

KKL submitted the deterministic fire analysis to ENSI as part of the current PSR at the end of 2022. This is currently being reviewed by ENSI.

In addition, KKL has analysed the effects of earthquake-induced fires as part of the new earthquake verification. This verification is also currently being reviewed by ENSI. According to the current test stand, the plant will also be transferred to a safe state in the event of this combination of events.

Probabilistic fire analysis

The fire PSA submitted by KKL in the PSR-2016 was assessed by ENSI as being in line with the state of the art, despite the identified potential for oversight described in the statement on the PSR-2016, and the CDF contribution of 4.9E-08 per year was classified as plausible.

The fire PSA of KKL, which was updated in 2022, shows a CDF contribution of 6.6E-08 per year for fires. The updated fire PSA has not yet been subjected to a systematic review by ENSI, but the result seems plausible based on the comparison with the result from the PSR-2016. There are no obvious open points regarding compliance with the requirements of guideline ENSI-A05.

Compared to the previous version, current technical approaches such as the expert panel for the treatment of fire-induced short circuits and a comprehensive set of fluid-mechanical fire propagation calculations are to be emphasised. Also, the quantitative exclusion procedure was carried out using a cumulative CDF criterion according to guideline ENSI-A05.

2.1.7.2 Lessons learned from inspection and assessment as part of the regulatory oversight

Beznau Nuclear Power Plant (KKB)

As part of the assessment of the fire PSA, an inspection by ENSI took place at the KKB in 2018. Random samples were taken to check whether

- the number of ignition sources in risk-relevant areas have been realistically assessed,
- only areas of the installation have been correctly excluded from investigation in the fire PSA which do not contain equipment the damage to which would trigger an incident or which is necessary for incident control,
- the components affected by the fire scenario were realistically determined unless the failure of all components in the corresponding fire compartment was assumed. For this purpose, the fire development to be expected due to the local conditions as well as the properties of the PSA components (e.g. temperature sensitivity) were taken into account.

In individual cases, a need for improvement was identified with regard to the assumptions for the distribution of fire loads and the possible fire effects. This has been remedied in the meantime.

Gösgen Nuclear Power Plant (KKG)

As part of the assessment of the fire PSA, an inspection by ENSI took place at the KKG in 2019. Random samples were taken to check whether:

- the number of ignition sources in risk-relevant areas has been realistically assessed,
- only areas of the installation have been correctly excluded from investigation in the fire PSA that do not contain equipment the damage of which would trigger an incident or which is required for incident control,
- the components affected by the fire scenario were realistically determined, unless the failure of all components in the respective fire compartment was assumed. For this purpose, the fire development to be expected due to the local conditions as well as the properties of the PSA components (e.g. their temperature robustness) were taken into account.

In individual cases, a need for improvement was identified with regard to the assumptions for the distribution of ignition sources as well as the possible fire effects. This has been remedied in the meantime.

Leibstadt Nuclear Power Plant (KKL)

As part of the assessment of the fire PSA, an inspection by ENSI took place at KKL in 2017. The inspection examined,

- whether the system behaviour in the event of damage to selected control cables by fire corresponds to the assumptions in the fire analysis, and
- the extent to which fire spreading across Chapters has the assumed low relevance.

Based on the spot check of the possible fire effects, no need for improvement of the fire PSA at that time was identified.

2.1.7.3 Conclusions drawn on the licensee's fire safety analyses

Beznau Nuclear Power Plant (KKB)

Deterministic fire analysis

The analysis methodology underlying the deterministic fire analysis of the KKB complies with the relevant requirements in guideline ENSI-A01. Guideline ENSI-A01 was updated in 2018 in accordance with international standards. The resulting deviations and potential for improvement in the fire safety analyses of the KKB, which were identified in the course of the PSR, made it possible to bring them systematically into line with the current state of the art.

From ENSI's point of view, the deterministic fire analysis carried out by the KKB covers the requirements in WENRA SRL SV 6.1 with regard to the operating states and plant areas to be considered. In ENSI's view, the analysis of the effects of seismically induced fires meets the requirement in WENRA SRL SV 6.1 and E 6.1 to consider credible combinations of fires with other events.

In accordance with a further requirement in WENRA SRL SV 6.1, the deterministic fire analysis is supplemented by a probabilistic fire analysis (fire PSA), with which, from ENSI's point of view, the risk contributions of fires are determined using internationally recognised risk parameters.

Manual fire extinguishing by the fire brigade has only been considered in a few fire scenarios in the deterministic fire analysis of the KKB, as the critical fire Chapters are mostly protected by automatic fire extinguishing systems. In addition, manual fire extinguishing was only taken into account if sufficient time was available for intervention on the basis of the fire spread simulations. From ENSI's point of view, WENRA SRL SV 6.2 is thus also fulfilled.

Overall, the KKB deterministic fire safety analyses meet the requirements of WENRA SRL Level E 6.1 as well as SV 6.1 and SV 6.2.

Probabilistic fire analysis

The basic approach to the preparation of the fire PSA of the KKB corresponds to the state of the art. The few remaining cases of unrealistic assumptions on the impact of fires are always of a conservative nature, but without significantly affecting the assessment of the risk contribution and the balance of the contribution of fires.

Gösgen Nuclear Power Plant (KKG)

Deterministic fire analysis

From ENSI's point of view, the KKG has comprehensibly identified the safety functions and associated systems required to control fires in the deterministic fire analysis and has demonstrated sufficient protection against internal fires due to the existing fire protection separation of the safety redundancies.

From ENSI's point of view, the deterministic fire analysis carried out by the KKG covers the requirements in WENRA SRL SV 6.1 regarding the operating states and plant areas to be considered. In ENSI's view, the analysis of the effects of seismically induced fires fulfils the requirement in WENRA SRL SV 6.1 and E 6.1 to consider credible combinations of fires with other events.

Due to the identified need for improvement with regard to the implementation of the methodological requirements in the updated guideline ENSI-A01, the deterministic fire analysis of the KKG has so far lacked a systematic analysis of the existing fire protection measures in the individual fire compartments of the plant. However, since the fire protection measures are systematically taken into account in the supplementary probabilistic fire analysis, ENSI believes that WENRA SRL SV 6.2 is also fulfilled.

In ENSI's assessment, the requirements of WENRA Safety Reference Levels E 6.1, SV 6.1 and SV 6.2 are fulfilled despite the identified need for improvement with regard to deterministic fire analysis.

Probabilistic fire analysis

ENSI identified various methodological needs for improvement in the fire PSA of the KKG. It is therefore difficult to compare the effectiveness of the fire protection measures in the individual areas of the plant. ENSI expects the risk contributions of the various areas to change as the need for improvement is successively addressed. However, there is nothing to suggest that the fire risk could become the dominant contribution to the overall CDF.

Leibstadt Nuclear Power Plant (KKL)

KKL has carried out new deterministic and probabilistic fire safety analyses as part of PSR-2022. In doing so, KKL was guided by the requirements of the ENSI-A01 guidelines as well as the latest international guidelines.

Deterministic fire analysis

The fire analyses took into account all plant conditions of KKL and all safety-relevant buildings of the plant, as well as the areas from which radioactive substances could be released in the event of a fire. KKL distinguishes between covering and detailed deterministic fire analyses. In the case of the covering analyses, the proof of the safe shutdown capability of the plant and the transfer to a safe and stable state after a fire event is provided under the assumption of a conservatively determined fire damage. The detailed fire analyses were performed to reduce conservatism with the aim of demonstrating the successful shutdown path.

From ENSI's point of view, the deterministic fire analysis includes the following basic analysis steps, which are also required by guideline ENSI-A05 :

- Systematic identification of buildings and fire compartments relevant for the analysis,

- Consideration of all operating conditions,
- Definition of the shutdown paths (Safe Shutdown Paths) to transfer the plant to a safe state after a fire,
- Determination of fire occurrence frequencies and classification into the corresponding incident category,
- Technical safety analysis of fire effects with conservative covering boundary conditions and detailed analyses with fire spread calculations,
- Radiological safety analysis.

The new deterministic fire analyses of KKL are currently being assessed in detail by ENSI as part of the current periodic safety review PSR2022. In ENSI's assessment, the requirements of guideline ENSI-A01 and thus also the requirements of WENRA Safety Reference Levels E 6.1, SV 6.1 and SV 6.2 are fulfilled despite the fact that the review has not yet been completed.

Probabilistic fire analysis

Before the last update of the fire PSA, KKL already had a fire PSA that was implemented according to the state of the art, with only a few potential improvements identified by ENSI. It can therefore be assumed that a realistic assessment of the fire risk is available with the update of the fire PSA.

2.2 Research reactors

Not applicable (see justification in ChapterChapter 1.1)

2.3 Fuel cycle facilities

Not applicable (see justification in ChapterChapter 1.1)

2.4 Dedicated spent fuel storage facilities

2.4.1 Types and scope of the fire safety analyses

Central interim storage facility Zwilag

Fire analyses of the required depth and quality were carried out in each approval phase of the individual Zwilag buildings. In detail, the following analyses were prepared for the relevant Zwilag buildings:

Building H (Cask storage hall)

- Aircraft crashes onto building H with subsequent paraffin fire

Building M (Storage hall for medium-level waste)

- Aircraft crash into building M: due to the full protection of the building, no subsequent fire in the building is to be assumed.
- Spontaneous ignition of a container in the storage shaft (hypothetical)

Building S (Storage hall for low- and medium-level waste)

- Aircraft crashes onto building S with subsequent paraffin fire

- Fire of a transport vehicle
- Fire of a storage container
- Fire of a storage container

Building K (Conditioning plant)

- Aircraft crash onto the high-bay storage with subsequent paraffin fire
- Spontaneous ignition of a container

Building V (Plasma plant)

- Fire of a barrel in the entrance area

Building Z (Hot Cell)

- No explosive, volatile or flammable substances are handled in the hot cell. The Hot Cell has full protection against aircraft crash.

Interim storage facility at Beznau NPP

A deterministic fire analysis was carried out for the ZWIBEZ. The type and scope of the analyses follow the ENSI-A01 guideline for deterministic safety analyses. For the classification into the relevant accident categories according to the Ordinance on Hazard Assumptions, the occurrence frequencies of various fire events were determined within the scope of the accident analysis for the LAW storage facility.

The fire analysis shall be used to demonstrate that the radiological criteria of the applicable accident category according to the Ordinance on Hazard Assumptions are met.

The HAW storage facility of the ZWIBEZ is a storage facility for dry storage of spent fuel elements and highly radioactive vitrified waste. Dry storage is characterised by the following features, among others:

- The removal of the decay heat is based on convective heat removal by natural convection of the air in the storage building and is thus purely passive.
- The building openings are dimensioned in such a way that the safe dissipation of decay heat is ensured even at temporarily high ambient air temperatures.

Fires resulting from paraffin leakage in an aircraft crash are assessed in the corresponding incident analysis and are not subject to the fire analysis.

Interim storage facility at Gösgen NPP

In the course of the construction of the wet storage facility, the potential hazard due to fire was analysed and assessed. Since there are only very low fire loads in the wet storage building, a hazard to equipment that serves to ensure nuclear protection objectives, in this case ensuring subcriticality and heat removal from the fuel pool, can be ruled out.

The spent fuel elements in storage are cooled by a passive cooling system that dissipates heat by natural convection. Since there are only very low fire loads in the wet storage facility and the use of the wet storage building will not change in the future due to licensing requirements, there is no requirement from the regulatory requirements to carry out a detailed analysis for internal fires that goes beyond the basic considerations that have been made.

2.4.2 Key assumptions and methodologies

Central interim storage facility Zwilag

All radioactive waste, which must not contain any spontaneously combustible or explosive substances according to the acceptance conditions, is encapsulated and conditioned or, in the case of raw waste, pressed and encapsulated. They are located in areas of the Zwilag that have a low immobile fire load. In general, the following basic boundary conditions were considered for the fire safety analyses:

- The immobile fire load in the storage areas of the buildings amounts to approx. 24 MJ/m², which is significantly less than 90 MJ/m². This means that there are no materials in the storage areas that could release a quantity of heat that could impair the protective function of the stored waste containers.
- The activity inventories are either conditioned or compressed and securely enclosed in containers, apart from individual drums being processed in each case, particularly in Building V.

This means that the criteria of guideline ENSI-G23 and the recommendations of the ESK are fulfilled. Based on this assessment, all fire scenarios are only to be assumed either due to external impacts or due to statistical spontaneous ignition. The accident analyses are performed in accordance with Guideline ENSI-A01 /20/ with deterministic methods.

The HAW storage in Building H of Zwilag is used for dry storage of spent fuel elements and highly radioactive vitrified waste. Heat removal is purely passive. For the interim storage, the following basic boundary conditions also apply:

- The storage containers are certified as type B(U) storage and transport containers (T/L-containers), which makes them able to withstand a 30-minute fire with temperatures of 800°C without loss of tightness.
- With the storage release, the T/L containers fulfil all reference requirements from the Zwilag licence. This is achieved, among other things, by compliance with the requirements in guideline ENSI-G05 /34/.
- All T/L containers are also protected by an aircraft crash bonnet against the mechanical effects of an aircraft crash.
- The additional radioactive waste from the Lucens experimental reactor stored in Building H is safely enclosed in steel containers with wall thicknesses of 5 cm.

Interim storage facility at Beznau NPP

The following basic assumptions apply to dry interim storage in the HAW storage facility:

- The activity inventories are safely enclosed in non-flammable containers.
- The storage containers in the HAW storage are certified as type B(U) storage and transport containers (T/L containers), which makes them able to withstand a 30-minute fire with temperatures of 800 °C without loss of tightness.
- The T/L containers meet all the requirements in the guideline ENSI-G05 /34/.
- All T/L containers are also protected against the mechanical effects of an aircraft crash.

Release calculations were carried out for the waste packages housed in the LAW storage facility. To determine the release fractions, each cask was assigned to a waste cask group. The classification is based on the properties of the containers themselves and the waste products contained therein (e.g. combustible fractions). Individual containers are still in concrete containers, which was taken into account in the classification into waste package groups. The loads are divided into different load classes according to the methodology of the Konrad transport study. For the calculation of the release fractions, each container is subjected to a thermal load caused by a fire at 800°C for a defined fire duration. The release fraction results from the combination of waste package group and load class.

The activity inventories of the various cask types are all taken from the KOMRA module of the Information System for Radioactive Materials (ISRAM) of the National Co-operative for the Disposal of Radioactive Waste (Nagra) and are listed per cask in the Basic Data Report. The source terms are calculated from the radioactive inventory of the respective waste group and the release fraction according to the Konrad transport study depending on the load class considered.

The waste volume structure considered includes the packages expected until the end of KKB's power operation, including the packages transferred from the nuclear power plant's residue storage facility to the ZWIBEZ.

Due to the monitoring of the ZWIBEZ with fire detectors, it is conservatively assumed that a fire will be extinguished by the fire brigade after 30 or 60 minutes, depending on the scenario. In addition, further extinguishing equipment is available to the staff in the building for initial firefighting.

Interim storage facility at Gösgen NPP

As a detailed fire analysis is not required due to the low fire risk in the wet storage facility (see Chapter 2.4.1), the KKG concludes that no further elaboration is required.

2.4.3 Fire phenomena analyses: overview of models, data and consequences

Central interim storage facility Zwilag

In the case of fire events caused by internal influences, it was generally assumed that they occurred due to a statistically assumed spontaneous combustion, although this can be practically ruled out due to the chemical-physical boundary conditions. Due to the very low frequency of spontaneous combustion, these events could be classified in accident category 3.

The accidental crash of a military aircraft was considered as a covering fire event for the external impacts for various buildings.

Based on general loads, the radiological impacts are divided into different load classes according to the methodology of the Konrad transport study. For the calculation of the release fractions, each container is subjected to a mechanical and/or thermal load.

Building H

The accidental crash of a military aircraft was considered as the covering fire event. The fire load introduced by this accident consists of the maximum amount of paraffin carried by a military aircraft according to guideline HSK-R102. Based on the free area not occupied by the T/L container and the paraffin burn rate, this leads to a paraffin fire which is safely covered by the type B(U) property of the T/L containers. The temperatures occurring at the T/L containers were determined using simple engineering methods (1-dimensional heat transport calculations).

Decommissioning waste from the Lucens experimental reactor is contained in six permanently welded steel containers of different sizes and is stored temporarily in Building H. The containers are not type B(U) approved. These containers do not have Type B(U) approval. Fire impacts on these containers do not lead to any releases due to the welded steel casing. Only a direct hit in the event of an aircraft crash can lead to releases into the vicinity of Zwilag.

Building M

For building M, it has been shown that the construction of the building's ceiling can withstand the effects of an impacting aircraft both locally and globally and that the structural safety is guaranteed. The penetration of paraffin into the interior of the building is therefore not to be assumed. Any spalling of the concrete ceiling does not cause any mechanical loads that could result in the release of radioactive substances from the containers stored in the building. Therefore, a radiological analysis of the aircraft crash on building M is not necessary.

The hypothetical spontaneous combustion of a container in the storage shaft is investigated as an internal fire event.

Building K

The radiological effects of the aircraft crash incident on Building K were determined, as were those of a hypothetical spontaneous combustion of a container.

Building S

The simulations of fire events for building S listed below were carried out, among other things, to be able to assess the possible effects of a fire on buildings and the possibility of interventions:

- Fire of a transport vehicle,
- Fire in a storage container (hypothetical),
- Fire of a storage bundle.

The aircraft crash with subsequent fire as well as other internal fire scenarios focussing on fire spread in the case of a fire involving several barrels and on building integrity in the case of a fire involving a 20' grid box loaded with barrels were also analysed.

Building V

The fire of a barrel with raw waste and failure of all active safety devices is analysed.

Building Z

Fires are practically excluded due to the very low fire load and the full protection against an aircraft crash.

Interim storage facility at Beznau NPP

Three covering fire scenarios were identified and investigated for the LAW storage of the ZWIBEZ:

- In the case of a container fire, a stackable container with combustible waste packages catches fire, thermally stressing other, non-combustible waste. The spatial arrangement of combustible waste in the LAW storage prevents the fire from spreading to other combustible waste.

- In the case of the fire in the reception area, it is assumed that a truck intended for the removal of a covering number of active wastes catches fire, whereby these wastes are thermally loaded. The fire does not spread to the storage area of the LAW storage.
- As an additional covering scenario, the thermal impact of a fire on the entire inventory of the LAW storage and the reception area was analysed.

In all scenarios, the assumption is made that all radioactive aerosols are released into the environment via the exhaust vents, i.e. any retention by the building is not credited.

For the determination of the dose values, a verified calculation programme is used, which is applied for the sites of nuclear facilities in Switzerland. Immersion, inhalation from the plume, ground radiation, resuspension and ingestion are taken into account for the calculation of exposure.

Due to the transport and storage containers stored in the HAW storage of the ZWIBEZ, which are protected against the effects of fire, or the absence of ignition sources or significant fire loads, no deterministic fire analyses were carried out for the HAW storage.

Interim storage facility at Gösgen NPP

As a detailed fire analysis is not required due to the low fire risk in the wet storage facility (see ChapterChapter 2.4.1), the KKG concludes that no further elaboration is required.

2.4.4 Main results / dominant events (licensee's experience)

Central interim storage facility Zwilag

Building H

The results of the fire safety analysis for Building H show that a fire can only occur due to external effects. In the case of the beyond-design-basis accident of an aircraft crash, no releases result according to the design of the T/L containers. The thermal load on the Lucens tanks caused by the subsequent paraffin fire does not lead to any release from the tanks. The mechanical-thermal loads on the Lucens containers from a direct hit lead to releases into the environment. These result in a maximum dose value that is far below the permissible limit of 100 mSv according to guideline ENSI-G23.

Building M

The hypothetical spontaneous ignition of a cask in the storage shaft results in a maximum dose value that is only a few percent of the dose limit of 100 mSv and thus safely complies with it.

Building K

The analyses for the internal fire show that due to the construction of the building and in combination with the additional measures taken in addition to the conventional fire protection measures, the specified protection goals can be met. The amounts of activity released into the environment in the event of a fire are low and the overall protection goals can be met.

Building S

The analyses for the internal fire in Building S show that even without a smoke and heat extraction system and without extinguishing systems in Building S, the conditions according to the VKF regulations /12/ are tolerable. Due to the construction of the building and in combination with the measures taken, the overriding protection goals can be met. The amount of activity released into the environment in the event of a fire is low.

The radiological effects of the aircraft crash accident in the vicinity of Building S were determined using various scenarios. The analysis for the covering scenario results in a maximum total dose with which the permissible dose of 100 mSv according to guideline ENSI-G23 is safely complied with.

Building V

From the fire analysis carried out, it can be deduced that even the hypothetical fire of a barrel with raw waste in the inner courtyard of Zwilag, calculated with covering boundary conditions, leads to a dose that remains well below the permissible limit of 1 mSv.

Interim storage facility at Beznau NPP

Based on the fire analysis of the ZWIBEZ, the operator comes to the conclusion that the prescribed dose limits are safely complied with in all covering fire scenarios, even under conservative assumptions with margin. No fire events have occurred in the ZWIBEZ since commissioning.

Interim storage facility at Gösgen NPP

As a detailed fire analysis is not required due to the low fire risk in the wet storage facility (see ChapterChapter 2.4.1), the KKG concludes that no further elaboration is required.

2.4.5 Periodic review and management of changes

2.4.5.1 Overview of actions

Central interim storage facility Zwilag

In the case of new hazard assumptions or in the case of a change of the underlying hazard assumptions, fire analyses are carried out with the current hazard assumptions in accordance with Art. 13 of the Hazard Assumptions Ordinance /19/ shall be renewed step by step. Fire analyses are updated on the basis of current regulations, such as the ENSI guidelines.

Interim storage facility at Beznau NPP

The updating of fire analyses as well as the processes for handling fire incidents are carried out in the ZWIBEZ in the same way as in the KKB.

Based on the results of the current fire analyses, the following administrative measures for the storage and handling of combustible waste and ignition sources were derived:

- Transport units with combustible waste are stored within the waste rack only in the uppermost position and spatially separated from other combustible waste.
- Combustible storage goods must always be stored in non-combustible packaging. This ensures that in the event of a fire in the reception area, sparks cannot spread to the storage area. During the time a motor vehicle is in the reception area, it is under permanent supervision.

This made it possible to carry out the fire analyses including bundles that are currently still in intermediate storage and are being transferred.

Interim storage facility at Gösgen NPP

The same principles apply to the wet storage as to the KKG (see ChapterChapter 2.1.5). In the case of plant modifications, fire protection concerns are always taken into account.

2.4.5.2 Implementation status of modifications

Central interim storage facility Zwilag

Building H

Due to an increase in the maximum number of T/L containers in Building H, the fire analysis for Building H (aircraft crash incident analysis) was revised and adapted to the current status of the regulations.

Interim storage facility at Beznau NPP

The current fire analysis of the ZWIBEZ was submitted to ENSI for approval of the updated acceptance conditions of the LAW repository. The administrative measures derived from this (see ChapterChapter 2.4.5.1) were implemented in the relevant administrative directives and work regulations of the ZWIBEZ.

Interim storage facility at Gösgen NPP

No changes relevant to fire protection have been made since the wet storage facility was commissioned in 2010.

2.4.6 Licensee's experience of fire safety analyses

2.4.6.1 Overview of strengths and weaknesses identified

Central interim storage facility Zwilag

Due to the low hazard potential of the conditioning plant and the plasma plant (buildings K and V), fire analyses using deterministic, engineering methods are suitable from the operator's point of view to determine the risk of a release of radioactive substances due to fire effects and the resulting exposure of the population with sufficient accuracy.

This also applies to building H and the other storage buildings M and S, in which structural and technical precautionary measures corresponding to the activity inventory are in place against internal and external fire effects. In these buildings, there are no facilities in which high pressures or temperatures exist or could arise that could lead to an accidental release.

Statistical data on failure frequencies of enclosing components are required solely for determining the frequency of occurrence of a fire event with subsequent exposure of the surroundings. These are derived from operational records of recurring tests. In particular, operational data from the testing of fire dampers were used for the fire analyses.

For the accidental occurrence of a fire in a raw waste drum, the many years of operation of the plants without such a fire event allows a robust frequency estimate of such an event.

Interim storage facility at Beznau NPP

Fire analyses using deterministic, engineering methods are adequate from the operator's point of view for the fire hazard potential in the ZWIBEZ to determine with sufficient accuracy the risk of a release of radioactive substances due to fire effects and the resulting exposure of the population.

The fire analyses show that the dose limits are complied with in the event of a release due to a fire at the ZWIBEZ, even under conservative assumptions with reserve.

Interim storage facility at Gösgen NPP

As a detailed fire analysis is not required due to the low fire risk in the wet storage facility (see ChapterChapter 2.4.1), the KKG concludes that no further elaboration is required.

2.4.6.2 Lessons learned from events, reviews, fire safety related missions

Central interim storage facility Zwilag

No relevant fire incidents have occurred at Zwilag so far, which led to checks of the fire analyses. Fire protection-related incidents that led to a review of the passive fire protection are described in ChapterChapter 3.3.3.2 described.

Interim storage facility at Beznau NPP

So far, no fire incidents have occurred at the ZWIBEZ that led to reviews of the fire analyses.

Interim storage facility at Gösgen NPP

So far, no fire incidents or fire protection-related events (e.g. false alarms to the fire brigade) have occurred in the wet storage facility.

2.4.7 Regulator`s assessment and conclusions on fire safety analyses

2.4.7.1 Overview of strengths and weaknesses identified

Central interim storage facility Zwilag

The regulatory requirements stipulate that safety analyses must be reviewed as part of the release procedure for every relevant safety-related change. In this context, the corresponding safety analyses, including the fire analyses, are checked by ENSI for acuteness and compliance with the applicable regulations.

In general, the fire analyses for Zwilag are very conservative with regard to possible release scenarios. For example, barrel fires are investigated, although the fire loads are very low, and a subsequent fire due to an aircraft crash is investigated as a covering assessment for external events. In ENSI's view, the Konrad transport study methodology used by the operator of Zwilag to determine the activity released from the storage casks in the event of a fire represents a state-of-the-art methodology.

Interim storage facility at Beznau NPP

The fire analysis of the LAW storage facility at the ZWIBEZ was completely revised in 2022 due to an adjustment of the acceptance conditions for LAW waste and evaluated by ENSI in 2023. The conceptual simplicity of the LAW storage facility and the encapsulation and separation of combustible waste make it possible to use fire scenarios with conservative coverage.

Since no probabilistic safety analyses are to be prepared for the interim storage facility, the fire occurrence frequencies were determined conservatively from ENSI's point of view using failure statistics.

As part of the evaluation of the updated fire analyses, ENSI requested that the possibility of seismic secondary fires in the LAW repository be investigated and evaluated (National area for improvement). This need for improvement is being pursued in the ongoing supervisory process.

Interim storage facility at Gösgen NPP

Due to the low fire loads, the spatial separation and the passive function of the heat removal system in the wet storage facility, it is plausible for ENSI that internal fires cannot endanger the protection goals of "residual heat removal" and "subcriticality" and cannot lead to an impermissible release of activity. ENSI considers the simplified evaluation of the fire protection measures to be appropriate due to the special design features of the wet storage facility.

2.4.7.2 Lessons learned from inspection and assessment as part of the regulatory oversight

Central interim storage facility Zwilag

No open points relating to the fire analyses have yet been identified in the course of the plant inspections carried out. For example, the fire analyses at Zwilag resulted in findings regarding crane operation in the area of low-level raw waste and its separation concept.

Interim storage facility at Beznau NPP

In the course of the plant inspections carried out, no open points concerning the fire analyses have been identified so far. No additional findings were made.

Interim storage facility at Gösgen NPP

In the course of the plant inspections carried out, no open points concerning the fire analyses have been identified so far. No additional findings were made.

2.4.7.3 Conclusions drawn on the licensee's fire safety analyses

Central interim storage facility Zwilag

The first fire analyses were carried out during the licensing phase of Zwilag at the end of the 1990s. The then supervisory authority HSK, ENSI's predecessor organisation, issued statements on this, in part with conditions, also with regard to the planned gradual commissioning of the individual planned facilities of the central interim storage facility. The fire analyses were updated as part of the gradual commissioning and implementation of the conditions. Further updates of the fire analyses were carried out in the context of release applications for the conversion of the various Zwilag buildings/facilities. The individual analyses were conducted in accordance with the regulations valid at the time.

In the meantime, updated fire analyses are available for most of the radiologically relevant buildings at Zwilag, and these were evaluated as part of the requested modifications. From ENSI's point of view, these analyses show that the "Defence in Depth" principle is consistently pursued in fire protection at Zwilag and that the existing fire protection measures are suitable for ensuring adequate protection against fire events. A comprehensive spectrum of internal and externally caused fires was analysed. The fire analyses are checked to ensure that they are up to date as part of the ongoing supervision by ENSI and in the event of changes requested by Zwilag.

The fire analyses at Zwilag largely meet the requirements of the ENSI-A01 and ENSI-A08 guidelines, which also implicitly ensures compliance with WENRA SRL E6.1 and S-30. The dose limits in the respective accident categories are complied with by a margin.

Interim storage facility at Beznau NPP

ENSI's review of the recently updated fire safety analysis of the LAW storage facility showed that the requirements in accordance with the relevant national ordinances and guidelines are basically met. From ENSI's point of view, this analysis shows that the "Defence in Depth" principle is consistently pursued in fire protection at the ZWIBEZ and that the existing fire protection measures are suitable for ensuring adequate protection against fire events. A covering spectrum of internal fires and fires induced by external events was analysed.

ENSI is of the opinion that the methodology used by the operator to determine the activity released from the storage casks in the event of a fire, as described in the Konrad transport study, represents the state of the art. The scaling rules for the release fractions contained in extensions to the Konrad transport study allow the underlying conditions of the analyses to be adequately captured.

Due to the passive design features of the HAW storage facility, the absence of significant fire loads and ignition sources, and the transport and storage containers for spent fuel elements that are designed to withstand the effects of fire, it is comprehensible to ENSI that a fire of relevance to nuclear safety can be ruled out. In accordance with guideline ENSI-A01, a detailed fire analysis is therefore not required.

The fire safety analyses of the ZWIBEZ interim storage facility thus basically meet the requirements of the ENSI-A01 and ENSI-A08 guidelines, which also implicitly ensures compliance with WENRA SRL E6.1 and S-30. The dose limits in the respective accident categories are complied with by a margin.

Interim storage facility at Gösgen NPP

From ENSI's point of view, the KKG has also demonstrated with the simplified assessment that the "Defence in Depth" principle is consistently pursued in fire protection at the wet storage facility and that the existing fire protection measures are suitable for ensuring adequate protection against internal fire events.

Due to the design of the wet storage facility against safety earthquakes and aircraft crashes, sufficient protection against fires caused by external events is also ensured.

According to ENSI's assessment, the requirements of WENRA SRL E6.1 and S-30 are thus also fulfilled.

2.5 Waste storage facilities

Covered by Chapter 2.4 (see justification in ChapterChapter 1.1.4)

2.6 Facilities under decommissioning

Mühleberg Nuclear Power Plant (KKM)

2.6.1 Types and scope of the fire safety analyses

For decommissioning phase 1 (SP1), the probabilistic safety analyses developed for the non-power operation of the KKM, which also include fire analyses, were adapted to the SP1-specific boundary conditions. Since the plant has been fuel-free since the transition to decommissioning phase 2 (SP2), there is no longer any need for a probabilistic safety analysis.

In contrast to the analyses in SP1, the deterministic safety analyses in SP2 are limited to the evaluation of the precautionary measures on safety levels 1 and 2, since no more safety systems are required to meet the protection goals. Within the scope of the analyses, the systems and components were systematically identified that are still required to comply with the only remaining protection goal, "prevention of the release of radioactive substances", and thus also to be protected against the effects of fire. Based on this, specific analyses were carried out for fires inside the controlled zone and for fires outside the controlled zone.

2.6.2 Key assumptions and methodologies

The existing fire protection measures in the plant were assessed in the fire analysis in terms of whether

- the development of fires is effectively prevented,
- any fire cannot spread over a large area,
- rapid detection and suppression of fires are ensured,
- people can safely leave the affected building,
- accessibility for intervention forces is guaranteed at all times, and
- safety-relevant functions are not impaired.

Within the controlled zone, the analyses focused on the one hand on fires in the machine house where the material treatment facilities are installed. These are equipped with local filter systems that specifically extract and filter the air from the treatment stations before it is fed into the nacelle. The covering fire scenario was assumed to be the fire of a filter maximally occupied with radioactive particles. Secondly, the analyses assumed a resin fire in the filling station of the solidification plant, which is located in the treatment building.

No fire was assumed in the interim storage facility due to the low fire loads. The operating resins stored there are conditioned and are stored in closed metallic containers within the individual chambers. The temporarily stored containers do not show any significant heat development, so that self-ignition of the containers can be excluded. As a covering scenario for the radioactive waste stored centrally on the plant site, it is assumed that a fire occurs inside the container during the handling of a transport container prepared for shipment, which represents the largest possible accumulation of activity on the plant site.

The analyses have shown that a fire-related loss of the fuel pool cooling system can be practically ruled out, since the KKM has two independent cooling systems that are separated for fire protection purposes. In the event of a failure of the operational cooling system as a result of fire, which cannot be ruled out, and an assumed individual fault in the second-line safety cooling system, fuel pool cooling is ensured at all times.

In addition, earthquake-induced fires in the plant were investigated by the KKM. An earthquake-induced filter fire corresponds to the above-mentioned covering fire scenario in the turbine building (the discharge height is reduced due to the damage to the turbine building). Furthermore, it is assumed that at the onset of the earthquake a waste package in the nacelle is being transported from the 8 m level to the 0 m level and that the package falls as a result of the earthquake. However, due to the local conditions in the nacelle (spatial separation of the crash site and potential ignition sources), a fire can be excluded.

2.6.3 Fire phenomena analyses: overview of models, data and consequences

The fire occurrence frequencies were determined for each plant area based on the data used in the probabilistic fire analysis. Based on this, the fire scenarios were assigned to different incident categories, for each of which radiological limits are specified. A fire is defined as a combustion process associated with a light appearance (fire, flame, embers, glow, sparks) that has arisen unintentionally or has left its intended location to spread in an uncontrolled manner.

2.6.4 Main results / dominant events (licensee's experience)

The results of the radiological analyses for the sites described in ChapterChapter 2.6.2 show that the total dose for all population groups is significantly below the permissible radiological limit for the respective accident category.

The assumed fire in a transport container represents a hazard potential until the end of SP2. The other hazards described in ChapterChapter 2.6.2 are no longer relevant after the dismantling of activated structures has been completed and the water has been removed.

Due to the continuously changing plant configurations during decommissioning, the fire protection measures implemented in the original plant design, such as division of the plant areas into fire compartments, use of fire detection and extinguishing systems, can no longer be fully complied with everywhere. Wherever possible, the escape route distances and specifications for emergency exits are observed.

In the course of decommissioning, these original measures are increasingly compensated for by substitute measures, such as instructions, definition of responsibilities and restriction of the group of people. Regardless of this, all buildings are subject to the specifications of the VKF fire protection standard.

2.6.5 Periodic review and management of changes

The overarching KKM fire protection concept applies both to existing buildings (conversions, modifications and extensions) and to new buildings and facilities to be constructed. Existing buildings and facilities are to be protected in accordance with Art. 2 of the fire protection standard. /12/ and in consideration of the fire protection concept to the protection target requirements.

2.6.5.1 Overview of actions

The measures for fire and lightning protection are defined in the respective concepts. These concepts, which originated during power operation, were adapted several times during the cessation of power operation with regard to the changed modes of operation and general conditions. The fire protection concept is part of the overall documentation submitted to ENSI for official approval of the respective decommissioning phase. The lightning protection concept was also adapted and submitted to the supervisory authority for evaluation.

2.6.5.2 Implementation status of modifications/changes

The fire analyses for SP1 also cover the changed plant condition in SP2.

2.6.6 Licensee's experience of fire safety analyses

2.6.6.1 Overview of strengths and weaknesses identified

Several fire protection improvements resulted from the periodic safety review in 2010. These concerned the revision of the existing extinguishing water and escape route concept and the resulting adaptation of the fire protection concept and fire plans.

Based on findings from the fire analyses, additional measures were implemented in 2014 to improve the fire protection separation of the safety systems in the reactor building.

2.6.6.2 Lessons learned from events, reviews, fire safety related missions

In 2019, the fire alarm system was triggered because a smoke detector falsely detected a fire due to dust exposure and triggered an alarm. As a result, staff were instructed and the order management procedure was improved. There have been no fire incidents at the site since the cessation of service operations (end of 2019).

Since PSR2010, six incidents have occurred involving fire protection equipment. These were a cable fire, a short circuit in a block transformer and an oil fire, a pressure surge in the extinguishing water system and non-compliance with the fire resistance class for fire partitions. No additional measures were derived from these individual incidents.

2.6.7 Regulator`s assessment and conclusions on fire safety analyses

2.6.7.1 Overview of strengths and weaknesses identified

As part of the approval of decommissioning phase 1, the KKM developed the event spectrum for decommissioning, taking into account the findings from the dismantling experience in Germany, the German guidelines and the IAEA Safety Guide "Decommissioning". With regard to internal fires, four scenarios were considered (cf. Chap. 2.6.2), two of which are considered as radiologically covering. The deterministic fire analysis carried out by KKM largely corresponds to the specifications of guideline ENSI-A01.

With regard to a fire inside buildings in the controlled zone, ENSI can understand that the effects of a filter fire in a material handling facility station are comprehensive. The cooling of the fuel pool is not affected by this event, which means that the technical verification criteria are met. According to ENSI's assessment, the maximum dose value for accident category 1 (SFK1) can also be complied with.

The analysed scenario for a fire outside buildings in the controlled zone is assessed by ENSI as covering the event. The cooling of the fuel pool is not affected by this event. Thus, the technical verification criteria are met. According to ENSI's assessment, the permissible dose value of SFK1 is complied with.

In ENSI's view, the two further fire analyses show that even in the event of a fire-related failure of one of the two systems for removing residual heat from the fuel pool, there will always be a sufficient number of system functions available for heat removal so that no radiological effects are to be expected.

In the opinion of ENSI, the analysis carried out by KKM on earthquake-induced fires showed that other fire scenarios are either covered (earthquake-induced filter fire in the turbine building) or cannot be assumed in the event of a cask crash due to the spatial separation of the crash site and potential ignition sources.

With the fuel-free status, there is no need in decommissioning phase 2 to demonstrate compliance with the technical acceptance criteria regarding the protection goals "control of reactivity" and "cooling of nuclear materials". Thus, only compliance with the radiological acceptance criteria has to be demonstrated. Against this background, the analyses carried out by KKM on fires inside and outside buildings in the controlled zone with potential activity release are still considered by ENSI to be comprehensive and comply with the regulatory requirements.

2.6.7.2 Lessons learned from inspection and assessment as part of the regulatory oversight

In the course of the plant inspections carried out, no open points concerning the fire analyses have been identified so far.

2.6.7.3 Conclusions drawn on the licensee's fire safety analyses

The fire analyses for power operation were evaluated and accepted by ENSI for the periodic safety review in 2010 and with the decommissioning application. With the implementation of all the required measures, the regulatory requirements in force at the time were met.

The fire analyses for decommissioning phases SP1 and SP2 were accepted by ENSI and it was confirmed that the legal acceptance criteria would be met at all times in the event of an internal fire. Also on the basis of the fire analyses, KKM has taken comprehensive protective measures against internal fires. In ENSI's assessment, the requirements of WENRA SRL S-30 for the implementation of the concept of staggered fire protection measures have thus been met. In addition, the analyses carried out by KKM on earthquake-induced fires meet the requirements of WENRA SRL E 6.1.

3 Fire Protection Concept and Its Implementation

3.1 Fire prevention

3.1.1 Design considerations and prevention means

Beznau Nuclear Power Plant (KKB)

Limiting the use of combustible materials or giving preference to materials that are difficult to combust is an essential part of preventive structural fire protection. Fire prevention in this context is achieved through the following passive measures: avoidance or reduction of fire loads; avoidance of ignition sources. This applies, among other things, to walls, ceilings, piping and mechanical components, floor coverings, paint coatings, varnishes and insulation.

The choice of materials also considered the possible corrosive effect of fire gases and vapours. This is achieved in particular through the sparing use of halogen-containing materials (e.g. for cable insulation).

Precautions have been taken in various areas of the plant to prevent the ignition of uncontrolled leaking oil on the one hand and to discharge large quantities of oil on the other hand in order to reduce the fire load. Particularly noteworthy are, for example, the block transformers. Escaping oil can be discharged via underground pipes into a specially constructed oil collection pit. In the event of a fire, burning and dripping oil is prevented from spreading to this drainage and collection system by means of a special grating under each block transformer. Inside the containment, the spread of oil leaks from the reactor main pumps can be prevented by specially equipped oil collection facilities. The collected oil can be pumped via a pipe system into a closed oil collection tank inside the containment, which is monitored from the control room by means of level measurement.

The existing fire loads are systematically recorded and continuously reduced where possible.

In the case of plant modifications, fire protection is a mandatory, integral part of the plant modification process.

Gösgen Nuclear Power Plant (KKG)

When designing the KKG system, the principle was observed that in the event of an assumed fire in safety-relevant buildings, the possible impact on the safety systems remains limited so that their effectiveness is not inadmissibly impaired. Accordingly, spatial separation and structural protection of mutually redundant strings of safety systems prevent that an impairment of an overarching character can result from fire, so that the safety systems can fulfil their task under consideration of an individual fault and the maintenance case. In accordance with the requirements of IAEA SSR-2/1, it is thus ensured that only plant conditions (faults) can occur that are controlled by the safety systems.

Where possible, redundant safety system equipment is located in different fire compartments. Where this is not possible (e.g. equipment in the annulus and in the containment), the redundancies are separated by spatial distance.

Sufficient spatial separation of the safety facilities, also from external possible sources of fire, is in place. In particular, all safety-related structures are separated from each other by sufficient distances or by fire walls and are basically further divided into fire compartments.

In addition, the following precautionary measures take effect in the KKG in order to be able to either completely exclude fire events or at least limit them:

- Minimisation or encapsulation/confinement of fire loads or ignition sources:
  - As a matter of principle, cable massing must be accommodated in separate, appropriately equipped rooms/ducts.
  - Storing the diesel fuel for the emergency power diesel and emergency diesel in separate storage rooms and in appropriately secured containers or tanks.
  - Encapsulation of activated carbon and fabric filters.
  - Selective protection of circuits with reliable protective devices.
  - Encapsulation and bulkheading of switchgear, control equipment and electronic cabinets.
  - Oil-tight sheet metal sheathing of the insulation materials in the area of the main coolant pumps (HKMP), all-metal insulation of the HKMP housings.
- Lubricants, oils and diesel fuels used with high flash points so that the formation of explosive gas-air mixtures in the safety-critical structures can be ruled out.
- Administrative precautions (directive "Rules for order in the facility regarding earthquakes and fire protection" with regular inspection rounds) ensure that no additional fire loads are introduced into safety-relevant rooms.
- Cable ducts divided into fire compartments by fire-resistant cable bulkheads.
- Oil tanks are equipped with troughs that can absorb the maximum amount of oil released, so that in the event of an oil fire the spread is largely limited.
- In areas where there are proximities between redundancies in the reactor building (e.g. superimposed cable routes), independently responding sprinkler systems prevent unacceptable cross-redundancy failures from occurring.
- Limitation of fires that nevertheless occur through fire detection and firefighting measures.
- A range of fire-fighting equipment (some of which are automatic sprinkler systems and deluge systems) and personnel specially trained in firefighting.

Leibstadt Nuclear Power Plant (KKL)

The uses of the individual areas and the associated fire loads were already considered during the design of the facility. Fire zones and fire compartments were formed on this basis. It was also considered that the individual divisions and emergency busbars are structurally separate from each other.

The fire protection separation of the individual divisions prevents a cross-redundancy fire event.

Central interim storage facility Zwilag

The waste delivered to Zwilag must be conditioned or compressed and encapsulated in non-combustible containers.

No radioactive fire loads are kept or temporarily stored at Zwilag. All radioactive waste that does not contain any spontaneously combustible or explosive substances according to the acceptance conditions is encapsulated and conditioned or, if necessary (in the case of raw waste), compressed and is located in areas of Zwilag that have an immobile fire load of significantly less than 90 MJ/m² and are secured by special fire protection measures. According to ENSI guideline G23 Chapter 8 d., this waste can be neglected as a fire load.

Operating rules for carrying out hot work ensure that the probability of ignition of the stored flammable substances in the work areas is minimised.

Finally, a strict building cleaning concept ensures that the amount of combustible waste in the operating rooms is minimised, which means that the overall fire loads in the individual fire compartments are always reliably kept far below 90 MJ/m².

Building H is a storage facility for dry storage of spent fuel and high-level vitrified waste (HAW). The storage facility and the storage containers are designed for the entire range of possible ambient conditions. A release of radioactive substances due to fire events with cause in the facility can be excluded due to the very low immobile fire loads, the massive packaging of the radioactive waste and the non-combustibility of the radioactive waste itself.

Passive dissipation of the decay heat is achieved by natural convection of the air in the storage building. A storage location concept for the stored containers ensures that the containers are always sufficiently cooled at each storage position. This has been proven by fluidic simulation calculations. In addition, this ensures that no unacceptable temperatures occur on the transport and storage (T/L) containers and on the concrete components of the storage.

Spent fuel elements are only stored in the HAW storage facility in T/L casks with a type B(U) approval that meet the reference requirement of the Zwilag licence. This is ensured by compliance with the respective guideline, today ENSI guideline G05 ("Design and manufacture of transport and storage casks for interim storage"). Compliance with these requirements ensures that the T/L containers can even withstand a direct impact of a military aircraft without significant loss of leak tightness. Even a subsequent paraffin fire lasting a maximum of 30 minutes will not affect the safe containment of the high-level waste.

An inadmissible development of gases is excluded if the criteria for tightness and integrity of the reference requirements of the Zwilag permit are fulfilled. The T/L containers themselves are equipped with a double lid sealing system that ensures a technically tight seal.

Reliable compliance with subcriticality is ensured by fulfilling the reference requirements of the Zwilag permit. Compliance with subcriticality was also generically demonstrated for the HAW storage facility with covering boundary conditions.

The fire load in the storage areas or in the areas where raw waste is temporarily stored is reduced far below the value of 90 MJ/m². As a result, a possible fire source cannot damage the encapsulation of the waste drums.

In Zwilag's operating history to date, there has been no case of spontaneous combustion.

Interim storage facility at Beznau NPP

Passive dissipation of the decay heat in the HAW storage facility is achieved by natural convection of the air in the storage building. A storage location concept for the stored containers ensures that the containers are always sufficiently cooled at each storage position.

In addition, this ensures that no inadmissible temperatures occur on the T/L containers and on the concrete components of the storage facility.

Spent fuel elements may only be stored in the HAW storage facility in T/L casks with a type B(U) approval that meet the requirements of ENSI Guideline G05.

An impermissible evolution of gases is excluded if the criteria for tightness and integrity of ENSI guideline G05 are fulfilled. The T/L containers themselves are equipped with a double lid sealing system that ensures a technically tight seal.

The exhaust air of the LAW storage is monitored for the flammable gases hydrogen and methane. Automatic venting keeps their concentration below the ignition limit.

Limiting the use of combustible materials or giving preference to materials that are difficult to combust is an essential part of preventive structural fire protection in the ZWIBEZ. Fire prevention in this context is achieved by avoiding or reducing fire loads and avoiding ignition sources. This applies, among other things, to walls, ceilings, pipelines and mechanical components, floor coverings, paints, varnishes and insulation. For electrical installations, only halogen-free, flame-retardant cables are used.

The existing fire loads are systematically recorded and, if possible, continuously reduced. In the case of plant modifications at the ZWIBEZ, fire protection is a mandatory, integral part of the plant modification process.

Interim storage facility at Gösgen NPP

The same design features for fire protection apply to the wet storage facility as to the KKG. There are only very low fire loads in the wet storage building. Due to the very low fire loads and ignition sources and the division of the building into fire compartments, a fire as well as a major fire spread can be assessed as unlikely. In addition, a risk to heat dissipation from the storage pool due to the effects of fire can generally be practically ruled out, since the spent fuel elements are cooled passively and are stored under water.

Mühleberg Nuclear Power Plant (KKM)

Preventive fire protection measures are subdivided as follows according to the fire protection concept:

- Structural (constructive) fire protection measures
- Technical fire protection measures
- Organisational fire protection measures.

Preventive fire protection measures are based on a staggered defence principle. This includes the fulfilment of certain protection goals: such as the actual prevention of fire (prevention), the rapid detection and extinguishing of developing fires (detection/intervention), and the prevention of the spread of an already existing fire (fire compartments). The design considerations considered, as far as possible, all fire effects such as flames, heat, smoke and sparks as well as fires inside and outside the buildings.

Structural fire protection includes measures for the formation of fire compartments (including fire protection bulkheads, doors and insulation). Technical fire protection includes in particular fire alarm systems, fire control systems, extinguishing systems and the supply of extinguishing water. Organisational fire protection includes the organisation and definition of target-oriented measures. The training of personnel on how to behave in the event of a fire and on preventive fire protection is also part of organisational fire protection. The KKM fire brigade, which is led by the internal fire brigade commander, and the general emergency organisation of the site are available for deployment in the event of a fire.

3.1.2 Overview of arrangements for management and control of fire load and ignition sources

Beznau Nuclear Power Plant (KKB)

In KKB, a systematic fire risk assessment of buildings and rooms is carried out. For this purpose, mobile and immobile fire loads in the assessed space are systematically recorded and subjected to a risk assessment taking into account the ignition readiness and the type of ignition sources present. Based on the fire risk assessment, appropriate risk reduction measures are taken. The remaining residual risk is also assessed.

For assessed buildings and rooms, regular inventory rounds are carried out to identify any changes in fire risk or risk assessment. The periodicity of the inventory rounds depends on the risk classification of the rooms concerned. The systematic inspection with corresponding documentation is carried out via internal maintenance processes.

Electrically operated equipment and components are regularly tested for safe operation. This reduces the potential for a component to become a source of ignition due to a defect.

The use of flammable materials shall be kept to an absolute minimum in auxiliary equipment for maintenance work and mobile equipment. During hot work, defined protective measures must be taken in advance to prevent accidental ignition.

Gösgen Nuclear Power Plant (KKG)

Temporary fire loads

For safety-relevant plant areas, the principle applies that no additional fire loads may be introduced. A corresponding room list is part of a directive that is used to carry out recurring inspections. Suitable areas are marked in the individual buildings for the (temporary) storage of materials regarding fire protection requirements.

Regarding fire protection, temporary parking areas are only released if plant safety is not impaired.

Immobile fire loads

The immovable fire loads were determined for the nuclear-relevant buildings and entered in a fire load inventory. The inventory is reviewed periodically.

Periodic checks are carried out by the fire protection and fire brigade department and pending matters are recorded if deviations are found. If significant changes occur, the lists are updated.

The shift personnel carry out weekly and monthly inspection rounds according to their checklists. Fire safety-related checks are also carried out, any deviations are documented and reported to the specialist department for rectification.

The open handling of ignition sources in operating buildings may only be carried out after internal work approval. As a rule, ignition sources must be kept away from flammable materials.

Leibstadt Nuclear Power Plant (KKL)

At KKL, fire loads are recorded using a database. Unmarked storage facilities are recorded using the fault reporting process, the person responsible for the storage facility is identified, the effect of the fire load on the fire hazard is assessed and finally measures for further action (removal if necessary) are defined.

The fire loads are periodically checked and compared with the technical database for each room or building and checked for compliance with the maximum permissible values. In the course of this, the intended use of the respective areas is also checked. If deviations are found, they are remedied via the maintenance process.

Based on nuclear safety as well as legal requirements, the maximum fire loads for the rooms were defined and documented at 1000 MJ/m^2 depending on the use in KKL. The total fire load for the fire compartment is determined based on the total size of the fire compartment and the fire load within it.

The ignition sources permanently present in KKL are included in the various risk assessments. Temporary ignition sources such as hot work (maintenance, construction technology, etc.) are registered via an implemented process, evaluated according to the situation and marked.

Central interim storage facility Zwilag

As part of fire protection, a check of the fire loads is carried out as a permanent assignment. All room areas of the Zwilag are cleaned regularly and any combustible waste is encapsulated, compressed and disposed of properly.

The immobile fire load in the HAW storage facility is comparable to the immobile fire load of Building S, where a value of approx. 24 MJ/m^2 was determined in the storage area. The spent fuel elements stored in building H and the vitrified waste from reprocessing are safely enclosed in type B(U)-approved T/L containers and do not represent a fire load. The latter also applies to the containers with radioactive waste from the Lucens reactor, which are also stored in Building H. These containers have a 5 cm thick steel shell. These containers have a 5 cm thick steel shell and are permanently sealed. No combustible waste may be stored in Building H.

Sources of ignition can be electrically operated devices. These are regularly checked for safe operation. The storage crane is only operated for storage and retrieval operations. The rest of the time it is de-energised and therefore no longer represents a potential source of ignition.

Interim storage facility at Beznau NPP

The same precautionary measures apply to the ZWIBEZ as to the KKB for the avoidance of fire loads and ignition sources.

The licensed T/L containers in the HAW storage facility are designed against the effects of fires. A fire load in the LAW storage facility results from the storage of combustible raw waste, the permissible quantity of which is administratively limited. The waste placed in the LAW storage facility does not constitute a fire load due to the storage of cemented or hardly combustible, metal-coated waste.

Interim storage facility at Gösgen NPP

For wet storage, the same measures apply to the avoidance of fire loads and ignition sources as for the KKG.

A possible gas leak from a fuel element is detected by the inert gas monitors at the edge of the pool or in the exhaust air of the ventilation system. If a threshold value is exceeded, an alarm is issued in the control room of the KKG.

Mühleberg Nuclear Power Plant (KKM)

At the time of decommissioning phase 2 (SP2), decommissioning is already well advanced and the major ignition sources and fire loads have been removed. Due to the ongoing decommissioning of systems and dismantling, the ignition sources and fire loads are continuously reduced in SP2 and thus the hazard potential for fire development is further reduced.

The fire loads and fire stresses are recorded and evaluated for each building on the site in the "Fire loads and fire stresses" list. The periodic overall review of this list is usually carried out at least every five years or on the occasion of significant changes due to plant modifications, decommissioning or dismantling. The fire loads and ignition sources are periodically checked by means of fire protection and housekeeping tours. Deviations are recorded and corrected on site or by means of work orders.

Fire loads are minimised by the following measures:

- Continuous decommissioning and dismantling including disposal of systems.
- Special regulations and codes of practice exist for the storage of flammable and explosive substances and strict compliance with these is required.
- Flammable substances may only be present in the workplace in quantities necessary for the progress of work in a day shift (controlled handling).
- Waste and residues must be removed regularly and safely.
- Waste that tends to self-ignite, e.g. oily cleaning material, oily iron filings and oil and varnish residues, must be collected in the containers marked for this purpose and disposed of properly.

3.1.3 Licensee's experience of the implementation of the fire prevention

3.1.3.1 Overview of strengths and weaknesses identified

Beznau Nuclear Power Plant (KKB) / Interim storage facility at Beznau NPP

Preventive fire protection is taken into account appropriately during plant modifications and upgrades.

The strength of the systematic fire risk analysis of all rooms, taking into account the respective safety significance for the facility, lies in the fact that it leads to an overall view of the fire risks present in the facility. On the one hand, this overall view serves as a control and shows the potential of targeted fire load reductions. The automatic triggering of the periodic inspections enables an appropriate control of the rooms. The selected intervals between the site inspections have proven to be purposeful and appropriate. It is mandatory that the main users of the respective rooms are included in these site inspections.

The plant was built more than 50 years ago. Fire protection has developed massively over these 50 years. Due to the existing conceptual, structural and technical conditions, the challenges are to keep the fire protection requirements and their implementation state of the art.

Gösgen Nuclear Power Plant (KKG) / Interim storage facility at Gösgen NPP

The internal work release procedure for dealing with open ignition sources has proven itself, especially since the temporary deactivation of fire detectors is released by fire protection. The fire load list was supplemented with the room areas to enable a determination of the fire load level according to the VKF specifications.

In the past, isolated violations were found during hot work. Possible deviations are detected at an early stage through work inspections.

Leibstadt Nuclear Power Plant (KKL)

The following points were identified as strengths of preventive fire protection:

- Regular training of the operating staff in fire protection.
- Annual special training for the operating personnel who work with fire protection systems.
- Checklist for fire protection, which is implemented in the process flows at KKL.

There is scope for optimisation in the following points:

- There is a separate plan type for each fire protection system, which can only be "superimposed" online to obtain an overview of the fire protection-relevant information at a glance.
- Fire load management is kept in a separate database. This means that work has to be done in two different systems.

Central interim storage facility Zwilag

The more than 20-year operating history without a real fire event is the result of effective preventive fire protection at Zwilag. No specific strengths or weaknesses were identified.

Mühleberg Nuclear Power Plant (KKM)

At the KKM, fire protection is regulated and ensured in accordance with the fire protection concept and the handling of electrical equipment in accordance with the safety concept. Therefore, no additional measures were defined or implemented.

3.1.3.2 Lessons learned from events, reviews, fire safety related missions

Beznau Nuclear Power Plant (KKB) / Interim storage facility at Beznau NPP

Fire incidents and near misses are recorded and analysed. Based on the events of the first 10 years of operation, numerous operational regulations on fire-safe behaviour, e.g. during hot work, or in the handling of bearings, have been developed.

Lessons were also learned from the experience of other plants and, among other things, the equipment of the company fire brigade was adapted and some technical extinguishing equipment was retrofitted.

No fire incidents have occurred in the interim storage ZWIBEZ since commissioning.

Gösgen Nuclear Power Plant (KKG) / Interim storage facility at Gösgen NPP

Fire incidents and near misses are recorded and analysed. The number of incidents is low because, among other things, internal employees are trained on the occasion of the annual safety day and external employees participate in an annual safety instruction in the area of fire protection.

In summary, it can be stated that the technical and structural fire protection measures generally function well. Non-functioning is mostly due to the misconduct of persons. No patterns of misconduct can be identified.

Leibstadt Nuclear Power Plant (KKL)

KKL has established processes for analysing incidents or near-misses. If relevant, adjustments to work processes are examined in this process and initiated if necessary. Due to the regular training of employees to raise their awareness of fire protection issues, the number of fire incidents at KKL is very low and is usually limited to trivial incidents.

Central interim storage facility Zwilag

The preventive fire protection measures implemented at Zwilag proved to be expedient and give no indication of any required inspections.

Mühleberg Nuclear Power Plant (KKM)

In 2019, the fire alarm system was triggered because a smoke detector falsely detected a fire due to dust exposure and triggered an alarm. As a result, staff were instructed and the order management procedure was improved. There have been no fire incidents since the cessation of service operations at the end of 2019.

3.1.3.3 Overview of actions and implementation status

Beznau Nuclear Power Plant (KKB) / Interim storage facility at Beznau NPP

As a targeted measure to reduce fire loads, existing combustible cables are replaced by qualified cables. This measure is implemented on an ongoing basis when existing cables are replaced.

As part of a fire protection upgrade of the containment, the existing filters of the ventilation system were replaced by flame-retardant filters.

When planning or retrofitting oil-carrying components and electrotechnical equipment, attention was paid both to avoiding the sources of ignition and to reducing the fire loads. For example, the turbines' control oil system contains a fire protection valve that reduces the amount of oil flowing out after a line rupture.

The measures implemented at the ZWIBEZ for preventive fire protection prove to be expedient and give no indication of any necessary inspections.

Gösgen Nuclear Power Plant (KKG) / Interim storage facility at Gösgen NPP

There are no open measures.

Leibstadt Nuclear Power Plant (KKL)

In order to be able to evaluate the possible optimisations in fire protection in a structured way and implement them, if necessary, there is a catalogue of measures that is updated. This is kept up to date via the fire protection project and the measures listed there are evaluated by the specialist departments.

The potential for improvement listed in ChapterChapter 3.1.3.1 will be implemented by drawing up fire protection plans in accordance with the currently valid regulations and by better integrating fire load management into the existing processes of KKL and implementing the database in existing IT solutions.

Central interim storage facility Zwilag

There are no plans to update the measures.

Mühleberg Nuclear Power Plant (KKM)

All corresponding changes in preventive fire protection were planned, approved and implemented in coordination with the fire protection authority. The status of the changes can be seen in previous monthly reports of the site.

3.1.4 Regulator's assessment of the fire prevention

3.1.4.1 Overview of strengths and weaknesses identified

Beznau Nuclear Power Plant (KKB)

The plant was designed and built more than 50 years ago. From ENSI's point of view, the great challenge is to follow and implement the current state of the art and science in fire protection. When the plant was built, care was taken to ensure that non-combustible or hardly combustible materials were used in the majority of cases. This principle continues to be followed today.

In 2020, the fire protection concept of the KKB was revised, which has been repeatedly adapted and supplemented in the past years. The fire protection measures required in accordance with the current VKF regulations /12/ that are part of a fire protection concept are missing. Up to now, fire protection has been mapped in various individual plan bases. From ENSI's point of view, a revision and division into an overarching fire protection concept and individual building concepts as well as the creation of comprehensive fire protection plans are therefore necessary (National area for improvement)

A fire load management system is in place at KKB to monitor the mobile and immobile fire loads present in the facility. Through the regular fire protection tours, compliance with the maximum permissible fire loads per fire compartment is regularly checked. Although the existing mobile and immobile fire loads are systematically recorded and evaluated in a fire load register, ENSI is of the opinion that there is no reference to the existing fire resistances of the respective fire compartments. In addition, ENSI found that some of the reported fire loads do not correspond to the fire loads encountered on site (National area for improvement).

The existing ignition sources are systematically recorded and evaluated. From ENSI's point of view, there is an established internal process for necessary hot work at the nuclear power plant, which ensures that no hot work is carried out without the necessary substitute measures being taken. Flammable operating materials are reduced to a minimum and appropriate measures are taken where flammable operating materials could leak.

All hazardous materials brought into the facility are assessed independently of fire protection. Flammable liquids are stored in buildings that are not critical for the operation of the facility. Care is taken to use flammable liquids (oils) with a high flash point.

Over the years of operation, the needs of the employees and the operator have changed, among other things, which has led to the installation of equipment in some areas of the KKB that ENSI considers to be a potential fire hazard. For example, there are additional fire loads in escape and rescue routes (automatic machines, charging stations for electrical equipment, battery-powered lifting equipment and cleaning equipment) that also pose a risk of ignition. ENSI will continue to monitor this development in the supervisory process (National area for improvement).

Gösgen Nuclear Power Plant (KKG)

During construction of the plant, care was taken to ensure that only non-combustible or hardly combustible materials were used. From ENSI's point of view, this principle will continue to be followed consistently. The fire protection concept and the associated fire protection plans were updated and revised in accordance with the current VKF requirements in 2022.

There is a fire load register in which the existing immobile fire loads are listed. For the mobile fire loads, the principle exists that no additional mobile fire loads may be introduced in safety-relevant areas of the facility. There is an internal directive for the recurring inspections/round rounds. In accordance with the national regulations, the room areas were also included in the fire loads. In ENSI's view, this provides a better overview of the existing fire loads in relation to the fire compartment area.

The handling of ignition sources (hot work) is regulated by means of a work permit.

All hazardous materials brought into the facility are assessed independently of fire protection. Flammable liquids are stored in buildings that are not critical for the operation of the facility. Care is taken to use flammable liquids (oils) with a high flash point .

Leibstadt Nuclear Power Plant (KKL)

During construction of the plant, care was taken to ensure that only non-combustible or hardly combustible materials were used. From ENSI's point of view, this principle will continue to be followed consistently. The fire protection concept and the associated fire protection plans are currently being revised in accordance with the current VKF specifications.

In the KKL, all fire loads are recorded in a database. Regular inspections ensure that there are no deviations from the maximum possible fire load. If unmarked fire loads are found during one of the tours, an internal fault reporting process is in place to determine the necessary measures.

The operating staff is trained regularly, and the system administrators also receive special training once a year. The KKL has recently started using a "fire protection" checklist, which has been implemented in the KKL process flow. Thus, from ENSI's point of view, the necessary attention is already paid to fire protection during the project phase.

All hazardous materials brought into the facility are assessed independently of fire protection. Flammable liquids are stored in buildings that are not critical for the operation of the facility. Care is taken to use flammable liquids (oils) with a high flash point.

At present, KKL still has different types of plans for fire protection, which do not allow a rapid and targeted assessment of the current status, and fire protection is still mapped in two different databases. From ENSI's point of view, KKL has taken targeted measures to improve this situation.

Central interim storage facility Zwilag

During the construction of the interim storage facility, care was taken to ensure that only non-combustible or hardly combustible materials were used. The storage facility for high-level waste (Building H) contains only conforming radioactive waste. The possible environmental conditions were taken into account when selecting the storage containers. The storage containers comply with guideline ENSI-G05. The decay heat is dissipated by natural convection.

By means of a flow simulation, it was demonstrated that sufficient passive cooling of the casks is ensured by the parking space concept in Building H. The casks are therefore not expected to reach inadmissible building or cask temperatures. From ENSI's point of view, unacceptable building or container temperatures are therefore not to be expected. The T/L containers are designed to withstand an impact of a military aircraft and a subsequent 30-minute paraffin fire. In the HAW storage facility, only storage containers that have a double-lid closure are brought in, so from ENSI's point of view no inadmissible gas leakage is to be expected. In addition, no flammable waste may be stored there.

From ENSI's point of view, there are clear acceptance conditions for the delivery of waste. The waste must be delivered conditioned or compressed in non-combustible containers.

The existing fire protection concept is from 2002 and refers to documents that have not been valid for a long time. There are no fire protection plans and no fire load register in accordance with the current VKF regulations. A target-performance comparison and thus the monitoring of the state of the art in science and technology has not taken place for a long time. ENSI therefore believes that a corresponding review of the fire protection concept is necessary (National area for improvement) .

Interim storage facility at Beznau NPP

During the construction of the ZWIBEZ interim storage facility, care was taken to ensure that only non-combustible or hardly combustible materials were used. The high-level waste is delivered in transport or storage containers that comply with guideline ENSI-G05. Consequently, the contents of the storage containers are not considered a fire load. Only packaged spent fuel elements are located in the HAW storage facility.

The ventilation in the HAW storage facility and the LAW storage facility ensures that no unacceptable ambient conditions (humidity, temperature) can arise. The decay heat generated in the HAW storage facility is dissipated by means of passive cooling (natural convection). In storage areas where flammable gases could form, the exhaust air is monitored accordingly. The ventilation system in the LAW storage facility ensures that no flammable gas/air mixtures can form.

There is a fire load register in which the existing immobile fire loads are listed. From ENSI's point of view, the regular inspections ensure that no inadmissible mobile fire loads are introduced into the building.

The basis of the fire protection concept of the KKB is now 23 years old. In 2006, the HAW and LAW storage buildings of the ZWIBEZ were included in the existing fire protection concept of the KKB. Although the basis has undergone nine revisions over the last few years, ENSI believes that a fundamental revision and division of the fire protection concept in accordance with the current VKF regulations /12/ into an overarching fire protection concept and detailed building-specific fire protection concepts is necessary, as well as the preparation of comprehensive fire protection plans (National area for improvement).

Interim storage facility at Gösgen NPP

During construction of the wet storage facility, care was taken to ensure that only non-combustible or hardly combustible materials were used. From ENSI's point of view, this principle will continue to be followed consistently. The fire protection concept and the associated fire protection plans were updated and revised in 2022.

There are only minor fire loads in the wet storage facility and the risk of activation, , from all types of ignition sources , is also considered low by ENSI. The handling of ignition sources is regulated by means of a work permit.

The spent fuel elements are handled exclusively under water. In order to monitor possible gas leaks from the fuel assemblies, inert gas monitors are used at the edge of the pool and in the exhaust air from the ventilation systems. If a threshold value is exceeded, an alarm is issued in the control room.

There is a fire load register in which the existing immobile fire loads are listed. For the mobile fire loads, the principle exists that no additional mobile fire loads may be introduced in safety-relevant areas of the facility. There is an internal directive for the recurring inspections/round rounds. In accordance with the VKF regulations, the room areas were also included in the fire loads, which in ENSI's view provides a better overview of the existing fire loads in relation to the fire compartment area.

Mühleberg Nuclear Power Plant (KKM)

The KKM is currently in the SP2 dismantling phase. From ENSI's point of view, the existing fire protection concept and the fire protection plans will be continuously adapted to the changing plant configuration.

3.1.4.2 Lessons learned from inspection and assessment as part of the regulatory oversight

Beznau Nuclear Power Plant (KKB)

The last fire protection inspection by ENSI clearly showed that deficiencies had arisen in the formation of fire compartments in non-safety-relevant areas in connection with the increased heat loads over the years, which have to be dissipated through ventilation.

The old age of the original components has led to higher oil consumption in some cases. To ensure smooth operation, more fire loads (hydraulic oil) are therefore brought into the fire compartments. ENSI found that these fire loads were not included in the fire load register.

ENSI has called for the implementation of the deficiencies identified and a systematic review of the other plant areas and is pursuing their implementation as part of the supervisory process.

Gösgen Nuclear Power Plant (KKG)

The last fire protection inspection by ENSI showed that the fire compartments were correctly maintained even during revision work. Neither open blocked fire doors nor otherwise compromised fire compartments were found. Only small amounts of mobile fire loads were encountered.

In some cases, cables are still present in the system that contribute too much to the fire in the event of a fire and develop corrosive gases. During replacement, these will be exchanged for cables that comply with current SN-EN standards (including halogen-free, flame-retardant, self-extinguishing behaviour). The KKG has submitted an initial application to ENSI for the replacement of cables.

Leibstadt Nuclear Power Plant (KKL)

ENSI's most recent fire protection inspections have shown that deficiencies have arisen in the formation of fire compartments in non-safety-relevant areas in connection with the increased heat loads over the years, which must be dissipated through ventilation.

In addition, fire doors were partially locked open during the annual inspection and in some cases considerable fire loads were temporarily stored in the connecting corridors.

ENSI has called for the implementation of the deficiencies identified and a review of the corresponding monitoring processes and is monitoring their implementation as part of the supervisory process.

Central interim storage facility Zwilag

During the last walkdowns, it was noticed that the fire compartmentation was impaired, especially during renovation work. For example, fire doors to the vertical escape routes were open or mobile ventilation units were set up in the vertical escape routes. ENSI arranged for these deficiencies to be rectified immediately.

No fire protection inspections have taken place at the Zwilag interim storage facility for quite some time. ENSI will intensify its inspection activities here (National area for improvement).

Interim storage facility at Beznau NPP

No fire safety inspections have taken place at the ZWIBEZ interim storage facility for quite some time. ENSI will intensify its inspection activities here (National area for improvement).

Interim storage facility at Gösgen NPP

No fire safety inspections have taken place in the wet storage facility for some time. ENSI will intensify its inspection activities here (National area for improvement).

Mühleberg Nuclear Power Plant (KKM)

The last fire safety inspections have shown that increased attention is needed with regard to the introduction of highly flammable liquids and their storage.

3.2 Active fire protection

3.2.1 Fire detection and alarm provisions

3.2.1.1 Design approach

Beznau Nuclear Power Plant (KKB)

Fire alarm system

In the Beznau nuclear power plant, all rooms with a significant fire load are monitored by fire detectors. In the controlled zone, every room is monitored by fire detectors, regardless of the existing fire load. The concept corresponds to full monitoring in accordance with national fire protection regulations.

The entire facility is equipped with manual alarm buttons along the escape and rescue routes, which allow manual triggering of a fire alarm by the operating personnel in the event of a fire.

All detectors together with the higher-level fire alarm control system form a fire alarm system for automatic monitoring of the entire facility. The emergency buildings of both blocks, which were retrofitted later, have self-sufficient fire alarm systems that have an interface to the fire alarm system of the rest of the facility. This interface allows the exchange of information and control commands between the individual fire alarm systems. All existing fire detectors and fire alarm control panels are recorded in the fire alarm control systems. Exceptions are the fire detectors that are subordinate to a halon extinguishing control centre.

The fire alarm control systems serve to forward alarm, fault and status signals to the main command room, as well as to trigger assigned automatic fire controls. Each main command room has a special screen display that allows the localisation of the triggered alarm element, as well as a redundancy display that shows alarms, fault and status signals synoptically for each fire alarm control panel. Fire alarms are indicated visually on the screen display and acoustically via an alarm horn in the main command room. The statuses of activated fire dampers and fans are displayed in the fire alarm control system. The messages of the stand-alone fire alarm systems in the emergency building are also displayed in the main command room and additionally on a fire alarm panel in the emergency control room.

The door positions of the extinguishing stations are also partially monitored by the fire alarm system. When opened, corresponding alarm signals are forwarded to the main command room and, in the emergency building, also to the emergency control room.

Alarm system/evacuation systems

Several information and alarm systems (e.g. fixed telephone lines, cordless transmission, radio, etc.) are available at the Beznau nuclear power plant for alerting operating personnel and, if necessary, external relief organisations in the event of a fire.

Gösgen Nuclear Power Plant (KKG) / Interim storage facility at Gösgen NPP

Fire alarm system

All buildings are fully monitored with a fire alarm system in accordance with the VKF fire protection guidelines. Individual rooms are not included in the monitoring scope of the fire alarm system. These are usually rooms that do not need to be monitored according to the VKF fire protection guidelines or have a high radiation exposure.

Alarm system/evacuation systems

An electro-acoustic emergency warning system is in use in the KKG. This system is operated by the permanently manned office in case of fire. If a fire occurs, all persons in the building concerned are alerted by an acoustic signal or by the electro-acoustic emergency warning system. Additional control points are installed in various entrance areas, which enable the emergency services to make a manual loudspeaker announcement.

The wet storage facility is integrated into the monitoring and alarm system of the KKG.

Leibstadt Nuclear Power Plant (KKL)

Fire alarm system

In principle, the principle of full monitoring via the fire alarm system (FAS) applies in the KKL. The fire alarm system in the KKL is equipped in accordance with the VKF fire protection guidelines. Individual areas are excluded from full monitoring due to internal circumstances (e.g. radiation).

Alarm system/evacuation systems

All buildings in the KKL are equipped with an electroacoustic emergency warning system (ENS). An ENS is used that complies with the quality requirements of the Association of Swiss Installers of Security Systems (SES).

Central interim storage facility Zwilag

Fire alarm system

The VKF-compliant fire alarm system consists of five fire alarm centres in buildings K, M, N, V and S, which report all conditions to the gate in building K, which is manned 24 hours a day and serves as an alarm receiving point. Without exception, all rooms except the storage hall in building H are monitored for heat and smoke development. Building H only has fire detection in the parking area of the crane system. Hand-held buttons are located in the area of the escape routes near the interior fire extinguishing stations.

Alarm system/evacuation systems

In the event of a fire alarm, the staff in the affected building are warned by means of sirens.

Interim storage facility at Beznau NPP

Fire alarm system

The interim storage facility ZWIBEZ is monitored by a large number of automatic fire detectors and is also equipped with manual alarm buttons that allow the operating personnel to trigger a fire alarm manually in the event of a fire. All detectors together with the fire alarm control panel and the higher-level fire alarm control system form a fire alarm system for automatic monitoring of the ZWIBEZ. A control panel is located on site in the access area of the LAW part of the building, on which a fire alarm is displayed. The door positions of the extinguishing stations are also partially monitored by the fire alarm system.

Alarm system/evacuation systems

In the event of a fire alarm, persons present in the ZWIBEZ are acoustically alerted to the alarm by means of alarm horns.

Mühleberg Nuclear Power Plant (KKM)

Fire alarm system

At the KKM site, all buildings are fully monitored by a fire alarm system. This fire alarm system is divided into a total of nine autonomous and battery-supported fire alarm centres. The type and arrangement of the fire detectors depends on the use, the ambient conditions and the room geometry and monitoring area.

In addition, manual call points are usually installed at all emergency exits and main entrances to buildings. In case of fire, various fire protection devices are automatically activated by the fire alarm control panel (FACP).

All fire alarm panels detect a fire independently and immediately forward it to the permanently staffed office at the site. In addition to the local control panels of the individual fire alarm control panels, a higher-level fire alarm control system is available at the permanently manned location. This system makes it easier for the user to safely operate the fire detection panels in daily use. It is used for the visualisation of alarms, faults, shutdowns as well as for the operation of the fire detection control panels. The fire alarm control system is not necessary for the function of the FACP, since all safety-relevant functions (detection, alarming, fire control, etc.) are carried out or triggered autonomously from the FACP.

As a fallback level to the fire alarm control system, a wired collective message of the respective fire alarm control panel is also available in the main command room. In addition, every fire alarm or malfunction of a fire alarm system is signalled visually and acoustically as a collective message in the control centre.

Alarm system/evacuation systems

Persons at risk are alerted acoustically and / or visually and, if necessary, asked to leave the building with the help of the public address system.

3.2.1.2 Types, main characteristics and performance expectations

Beznau Nuclear Power Plant (KKB) / Interim storage facility at Beznau NPP

Fire alarm system

The fire detectors detect e.g. fire outbreaks, smouldering fires with smoke development, invisible fire gases in the rooms. Different types of detectors are used, the selection is made according to the conditions of the monitored area. Ionisation smoke detectors, scattered light smoke detectors and infrared flame detectors are used.

Smoke detectors are also installed in the ducts in front of some filters of the ventilation systems. Important control technology cabinets are directly monitored by detectors or they are connected to a smoke aspiration system. The smoke aspiration system permanently takes some air from several cabinets and leads it to a common fire detector.

In the containment, five video cameras are used to assess the situation in the event of a fire alarm. Two cameras are directed at each of the two main reactor pumps; another camera is adjustable and is used for video surveillance of the operating floor.

All fire alarm systems have two independent power supplies, a primary AC power supply and a battery-backed emergency power supply.

Gösgen Nuclear Power Plant (KKG) / Interim storage facility at Gösgen NPP

The wet storage facility is integrated into the monitoring and alarm system of the KKG.

Fire alarm system

A total of 9 fire alarm centres are installed in the KKG, in two different networks. The above-mentioned fire alarm centres monitor the entire premises of the KKG. The rooms are primarily monitored via point detectors (multi-criteria detectors).

Areas or rooms requiring special protection are additionally monitored with more sensitive detection devices such as aspirating smoke systems. Other monitoring devices such as linear smoke detectors and manual call points (for manual alarming) guarantee safe and reliable operation of the fire alarm system.

The fire alarms detected by the detection devices connected to the fire alarm system (e.g. point detectors) are automatically forwarded to the internal and external fire brigade via the telephone system. In addition, the necessary fire controls are activated in the event of a fire alarm, thus delaying or preventing the spread of the fire.

All fire alarm control panels have an independent, double mains supply. Furthermore, additional batteries for emergency power supply are installed in all fire panels. This ensures the highest possible availability of the fire alarm control panels.

Alarm system/evacuation systems

All buildings in the KKG are equipped with a public address system. In the event of an incident, e.g. fire in the building, the persons in the building are alerted or informed that they must leave the building. The public address system is not automatically activated by the fire alarm system. An automatic alarm in case of fire is triggered by the alarm horns connected to the fire alarm system.

The loudspeaker system has several components (e.g. amplifiers), some of which are redundant. The individual components have redundant 220 V DC feeds. In order to ensure the greatest possible availability of the system, it is additionally supplied with battery-buffered (48 V DC) power.

Furthermore, there is the possibility for the intervention forces to make on-site announcements in various buildings.

Leibstadt Nuclear Power Plant (KKL)

Fire alarm system

The fire alarm system is divided into several area fire alarm control panels. The detectors suitable for the respective location are used. In the KKL, 4 different detector types were defined as standard due to the different conditions on site. As a rule, multi-criteria detectors are used to ensure early fire detection. Furthermore, smoke extraction systems are used in some areas for optimal monitoring of the areas.

All FACP and FAS detector groups can be displayed and operated on the monitor of the control system. As a fallback level in the event of a control system failure, an emergency synoptic is available in the main command room for alerting. The power supply is ensured without interruption and *is* battery-buffered.

Alarm system/evacuation systems

The alarm system is installed in all KKL buildings. All loudspeaker lines of the system are monitored. This means that faults or failures can be detected immediately. In order to guarantee constant alerting, the redundant Digital Enhanced Cordless Telecommunications (DECT) system (Short Message Service (SMS) alerting via the telephone system) is used in the event of a malfunction and for larger work where large areas are not available for acoustic alerting. This can also be used to send alarms and notifications.

Central interim storage facility Zwilag

No fire detection and alarm systems are required for Building H.

Mühleberg Nuclear Power Plant (KKM)

In safety-relevant buildings, the existing assigned fire alarm control panel is classified accordingly. The connected peripherals such as manual and smoke detectors or room indicators etc. are electrically and seismically unclassified. The remaining conventional industrial, commercial, office and ancillary buildings and facilities are also fully monitored with unclassified fire alarm control centres.

To monitoring larger rooms, linear or flame detectors are used in addition to multi-criteria detectors. Systems with aspirating smoke detectors are used in particular for special room geometries or installations requiring special protection.

The fire controls are defined according to protection targets and are selectively or collectively controlled by the fire alarm control panel. The fire control system is designed in such a way that the technical fire protection devices controlled by it are set to the "fire" operating state in the event of a fire or fault (fail-safe behaviour) .

3.2.1.3 Alternative/temporary provisions

Beznau Nuclear Power Plant (KKB) / Interim storage facility at Beznau NPP

Individual fire detectors or fire detector groups are only taken out of service for maintenance purposes. Maintenance work is carried out during normal attendance times and is planned in such a way that the system can be put back into operation by the end of the working day. If this is not possible in individual cases, further organisational measures will be taken to compensate for this outside the attendance times.

During hot work, the fire detectors remain in operation. It is administratively regulated that hot work must be reported to the command room before it is carried out. In the event of a fire alarm in the area of hot work, a telephone connection is immediately established between the person carrying out the work and the main command room so that the correctness of an alarm can be verified as quickly as possible. Additional extinguishing agents are provided on site.

Gösgen Nuclear Power Plant (KKG) / Interim storage facility at Gösgen NPP

The wet storage facility is integrated into the monitoring and alarm system of the KKG.

Fire alarm system

Deactivations of fire alarm systems or detection equipment are kept to a minimum. If the shutdown lasts more than 24 hours, it is reported to the necessary authorities using the official VKF form and the necessary replacement measures are taken. Shorter shutdowns, e.g. due to welding work, are handled via the maintenance process. In this way, shorter shutdowns are also recorded.

Deactivations of the fire alarm systems or the detection equipment are indicated on the fire alarm system or the security control system. Among other things, these systems are available in the main command room. This ensures the greatest possible availability and clear status control of the fire alarm system.

Alarm system/evacuation systems

Decommissioning of entire loudspeaker lines is only carried out in exceptional cases. In the case of conversions or extensions, only the corresponding area is not equipped with loudspeakers. The large number of loudspeakers ensures audibility in the areas that are not "monitored".

Malfunctions in the public address system are repaired by trained KKG staff themselves. This ensures that faults can be rectified quickly. This contributes to the greatest possible availability of the system.

Disconnections or malfunctions are indicated on the public address system. Among others, these systems are available in the main command room.

Leibstadt Nuclear Power Plant (KKL)

Fire alarm system

The fire alarm control panels in the individual plant areas have a battery supply in addition to the normal power supply. This ensures a constant power supply to the fire alarm control panels.

Alarm system

An electro-acoustic emergency warning system (ENS) according to the SES state of the art is used in the KKL. The system has 2 feeds that can be switched manually. If the system fails, all staff can still be alerted via the DECT system (Short Message Service (SMS) alerting) via the telephone system.

Central interim storage facility Zwilag

No fire detection and alarm systems are required for Building H.

Mühleberg Nuclear Power Plant (KKM)

If necessary, short-term deactivation (less than 24 hours) of individual smoke detectors is permitted at the site, in particular to avoid false alarms, and is carried out and documented by the permanently staffed office in the KKM (currently in the main command room). For this purpose, an order is always required, which is created via the order procedure and evaluated by the respective departments. Any necessary substitute measures are specified by the departments on the corresponding protection certificates (e.g. fire protection certificate).

According to the fire protection concept in SP2 and based on the VKF regulations, full monitoring can be deviated from while decommissioning buildings, rooms and areas that are exempt and separated in terms of fire protection. These are usually rooms in which a fire does not occur at all due to a lack of ignition sources or fire loads and therefore full monitoring can be reduced in consultation with the fire protection authority. In addition, depending on the building retreat (room and building closure) and taking into account the use and hazard, a complete removal of the fire alarm system can take place in consultation with the fire protection authority. These rooms that are no longer monitored will be marked accordingly on the fire protection plans and on site during SP2. Likewise, due to the decommissioning process and the resulting reductions in hazards, fire loads and ignition sources as well as the omitted safety significance, specific fire controls can be adapted or reduced or completely omitted.

3.2.2 Fire suppression provisions

3.2.2.1 Design approach

Beznau Nuclear Power Plant (KKB)

A wide range of fire-fighting equipment is available at the Beznau nuclear power plant. These can be used fully automatically, remotely (controlled) or manually on site. Only stationary extinguishing systems are used for automatic firefighting.

These stationary extinguishing systems are specifically used for areas and components with an increased fire hazard, with special safety significance or with increased time required to initiate manual fire fighting. The type of extinguishing system and the scope of protection are matched to the existing fire hazard and the effects of possible water damage. Depending on the system, the scope of protection is limited to individual rooms, areas or facilities within rooms and buildings or outdoors.

Inside the buildings, there are fire extinguishing posts (indoor hydrants) which are used for manual fire fighting. Each extinguishing post is equipped with a connection for mobile extinguishing water pipes, as well as with a coiled extinguishing pipe with a turning pipe. In addition, hand-held fire extinguishers are available at each extinguishing post and at other locations along the intervention routes. The number and type of portable fire extinguishers depends on the existing fire risk.

There are a number of outdoor hydrants on the grounds of the facility, which are connected to the facility's extinguishing water supply. The facility's extinguishing water supply provides the quantities of extinguishing water required in case of need for each individual consumer (hydrants, extinguishing posts, deluge systems, sprinkler systems, etc.). The extinguishing water is fed through a ring main and the connected distribution network into the individual buildings and to the corresponding consumers. The extinguishing water can be drawn from several diverse sources, e.g. from a high reservoir system or from an Axpo groundwater pumping station. Furthermore, the extinguishing water supply can also be fed from the networks of neighbouring communities, e.g. another reservoir and another groundwater pumping station from the surrounding communities are available. In the event of failure of the aforementioned supply sources or if required, extinguishing water can alternatively be drawn from the headwater canal or the Aare River by means of fire brigade pumps. For this purpose, a distribution network is available consisting of partly permanently installed pipes and partly pipes that still have to be installed if necessary.

The supply sources and the distribution network for extinguishing water are dimensioned in such a way that a supply of extinguishing water in accordance with the design can be guaranteed for all extinguishing systems and the other extinguishing agents.

The emergency buildings also have their own emergency supply by means of a dry line, which ensures the supply of extinguishing systems and risers by mobile equipment from the outside if required.

Gösgen Nuclear Power Plant (KKG) / Interim storage facility at Gösgen NPP

The extinguishing water supply consists of a main reservoir with two chambers and an additional reserve from the water supply of the surrounding communities. Transport pipes lead from the extinguishing water supply to the double-ring-shaped distribution network on the power plant site. The distribution network feeds the hydrants in the open, the water extinguishing stations in the buildings and the deluge and sprinkler systems.

The water reserve in the main reservoir is divided into an operational water reservoir and a fire-fighting water reserve. The latter can only be used when remotely operated flaps are opened.

Leibstadt Nuclear Power Plant (KKL)

In order to be able to react to possible events at KKL, the following systems and processes have been implemented:

- Extinguishing systems
- Extinguishing water supply
- Fire extinguisher
- Trainings

The type of extinguishing media and their arrangement (number of fire extinguishers/installation of wall extinguishing posts, etc.) are defined on the basis of the use on site and the resulting hazards. The hazards posed by the extinguishing system itself (e.g. false activation) were also taken into account. In addition, all KKL employees are periodically trained in the use of the extinguishing agents (e.g. fire extinguishers) on site.

The periodic inspections and tests of fire protection equipment (e.g. fire alarm systems, extinguishing systems, fire extinguishers) at KKL are carried out in accordance with the manufacturer's specifications. The test results are documented at.

Central interim storage facility Zwilag

In accordance with the assessment of the respective fire hazard, suitable fire extinguishing equipment is installed in all rooms of Zwilag. This is described in detail below.

Rooms where radioactive raw waste may be handled, and the high-bay storages are equipped with deluge spray systems or sprinkler systems. All other rooms are equipped with small extinguishers.

The following systems and equipment are available for fire fighting:

- Sprinkler and deluge systems are installed in the K, V and M buildings. The sprinkler systems are activated autonomously by the application of heat to the spray heads. The deluge systems are activated manually by means of manual buttons. The pressure and volume flow required for proper functioning of the systems is ensured at all times.
- Indoor fire extinguishing posts are installed in the main stairwells. The 30 m long hose is connected via a separate valve and a 55 mm Storz coupling. The indoor fire extinguishing posts are marked with a photoluminescent pictogram.
- Small extinguishers are installed at easily visible locations near the exits and in the area of the escape routes. In addition, locations that are difficult to see are marked with the luminescent pictogram "F". The number and type of hand-held fire extinguishers depends on the hazardous materials present.

There is no fire load in the HAW storage, so defensive fire protection can be reduced to a minimum.

Small fire extinguishers are available for fire fighting. Small extinguishers are installed at easily visible locations near the exits and in the area of the escape routes. In addition, locations that are difficult to see are marked with the luminescent pictogram "F". The number and type of hand-held fire extinguishers depends on the hazardous materials present.

The technical systems, such as safety lighting and small extinguishers, are periodically checked by internal and external inspection bodies. All activities such as inspections and audits are recorded in writing.

Interim storage facility at Beznau NPP

Fire-fighting equipment is available at the ZWIBEZ, which is used manually on site.

Within the secondary area there are two extinguishing posts (indoor hydrants), which are used for manual fire fighting. Each extinguishing post is equipped with a connection for mobile extinguishing water lines, as well as with a coiled extinguishing line with a turning pipe. In addition, hand-held fire extinguishers are available at each extinguishing post and at other locations along the intervention routes. The number and type of portable fire extinguishers depends on the existing fire risk.

There are a number of outdoor hydrants on the grounds of the facility, which are connected to the facility's fire water supply.

The facility's extinguishing water supply provides the quantities of extinguishing water required in case of need for each individual consumer (hydrants, extinguishing posts, etc.). The extinguishing water is fed through a ring main and the connected distribution network into the individual buildings and to the corresponding consumers. The extinguishing water can be drawn from several diverse sources, e.g. from a high reservoir system or from an Axpo groundwater pumping station. Furthermore, the extinguishing water supply can also be fed from the networks of neighbouring communities, e.g. another reservoir and another groundwater pumping station from the surrounding communities are available. In the event of failure of the aforementioned supply sources or if required, fire-fighting water can alternatively be drawn from the headwater canal or the Aare River by means of fire brigade pumps. For this purpose, a distribution network is available consisting of partly permanently installed pipes and partly pipes that still have to be laid if necessary.

The supply sources and the distribution network for extinguishing water are dimensioned in such a way that a supply of extinguishing water in accordance with design can be guaranteed for all extinguishing systems and the other extinguishing agents.

If required, the fire water network of the ZWIBEZ can also be supplied from an external water supply point (hydrant, motorised fire engine, tanker).

Mühleberg Nuclear Power Plant (KKM)

At the beginning of SP2, the following sources are generally available for the supply of extinguishing water at the site:

- Runtigenrain elevated reservoir with 500 m^3 volume, secured fire-fighting water reserve 300 m^3 (2 x 150 m^3)
- Stockeren reservoir with 400m^3 fire-fighting water reserve
- Rewag" distribution pumping station, flow rate of 2 x 2,400 l/min, redundant feed into the extinguishing water supply and into the "Runtigenrain" reservoir
- Emergency supply from the Aare (or Saane), motorised fire pump type II or fire pump with a delivery rate of 1,400 l/min or 1,000 l/min, can be fed directly into the fire water supply via existing connections.

Normally, the extinguishing water supply of the power plant area is carried out via the distribution network of the drinking water supply, with water drawn from the Runtigenrain high reservoir. On the power plant site, the extinguishing water is supplied from the internal distribution network (ring main) of the drinking water supply, which is assigned to system 094 from the building entrance. On the power plant site, the individual above-ground hydrants are fed via an NW 100 pipe from the internal distribution network of the drinking water supply. Each hydrant can be disconnected with an underground gate valve. Inside the buildings, water extinguishing points are supplied with additional Storz outlets (ON 55) and internal hydrants (system 094) from the fire water supply. Spray flooding systems can also be supplied from this distribution network of the drinking water supply or via the extinguishing water supply.

Buildings and facilities with special hazards, high safety significance or high fire risk and difficult intervention conditions shall be equipped with sufficiently dimensioned, suitable stationary fire extinguishing equipment (special dry or cool extinguishing systems) for initial fire fighting. The number, type and arrangement depend on the occupancy, type of construction, location, extent and use of buildings, facilities or fire compartments. In the course of SP2, all of these existing stationary extinguishing systems at the site will become obsolete and be removed.

Hydrants, water extinguishing posts and hand-held fire extinguishers are located at neuralgic points on the power plant site. In building classes I and II, individual water extinguishing points are equipped with additional Storz connections and hand-held fire extinguishers near the vertical escape routes. Hand-held fire extinguishers are distributed throughout the site in such a way that, if possible, all rooms and parts of the building can be reached with extinguishing agent. The walkway line to the nearest extinguisher is limited to 40 m if possible. Due to the decommissioning process and the resulting reduction of hazards, fire loads and ignition sources as well as the omitted safety significance, specific extinguishing systems will be reduced or completely eliminated.

3.2.2.2 Types, main characteristics and performance expectations

Beznau Nuclear Power Plant (KKB)

The following mobile and stationary fire-fighting equipment is available on the site:

- Sprinkler systems
- Flood spraying systems
- Foam extinguishing systems
- Gas extinguishing systems (with Novec 1230 or with Halon)
- Extinguishing water system with external hydrants and extinguishing posts (internal hydrants)
- Portable fire extinguisher

The enclosing walls of the turbine building are equipped with a sprinkler system inside the building. The sprinkler system is permanently under water pressure. The sprinkler nozzles are triggered automatically when the ambient temperature rises and the extinguishing process begins immediately. The activation of the sprinkler system triggers an alarm via the fire alarm control system, which also starts the booster pump. This ensures the effectiveness of the sprinkler system in further operation.

Due to their mode of operation, deluge systems are limited to smaller areas. A hydraulic remote control valve station is assigned to each deluge system. The control is electrical or pneumatic. The deluge systems can be triggered either automatically via fusible plugs, manually via a control point on site or from the main command room. The extinguishing time of a deluge system is always at least five minutes. If necessary, further post-extinguishing processes can be triggered.

Foam extinguishing systems exist for pumps in the engine house and in the diesel buildings. The foam extinguishing system for the pumps is triggered remotely. The foam extinguishing systems for the emergency diesel and the fuel supply are triggered automatically, but can also be triggered manually.

Gas extinguishing systems are used in fire compartments with electrical components, control technology and IT equipment, as well as in relay rooms and battery rooms. The gas extinguishing systems are usually triggered manually. In emergency buildings, the halon extinguishing systems can also be triggered automatically. The extinguishing effect is achieved by displacing oxygen from the atmosphere of the affected room, the suppressing effect remains until the room atmosphere is restored by manual operation of the ventilation.

Firefighting via outside or inside hydrants, as well as with hand-held fire extinguishers, is done manually. For this purpose, sufficient extinguishing agents are available outside and inside the buildings to be used in areas without further fire-fighting facilities.

Gösgen Nuclear Power Plant (KKG) / Interim storage facility at Gösgen NPP

The following mobile and stationary fire-fighting equipment is available on the site:

- Extinguishing water reserve of 2 x 1200m^3 and 500 m^3, which run geodetically towards the KKG
- Fire-fighting water reserve of 500m^3 from the surrounding communities with partial geodesic inflow
- Water extinguishing posts at neuralgic points (e.g. staircases, vestibules, corridors)
- Protected with sprinkler systems (wet or dry) are: Cable ducts, cable distributions, cable rooms and cable floors, pullers, drum stores, service aisles with cable routes, radiation protection stores, electrical stores, captive and block transformers.
- Protected with deluge systems are: Oil supply rooms, oil installations and ducts, special pumps, bearings, drives and valves, diesel oil rooms and diesel oil day tanks.
- Protected with gas extinguishing systems are: Electrical and electronics rooms, cable floors under electronics rooms, control room, control room adjoining rooms, emergency control room, programming, server and computer rooms, solvent storage, concentrate and resin filling room.

Leibstadt Nuclear Power Plant (KKL)

Extinguishing systems

The type of extinguishing system is defined depending on the location and the hazard potential. The following extinguishing systems are used in the KKL.

- Sprinkler systems
- Flood spraying systems
- Gas extinguishing systems

The extinguishing systems should detect a fire event on the basis of the system-dependent defined fire parameters, report it further and, depending on the system, independently start with the defined fire fighting.

Extinguishing water supply

The water supply of the KKL basically consists of the drinking, service and fire-fighting water supply. This also includes a groundwater pumping station, an elevated reservoir, a ring main on the power plant site including the associated connection lines and the external hydrant system.

Drinking-. service and fire-fighting water supply

The requirements of the authorities, in particular the AGV, which approved the planning basis and the construction, were all met.

Fire extinguishing water network (building internal)

Depending on the safety classification of the buildings, they are either connected to the extinguishing water network of the external hydrants or to a separate ring main.

Hydrants

In addition, above-ground hydrants are installed in the KKL to ensure the supply of extinguishing water from outside or in the event of incidents outside the buildings.

Fire extinguishers and wall extinguishing posts

Based on risk assessments, fire extinguishers or wall extinguishing stations are positioned in all areas of the KKL. The choice of the extinguishing agent and the extinguishing quantity took into account the environmental conditions determining the location. The wall extinguishing points are connected to the extinguishing water system.

Central interim storage facility

Not relevant for building H, as only standardised small extinguishers are used.

A deluge spray system is installed in the high-bay storage of building K. The deluge system is divided into three independent extinguishing sections that are supplied via a separate valve station. In each extinguishing section, the extinguishing nozzles are arranged in three levels and distributed over the entire area of the section. The water capacity or the water supply is 700 l/min per extinguishing section. The deluge system can be triggered manually at the fire brigade control centre and at the fire alarm centre.

Interim storage facility at Beznau NPP

The following fire-fighting facilities are available on the site:

- Extinguishing water system with external hydrants and extinguishing posts (internal hydrants)
- Portable fire extinguisher / portable fire extinguisher trolley

Fire fighting via outside or inside hydrants as well as with hand fire extinguishers is done manually. For this purpose, sufficient extinguishing agents are available outside and inside the ZWIBEZ.

Mühleberg Nuclear Power Plant (KKM)

Chapter 3.2.2.1 contains all the information.

3.2.2.3 Management of harmful effects and consequential hazards

Beznau Nuclear Power Plant (KKB)

The buildings of the facility have building sumps that absorb the firefighting water used in the event of a fire. The filling level of the sumps is monitored. In the controlled zone, when the sump level is high, the sump contents are pumped into the wastewater tanks of the residue system. The residue system is designed to receive wastewater from the controlled zone, clean it and then release it into the environment in a controlled manner. The waste water tanks have a sufficient volume to hold extinguishing water used in the event of a fire. The contents of the wastewater tanks can be transferred to the wastewater tanks of the other block via a connecting pipe, if necessary, so that sufficient collection capacity is available.

Outside the controlled zone, the extinguishing water is collected in the building sump of the affected fire compartment. When an extinguishing system is triggered, the building sump pumps are blocked, thus preventing uncontrolled discharge of extinguishing water into the surrounding area.

The initial operation of automatically triggered deluge systems is limited to five minutes to avoid excessive use of extinguishing water. Further extinguishing processes can be triggered manually.

Gösgen Nuclear Power Plant (KKG)

In the event of a fire, the extinguishing water that accumulates can be automatically discharged into the emergency water retention basin with a volume of 1,200 m^3 by pressing a button. If extinguishing water accumulates in the controlled area in the event of a fire, it collects via the TC system in the building sumps (approx. 1 m^3) of the affected fire Chapter and is pumped by sump pumps into the waste water collection tanks (65 m^3 each).

Leibstadt Nuclear Power Plant (KKL)

The hazards posed by fire protection systems (such as gas extinguishing systems) are known, marked on site where necessary and communicated to the relevant operating personnel through training. Explicitly for the gas extinguishing systems, devices are installed to warn the persons on site. In addition, extinguishing water retention systems are installed at defined locations to prevent negative effects of extinguishing operations on adjacent areas.

Furthermore, the extinguishing devices are designed in such a way that a malfunction does not have any negative effects on safety-related systems or equipment.

Central interim storage facility Zwilag

Structural measures prevent radioactive extinguishing water from entering the surrounding area. The basements of buildings E, K, S, V, and Z as well as the connecting channel U are intended to receive extinguishing water. The connecting channel has a slope in the direction of building K (conditioning plant). The threshold heights are designed according to the calculated extinguishing water volume.

Interim storage facility at Beznau NPP

To ensure the impermeability of the floor in the basement of the SAA storage facility and in the cable duct of the HLW building, these are covered with an epoxy coating which is raised approx. 15 cm up the walls. Together with the plastic sheeting attached to the outside of the building, this results in reliable groundwater protection, also against any extinguishing water present in the building in the event of a fire.

Interim storage facility at Gösgen NPP

In the wet storage building, extinguishing water is retained via the free volume in the basement.

Mühleberg Nuclear Power Plant (KKM)

Fire-fighting water retention within the controlled zone of building class I and II is basically carried out in the building sumps or at the lowest building points of the affected building. Treatment of the wastewater and controlled discharge is carried out via the waste water treatment plants (existing Radewaste or replacement waste water treatment). The meteoric water from the power plant area is normally discharged into the Aare via the outlet structure. The extinguishing water produced during firefighting in the outdoor area can be prevented from flowing uncontrolled into the Aare by closing several gates in the discharge system of the meteoric water. The collected extinguishing water is pumped by means of permanently installed pumps into mobile extinguishing water retention systems set up by the company fire brigade. The collection volume is 2 x 300 m^3 and 1 x 400 m^3. The contaminated extinguishing water is analysed by the chemical fire brigade base of the Berne professional fire brigade and the disposal is determined with the Office for Water and Waste. The extinguishing water retention measures are prepared by the plant fire brigade in accordance with the work instructions.

3.2.2.4 Alternative/temporary provisions

Beznau Nuclear Power Plant (KKB)

Extinguishing systems are only taken out of service for maintenance purposes. Maintenance work is carried out during normal attendance hours and is planned in such a way that the system can be put back into operation by the end of the working day. Should this not be possible in individual cases, further organisational measures will be taken outside of the attendance times to compensate for this.

Administrative regulations ensure that the main command room and the day officer of the fire brigade have been informed before an extinguishing system is taken out of service.

Gösgen Nuclear Power Plant (KKG) / Wet storage facility at Gösgen

The KKG has various mobile firefighting means at its disposal to establish an alternative water transport, e.g. from the cooling tower cup or from the Aare.

Leibstadt Nuclear Power Plant (KKL)

If extinguishing systems fail due to maintenance or other events, substitute measures are defined to ensure the necessary fire protection for the area. This can be done by providing more extinguishing agents (fire extinguishers) or by increasing fire protection rounds. Furthermore, possible sources of ignition are analysed and, if possible, restricted for the period during which the facility is unavailable.

The fire-fighting water supply at the KKL is ensured by two different fire-fighting water supplies (groundwater pumping station, high reservoir) and the possibility of drawing additional fire-fighting water directly from the Rhine via the company fire brigade.

Additional extinguishing agents are always kept in stock at the KKL in order to replace defective devices immediately if necessary.

Central interim storage facility Zwilag

Assessed as not relevant by the operator.

Interim storage facility at Beznau NPP

All fire-fighting equipment in the ZWIBEZ is operated manually. The equipment is checked regularly and maintained appropriately.

Mühleberg Nuclear Power Plant (KKM)

In the course of SP2, no more stationary extinguishing facilities (dry or cool extinguishing systems) are available. In order to reduce the risk of disruptive edges and to meet milestone MA4 (water-free), the permanently installed extinguishing water supply within the buildings with a controlled zone will be reduced in the course of the decommissioning, taking into account the risk, and will be completely eliminated at the appropriate time. Changes to or decommissioning of extinguishing equipment are coordinated with the quality assurance officer (QAO) and, if necessary, with the fire protection authority.

The failure of mobile extinguishing systems is detected and replaced with equivalent extinguishing agents or alternative measures. The processes for decommissioning or dismantling extinguishing systems are defined in detail and shown in the quality assurance concept as an attachment to the SP2 fire protection concept.

3.2.3 Administrative and organisational fire protection issues

3.2.3.1 Overview of firefighting strategies, administrative arrangements and assurance

Beznau Nuclear Power Plant (KKB) / Interim storage facility at Beznau NPP

After a fire alarm is received, the operators initiate an investigation by the shift personnel based on the information in the fire alarm control system in order to check the correctness of the fire alarm. If it is a real fire, the operators report the fire and the company fire brigade is immediately alerted in the control room. Until the company fire brigade is called in, the shift personnel initiate the first measures for rescuing people and, if possible, for fighting the fire, while ensuring self-protection. This also includes the remote-controlled or manual activation of extinguishing systems.

The company fire brigade consists of about 70 people who are well acquainted with the plant and the operational hazards. The organisation of the company fire brigade is based on the general fire brigade law, which also results in requirements for resources, equipment and training according to the classification in a size class. The fire brigade advances to the scene of the fire in accordance with defined intervention routes. After the fire has been extinguished, a fire watch is set up by the firefighting team, which continues to check and monitor the fire site and neighbouring rooms for swell fires or hot spots for a certain period of time.

The company fire brigade ensures that its members have sufficient knowledge of the plant and how to behave in the event of a fire by carrying out regular exercises at the plant.

Depending on the type of operation and the severity of the fire incident, other emergency services from the surrounding area or the canton may be called out.

Gösgen Nuclear Power Plant (KKG) / Interim storage facility at Gösgen NPP

The incident "fire" or "explosion" is to be classified as an emergency. The procedure is mapped and defined in the emergency regulations and describes management hierarchies, functions and areas of responsibility. The "Fire or Explosion" checklist is used for fires and explosions. This checklist defines the alerting, the summoning and the measures to be taken by the shift, the guard and the fire brigade, among others.

Leibstadt Nuclear Power Plant (KKL)

A company fire brigade is operated at the KKL for defensive fire protection. This fire brigade is called out on the basis of emergency instructions that are available for various scenarios in the KKL.

Clearly formulated checklists are used to send shift personnel to the site to check the situation after a fire alarm is received by staff in the control room. If the fire alarm is confirmed, the company fire brigade is alerted according to the checklist. Until the arrival of the fire brigade, the shift personnel start securing the plant, rescuing persons and, if necessary, fighting the fire, while ensuring their own safety.

Central interim storage facility Zwilag

In the event of a fire during normal working hours, the PSI plant fire brigade shall be called out directly; if necessary, the Würenlingen local fire brigade may be called in to provide neighbouring assistance. Outside normal working hours, the Würenlingen local fire brigade shall be alerted at the same time as the PSI fire brigade and shall also be the first response element to arrive at the scene of the fire. The same situation applies to a fire at PSI. The Würenlingen fire brigade has therefore trained some specialists in dealing with ionising radiation. The cooperation between the fire brigades of the municipality and the PSI is contractually regulated. Zwilag is included in this agreement.

In general, a distinction is made between the presence and absence of personnel in the event of a fire alarm from an automatic detector. If the staff is absent, the fire brigade and the emergency staff are alerted directly. If staff are present, a defined time of 5 minutes is waited for a response from any staff in the vicinity.

If this time elapses without a reaction, the fire brigade and the emergency staff are called out. If there is a fire alarm from several automatic detectors or a report from personnel, the fire brigade and the emergency staff are called out immediately.

For example, during intervention by the fire brigade, a distinction is made in Building S between the storage and reloading area and the rest of the building. The storage and reloading area represents a zone with radioactive materials and minimal fire risk, while the operating and technical area normally does not contain radioactive materials and has a normal fire risk.

Mühleberg Nuclear Power Plant (KKM)

In the event of a fire, the following steps are initiated by the internal, permanently staffed office:

- Alerting BFW/IvG (BFW standby is automatically alerted by the FAS)
- Triggering of emergency alarm (possible Chapter by Chapter)
- Immediate evacuation of the affected localities or information of the power plant personnel via the public address system.
- Triggering the emergency staff groups
- Alerting the site manager or the members of the site management.
- Information of the company guard (automated, details are given by telephone)
- Calling up the external emergency services

The emergency organisation and the behaviour during an emergency situation (incl. fire) are defined in the site regulations and in the emergency regulations. The detailed list of individual emergencies and incidents, with reference to the individual emergency and incident instructions, can also be found in the emergency regulations. In the event of a corresponding incident, the staff member on call or the emergency manager takes charge until a member of the site management arrives. The emergency manager leads, monitors and coordinates the deployment of the various internal emergency Chapters and, if necessary, the additional external emergency organisations.

3.2.3.2 Firefighting capabilities, responsibilities, organisation and documentation onsite and offsite

Beznau Nuclear Power Plant (KKB) / Interim storage facility at Beznau NPP

The behaviour of the operators in the event of a fire alarm is laid down in writing in the operating regulations. The responsibilities and duties of operators, shift personnel, picquet engineer, fire brigade commander, emergency staff are also laid down in writing. The responsible persons are officially appointed and involved in the organisation in case of fire according to their function. The required training and competences of the responsible persons are regulated in writing.

KKB operates a company fire brigade made up of power plant employees. The organisation of the plant fire brigade, the individual tasks of various functions and the necessary training are laid down in writing and are based on the Fire Brigade Act and the valid guidelines and regulations of the responsible fire protection authorities. The alarm is sounded in accordance with internal guidelines on emergency instructions via the command room and the plant guard.

Gösgen Nuclear Power Plant (KKG) / Interim storage facility at Gösgen NPP

The fire brigade is under the supervision of the power plant management. The KKG has a company fire brigade (BFW) with about 55 members. The fire brigade is divided into two piquets. 90 % of the target number of members of the company fire brigade perform breathing protection duties. The company fire brigade is integrated into the fire brigade system of the canton of Solothurn. Training and exercise activities are therefore carried out in accordance with the cantonal guidelines.

In the event of a fire, the external fire brigade is automatically alerted for support. To ensure proper procedures in the event of a call (also with regard to local knowledge), the external fire brigade is regularly involved in exercises of the plant fire brigade.

Leibstadt Nuclear Power Plant (KKL)

All KKL employees are periodically trained in the handling of small extinguishers.

The performance expectations of the KKL company fire brigade are equivalent to the performance expectations of a public fire brigade. All members of the company fire brigade must participate in regular internal and external training courses and exercises. In addition, special training (IFOPSE) for respiratory protection equipment carriers is organised regularly in France.

At KKL, the company fire brigade is responsible for fighting fires on the premises. Should external support be necessary in the event of an incident at the KKL, a member of the internal company fire brigade is always with the external forces on the basis of specifications. This prevents independent movement and thus possible danger to external forces on the KKL premises.

The fire brigade of the KKL can be alerted for neighbourhood assistance by means of agreements with the canton and the surrounding municipalities. This is done in consideration of ensuring defensive fire protection at the KKL.

Central interim storage facility Zwilag

The PSI fire brigade is also responsible for Zwilag. Zwilag employees participate in the PSI fire brigade, so that knowledge of the Zwilag facilities is also available to the PSI fire brigade.

A fire protection officer and a deputy are appointed to coordinate and ensure compliance with all fire protection elements. The tasks and competences are set out in the fire safety officer's duties and responsibilities.

The staff is regularly trained in the areas of alerting, behaviour in case of fire and operation of the extinguishing equipment. The guard is trained in the areas of alerting the fire brigade and operating the fire alarm system and the means of communication. The training courses are recorded.

Mühleberg Nuclear Power Plant (KKM)

The site management shall ensure the necessary organisational and personnel measures for fire protection (fire protection organisation, company fire brigade) in accordance with the site regulations. The site management delegates competences in this regard in particular to the fire safety officer and the fire brigade command of the KKM. The fire safety officer and the fire brigade commander are appointed by the site management and have direct access to the site manager. The processing of the specialist fire protection topics is carried out in a supportive manner by the responsible KKM specialist departments. The Quality Assurance Officer (QAO) is responsible for quality assurance within the scope of project planning, tendering and realisation of all structural, technical, organisational and defensive fire protection measures in the KKM. He/she must qualify as a fire protection expert or equivalent in accordance with the applicable requirements.

The fire brigade regulations are the basis of the Mühleberg nuclear power plant (KKM) fire brigade, hereinafter referred to as BFW-KKM. The fire brigade regulations govern the organisation, responsibilities and training of the members of the fire brigade as well as the procedures for training and emergency response. The fire brigade regulations summarise the relevant documents for the BFW-KKM. The BFW-KKM is available around the clock for the following tasks:

- Rescue and recovery of endangered persons
- Firefighting
- Protection of water bodies from leaking harmful liquids
- Protection against floods
- Creating emergency feed lines and ensuring water transport
- Other tasks as specified by the emergency management.

In order to guarantee the intervention time of 15 minutes, a KKM fire brigade standby duty is available. This consists of two members of the fire brigade who are on standby duty at regular intervals.

The BFW-KKM Schutz und Rettung Bern is available for support. The Regio Laupen fire brigade can be called out in the event of an incident at the KKM. Their tasks include water transport, traffic service and the provision of additional resources. A gradual integration of the local fire brigade and the locally responsible special bases into the fire brigade tasks outside the controlled radiological zone (analogous to a normal industrial plant) is planned. The Building Insurance Bern (GVB) orders periodic inspections of the BFW-KKM.

In SP2, defensive fire protection is reduced from the plant fire brigade to an intervention group in accordance with the SP2 fire protection concept, in line with the decommissioning process.

In addition, all employees at the site are jointly responsible for fire prevention (alerting, rescuing, fighting incipient fires with existing extinguishing agents). The necessary information is imparted to in-house and external staff during safety instruction and to in-house staff through the annual obligatory safety training (fire fighting with small extinguishers).

The target number of company fire brigades is defined in the 'Company Fire Brigade Concept'. It is based on the guidelines of the Swiss Fire Brigade Association for company fire brigades and the local requirements defined by ENSI and the fire inspector.

3.2.3.3 Specific provisions

Beznau Nuclear Power Plant (KKB) / Interim storage facility at Beznau NPP

The KKB is located on an island in the river Aare and has two separate entrances, one from each bank. The plant is located between the two accesses. It is highly unlikely that a fire event could block both accesses.

Gösgen Nuclear Power Plant (KKG) / Interim storage facility at Gösgen NPP

The minimum staffing level with the corresponding requirements and responsibility is defined and specified in the power plant regulations and the security regulations. The measures to be taken in an emergency (e.g. loss of access) are regulated in the emergency manual.

Leibstadt Nuclear Power Plant (KKL)

External emergency forces are not allowed to move freely on the KKL premises. The organisation of the "Plant and Plant Fire Brigade" areas ensures that the required operational readiness is guaranteed.

For emergency services, alternative access routes to the site and the individual buildings ensure access even if the main access is lost.

Central interim storage facility Zwilag

Not relevant from the operator's point of view.

Mühleberg Nuclear Power Plant (KKM)

For access, there is an access road to the KKM, which then leads to the power plant area via two independent area accesses. Security systems (e.g. security centre) that allow access to the power plant site are located in the security area. Controlled access to the site as well as access to specific buildings for external emergency organisations is always carried out under local supervision from the KKM site. The KKM site and buildings are divided into different access zones. The access conditions are particularly relevant for defensive fire protection. Access to the various zone areas is restricted.

In the event of an emergency or fire, access to the KKM and to the individual buildings and facilities is regulated within the framework of the emergency organisation and by means of intervention routes, see also SP2 Fire Protection Concept or Emergency Regulations.

3.2.4 Licensee's experience of the implementation of the active fire protection

3.2.4.1 Overview of strengths and weaknesses identified

Beznau Nuclear Power Plant (KKB)

The active fire protection was implemented according to the currently valid fire protection concept. From the previous operation of the facility, the concept of active fire protection has proven itself overall. The facility was built more than 50 years ago. Fire protection has developed massively during this time. The challenges are to keep the fire protection requirements and their implementation state of the art.

The intervals for the periodic inspections and maintenance of the fire alarm system and the extinguishing equipment correspond to the state of the art. They have proven to be purposeful and expedient.

Active fire protection is taken into account appropriately during plant modifications and upgrades.

Gösgen Nuclear Power Plant (KKG) / Interim storage facility at Gösgen NPP

The elements of technical fire protection provide a valuable safety gain. Knowing that in the event of an incident, measures are automatically taken for early fire detection or containment gives the intervention forces a good feeling and contributes to offensive deployment tactics. Maintenance and servicing work has become increasingly intensive in recent years. Regulations have been tightened and inspection intervals shortened.

The stricter regulations and the shortened inspection intervals lead to additional work in maintenance and documentation. The large number of extinguishing systems requires a great deal of effort.

Leibstadt Nuclear Power Plant (KKL)

Thanks to uniform and process-regulated communication in the KKL and the continuous professional training of employees, fire protection incidents can be handled and documented in a targeted manner. In addition, rapid detection by the fire alarm system and rapid firefighting by the extinguishing systems in the KKL are ensured. In the past, various minor incidents could be handled by internal staff or by calling in parts of the company fire brigade without any relevant consequential damage.

Due to the high reservoir and the associated geodesic feed, no additional pumps are needed to feed the extinguishing water. This reduces maintenance costs and increases reliability. The installed ring main system ensures the availability of the extinguishing water supply even if Chapters are not available.

Due to the preventive and precautionary fire protection philosophy at the KKL and the constant training of employees, no major fire incidents have occurred at the KKL since its commissioning.

Due to the increasing requirements for the maintenance and testing of the fire protection systems, this not only represents an additional burden for the material of the fire protection system, but also an additional burden for the maintenance of the corresponding systems.

Central interim storage facility Zwilag

Active fire protection was implemented in all Zwilag buildings in accordance with the approved fire protection concept. The operating history shows that no systematic weaknesses in active fire protection have been identified to date.

Interim storage facility at Beznau NPP

The active fire protection was implemented according to the currently valid fire protection concept. From the previous operation of the ZWIBEZ, the concept of active fire protection has proven itself overall.

The intervals for the periodic inspections and maintenance of the fire alarm system and the extinguishing equipment correspond to the state of the art. They have proven to be purposeful and expedient.

Active fire protection is taken into account appropriately during plant modifications and upgrades.

Mühleberg Nuclear Power Plant (KKM)

The technical measures for active fire protection planned and applied on the basis of the fire protection concept provide sufficient and targeted protection against fires and their impact on the site as well as the intervention. One strength is the monitoring scope of the fire alarm system, which is divided among several fire alarm centres, and the resulting high availability of these systems. The direct internal alarm chain and the internal emergency forces are also a strength at the site.

In the course of decommissioning, the technical fire protection measures often form interference edges to the dismantling. These interfering edges can only be adapted at great expense or with a time delay (weakness). Technical fire protection measures are continuously evaluated and, if necessary, adapted due to the course of decommissioning and the resulting constantly changing environmental conditions. In the event of corresponding changes, the fire protection authority is involved in the decision-making process. During decommissioning, the proven maintenance process is applied, which includes all measures to maintain and restore the target condition as well as to determine and assess the actual condition of electrical and mechanical components of the dismantling operating systems and of building structures. This proven process fulfils the requirement to maintain the functionality of the building structures and the operational capability of the systems and components through maintenance measures in compliance with the relevant regulations and guidelines.

3.2.4.2 Lessons learned from events, reviews, fire safety related missions

Beznau Nuclear Power Plant (KKB) / Interim storage facility at Beznau NPP

The events that have occurred during operational experience only concern conventional fire protection.

Operational events or incidents with safety relevance are handled internally through a defined process, whereby the effects on operational safety are analysed and evaluated. Finally, appropriate measures are taken to reduce the possibility of a similar event occurring again in the future or to limit its impact on operational safety to an acceptable level.

An analogous process is carried out for reported events or operating experience from other nuclear facilities, with the focus on analysing whether a similar event could occur at the Beznau nuclear power plant and what measures exist to prevent negative effects on operational safety.

The events managed in the past have confirmed the existing active fire protection measures. All events were detected by the fire alarm system at a very early stage, so that there were no effects on other parts of the facility.

Gösgen Nuclear Power Plant (KKG) / Interim storage facility at Gösgen NPP

So far, there have been no fire incidents where an extinguishing system was requested. Extinguishing systems have only been triggered on the basis of fire drills or technical tests.

Triggerings of the fire alarm system train the fire brigade in the operational routine. The very small number of false alarms contributes to the fact that the seriousness of the alarms is still very high.

Leibstadt Nuclear Power Plant (KKL)

Due to the sophisticated processes in the KKL and the constant sensitisation of the employees, only very few triggers of the fire alarm system occurred in the KKL. There was no triggering due to a major event or a larger fire incident at the KKL. In all the smaller incidents, the implemented processes worked and the company fire brigade was able to deal with all incidents, also due to the systematic training.

Central interim storage facility Zwilag

In the operating history to date, there was one event in which a fire alarm was triggered. Due to bearing damage on an exhaust fan, a fire alarm was triggered by a smoke detector. The fire brigade and the emergency staff were correctly alerted according to the checklist. There was no need for a further review of operations related to fire protection due to this event. The handling of this event was exemplary.

Mühleberg Nuclear Power Plant (KKM)

Since the discontinuation of power operation at the end of 2019, no internal event has occurred at the KKM that would have led to a triggering or deployment of an extinguishing system.

3.2.4.3 Overview of actions and implementation status

Beznau Nuclear Power Plant (KKB) / Interim storage facility at Beznau NPP

The fire alarm control system was completely renewed. In the process, the positions and settings of the on-site detectors were also checked and adapted to the new findings.

Based on past experience, no measures to improve active fire protection are currently planned.

Gösgen Nuclear Power Plant (KKG) / Interim storage facility at Gösgen NPP

The measures taken, including the training of internal employees and external staff in the area of active fire protection, have proven successful and will continue to be implemented.

Leibstadt Nuclear Power Plant (KKL)

Identified fire protection deficiencies are transferred to a catalogue of measures, where they are classified, prioritised and processed accordingly.

Central interim storage facility Zwilag

No measures to optimise active fire protection are currently planned for Building H.

Mühleberg Nuclear Power Plant (KKM)

All technical measures can be found in the fire protection concept. All corresponding changes in active fire protection were planned, released and implemented in coordination with the quality assurance in fire protection and the fire protection authority. The status of the changes can be seen in previous monthly reports of the site.

3.2.5 Regulator's assessment of the active fire protection

3.2.5.1 Overview of strengths and weaknesses identified

Beznau Nuclear Power Plant (KKB) / Dry storage facility at Beznau NPP

From ENSI's point of view, the fire alarm systems at KKB meet the requirements. Previous events involving smoke were reliably detected. Parts of the fire alarm system have been renewed in recent years and adapted to the current state of the art. The corresponding work was supervised by ENSI and cantonal specialists.

The alarm in the main command room is visual (screen) and acoustic (alarm horn). A loudspeaker system, which is checked periodically, is available for alerting within the facility. Communication within the facility is ensured by fixed telephone lines, cordless transmission and voice radio.

The fire alarm systems are continuously maintained. Appropriately trained personnel are available at the facility to provide support. ENSI is not aware of any deficiencies with regard to fire detection and alarms.

The alarm system in the KKB is a loudspeaker system that can be operated from the command room and the guard room. ENSI is not aware of any specifications according to which these facilities were constructed. ENSI is therefore of the opinion that additional regulatory requirements are needed as to how these are to be designed (National area for improvement).

From ENSI's point of view, the extinguishing equipment at the KKB is adapted to the uses and facilities. Where water cannot or may not be used as an extinguishing agent, the facility is equipped with gas extinguishing devices. The emergency building is equipped with an emergency feed (dry pipe); if necessary, the supply of extinguishing water can be ensured by mobile means of the fire brigade. The facility has a sufficiently dimensioned extinguishing water retention in all areas.

Gösgen Nuclear Power Plant (KKG) / Interim storage facility at Gösgen NPP

The fire alarm systems and parts of the fire control system were renewed in the KKG together with the fire dampers. Due to the design of the system, the existing fire dampers were designed in such a way that they had to be actively controlled in order to close. During the renovation, fire dampers were installed that close without active control (fail-safe).

As a result of the renewal, the fire alarm systems are in a good state of repair. From ENSI's point of view, well-trained personnel are available at the facility to provide support. By actively using the new technical possibilities of the fire alarm system, the closing times of fire dampers could be evaluated and weak points discovered, which led to the replacement of the fire dampers.

In addition to the acoustic signal of the fire alarm system, all buildings are also equipped with a loudspeaker system as an alarm system. The system has a high availability due to the redundant power supply. Faults can be repaired by trained internal personnel. The public address system can be operated from the command room and the control centre. Here, too, ENSI is not aware of any specifications according to which these facilities were constructed. As already noted as a potential for improvement, there is a need for uniform regulatory specifications for the design of the alarm systems (National area for improvement).

Extinguishing equipment adapted to the uses and facilities is available. Where water cannot or may not be used as an extinguishing agent, the facility is equipped with gas extinguishing devices. The wet extinguishing points are designed in accordance with national regulations. The extinguishing systems are maintained and serviced in accordance with national regulations. Since the plant was commissioned, there has been no fire incident in which an extinguishing system has been triggered.

The targeted use of suitable extinguishing agents and automatically triggered extinguishing systems results in a safety gain. The personnel-intensive replacement measures for upcoming maintenance work or the replacement of automatic extinguishing systems result in increased personnel costs.

Leibstadt Nuclear Power Plant (KKL)

In 2021, a comprehensive compilation of all fire protection-relevant structures, systems and components and the assigned inspection periods was carried out. Based on the identified inspection periods, a comprehensive adjustment of the maintenance work was initiated.

All buildings are monitored with a fire alarm system. The existing fire alarm systems are state of the art. From ENSI's point of view, well-trained internal personnel are available to look after the systems.

Where water cannot or may not be used as an extinguishing agent, the buildings are equipped with gas extinguishing devices. Wet fire extinguishing posts and hand-held fire extinguishers are also provided at suitable locations. The facility has adequately dimensioned extinguishing water retention in all areas.

The existing loudspeaker system complies with the national regulations of the SES and fulfils the requirements of an electroacoustic emergency warning system (ENS).

Central interim storage facility Zwilag

Buildings K, E, M and S are monitored by a fire alarm system. Building H only has fire detection in the parking area of the crane facility. The fire alarm system was renewed in 2019. The alarm is sent to the plant guard and the fire brigade.

An evacuation system is available in the buildings. All systems in the individual buildings are networked with each other. Loudspeakers are installed in all rooms where people are present to enable evacuations and announcements. Here, too, ENSI is not aware of any specifications according to which these facilities were constructed. As already noted as a potential for improvement, there is a need for uniform regulatory specifications for the design of the alarm systems (National area for improvement).

From ENSI's point of view, only hand-held fire extinguishers are available in Building H, in accordance with its use. In the other buildings, fixed extinguishing equipment is correctly installed because of the fire loads in the critical areas. Where water cannot or may not be used as an extinguishing agent, the buildings are equipped with gas extinguishing systems. In addition, wet extinguishing posts and hand-held fire extinguishers as well as sufficient extinguishing water retention facilities are available at suitable locations.

Zwilag did not explain what substitute measures exist for the decommissioning of sprinkler or deluge systems. ENSI will address this point during the required review of the fire protection concept (see ChapterChapter 3.1.4.1).

Mühleberg Nuclear Power Plant (KKM)

Since the KKM is in the SP2 decommissioning phase, is fuel-free and the high fire loads (turbines, generators, transformers, emergency power generators) have been removed, ENSI believes there is no longer any long-term need for permanently installed extinguishing systems.

As a result of the extensive deconstruction work, organisational fire protection (walkways, hot work) is justifiably given increased attention.

3.2.5.2 Lessons learned from inspection and assessment as part of the regulatory oversight

Beznau Nuclear Power Plant (KKB) / Interim storage facility at Beznau NPP

No acute need for action is apparent with regard to the fire alarm system. A project to replace the fire alarm control panels will start at the end of 2023. With regard to the stationary extinguishing systems, ENSI has not identified any need for action in recent years.

Gösgen Nuclear Power Plant (KKG) / Interim storage facility at Gösgen NPP

During the renewal of the fire alarm system and the replacement of the fire dampers in the KKG, the control of the fire dampers and their integration into the existing control of the ventilation systems was a fundamental issue. Based on the VKF regulations, ENSI demanded a changeover from active control of the closing function of the fire dampers to automatic closing of the fire dampers if the control is omitted. In individual cases, it had to be clarified to what extent the ventilation of safety-relevant control rooms had to be maintained.

Leibstadt Nuclear Power Plant (KKL)

ENSI found that the maintenance work required for the extinguishing systems at KKL had not been documented and that it was therefore not possible to determine whether the prescribed maintenance work had been carried out. An inspection carried out by external specialists at the instigation of ENSI showed that the extinguishing systems had no significant defects. The maintenance work carried out on extinguishing systems is now documented at KKL in accordance with the VKF regulations.

No need for action is apparent with regard to fire detection and alarm systems.

Central interim storage facility Zwilag

No failures of fire alarm or fire extinguishing systems have been reported to ENSI.

Mühleberg Nuclear Power Plant (KKM)

The findings of the last inspections at the KKM relate in particular to organisational fire protection. For example, fire loads were brought in that were not accounted for, or the operator had no knowledge that an external company had brought in highly flammable liquids.

Furthermore, ENSI found that the positions of mobile extinguishers such as portable fire extinguishers were not systematically recorded during the dismantling work. As a result, some portable fire extinguishers were not properly maintained.

ENSI has demanded the removal of the unauthorised fire loads and the systematic recording and maintenance of the hand-held fire extinguishers, and has followed up on the implementation of the demands as part of the supervisory process.

The dismantling of the facility also resulted in adjustments to the fire alarm system. In some cases, the scope of monitoring was reduced in consultation with ENSI, but in one case it was also expanded because a previously inaccessible area had to be monitored for the first time.

For SP2, the procedure for adjustments in fire protection was simplified in the fire protection concept. In accordance with the VKF specifications for conventional fire protection, it is no longer necessary to apply for approval for all changes (e.g. changes to fire detectors < 10 units). In deviation from the previous full monitoring by the fire alarm systems, rooms without use in which all equipment and systems have been removed can now be taken out of the full monitoring. For this purpose, a superordinate "withdrawal process" was defined. The associated new procedural steps are to be verified by targeted inspections by ENSI.

3.3 Passive fire protection

3.3.1 Prevention of fire spreading (barriers)

3.3.1.1 Design approach

Beznau Nuclear Power Plant (KKB) / Interim storage facility at Beznau NPP

Each building in the KKKB is sufficiently separated from neighbouring buildings or has a fire-resistant partition. The buildings are usually divided into different fire compartments. If several redundancies are located in the same fire compartment, they are sufficiently spatially separated, if possible, to minimise mutual negative influence. Electrical rooms, horizontal and vertical escape routes form separate fire compartments. In the safety building, the containment and the annular space form separate fire compartments. Underground supply ducts connecting several buildings form separate fire compartments.

Only fire doors that are closed again after they have been passed through are installed in building components that form fire compartments. Fire doors that are kept open for operational reasons are connected to the fire alarm system and have a fire control system. In case of fire or power failure, these fire doors close automatically.

Recesses for pipelines and cables in building components that form fire compartments are closed off in a fire-resistant manner by means of bulkheading systems. The fire protection bulkheads prevent the unhindered spread of fire gases and flames across several fire compartments. Escape routes are designed in such a way that they lead directly or indirectly, via corridors and stairwells, to the outside by the shortest route. The escape routes shall have a minimum width of 1.20 m. The escape routes also serve as intervention routes for rescue and firefighting. The escape routes are clearly marked with luminescent pictograms and equipped with escape route lighting.

The HAW and LAW storage buildings of the ZWIBEZ are divided into different fire Chapters. The primary area and the secondary area are separated from each other with fire resistance and in turn consist of several fire Chapters. The buildings are separated from each other with fire resistance. The same requirements for components forming fire compartments apply as in the KKB.

Gösgen Nuclear Power Plant (KKG) / Interim storage facility at Gösgen NPP

When determining the fire compartments, in addition to the aspects valid for conventional fire protection, such as existing fire loads or room utilisation, above all the aspects of nuclear safety and radiation protection must be taken into account. Separation criteria between redundancies are taken into account. Where possible, equipment of redundant safety systems is located in different fire compartments. Structural measures ensure that in the event of a fire, the effects are limited to one redundancy.

The basis for the construction of the wet storage facility was the VKF fire protection regulations 2003. The division into fire compartments is based on their use.

Leibstadt Nuclear Power Plant (KKL)

The design of the KKL already took into account that the individual divisions and emergency busbars are structurally separated from each other. The fire protection separation of the individual divisions largely prevents a cross-redundancy fire event.

In the KKL, a distinction is made between fire zones and fire compartments. In the case of directly adjoining buildings, the areas of the buildings that are directly adjacent to each other are defined as fire zones. A higher fire resistance is defined here than for fire compartments. A fire zone defines an area in a building or part of a building that is completely surrounded by barriers with sufficient fire resistance. The fire resistance of the fire compartments depends on the classification of the building and the uses defined in the fire compartments as well as the fire load. The fire resistances are defined in the fire protection concept and can be seen in the fire protection plans.

The protection goals in fire protection are described on the basis of documents and processes supporting the nuclear protection goals. Compliance with the protection goals is initially ensured structurally (e.g. through the use of specific building materials such as halogen-free cables). If supplementary fire protection measures are required, these are implemented technically. Organisational fire protection measures are defined to complement and complete the structural and technical measures.

Central interim storage facility Zwilag

The concept of passive fire protection includes the selection of materials, structural specifications as well as the design of fire protection closures according to the following principles:

- All operating equipment such as cables, ducts, equipment in control cabinets, etc. are at least flame-retardant. Only halogen-free and flame-retardant materials are used.
- Building H is designed as a separate fire zone. Other existing buildings, as well as the connecting canal, are designed as separate fire zones.
- The fire zone of building H is divided into two fire compartments with the storage area and the room with the emergency exit. The fire compartments are formed according to the uses, protection requirements (escape routes) and the fire loads (electrical rooms, storage).
- The escape routes are designed in such a way that they lead directly or indirectly, via corridors and staircases, to the open air or to the connecting duct by the shortest route. The paths have a minimum width of 1.20 m. The escape routes serve as intervention routes in the opposite direction. The escape routes are clearly marked with photoluminescent pictograms and equipped with escape route lighting.

Mühleberg Nuclear Power Plant (KKM)

The defined protection goals at the site are achieved through the structural fire protection concept and structural fire protection measures contained therein. Additional technical fire protection measures are used depending on the use. The detailed structural fire protection measures are defined and documented in detail by the Safety Officer Fire Protection together with the QAO.

At the site, structural fire protection measures include in particular:

- Use of suitable building materials (building envelopes, building finishes, building technology).
- Compliance with protective distances
- Protection of supporting structures
- Formation of fire compartments
- Ensuring escape and rescue routes

3.3.1.2 Description of fire compartments and/or cells design and key features

Beznau Nuclear Power Plant (KKB) / Interim storage facility at Beznau NPP

The definition of the requirements for components with fire resistance is based on nationally and internationally applicable standards, guidelines and regulations. The qualification of a building component is carried out according to a standardised unit temperature curve, which represents an envelope for different types of fires (gas, oil, wood, paper fires). The fire resistance duration of fire compartments in the KKB is at least 90 minutes. Where appropriate, individual fire compartments have also been designed with fire resistances of longer duration.

During the construction of walls and ceilings, care was taken to use combustible building materials sparingly, which kept the amount of immobile fire loads low. The same applies to floor coverings, paint coats, varnishes and insulation. For components and building elements with fire resistance, qualified building elements are used wherever possible. Components that do not have a fire protection qualification according to national or international standards are assessed according to their construction method.

Gösgen Nuclear Power Plant (KKG) / Interim storage facility at Gösgen NPP

The design of the individual fire compartments is primarily based on nuclear requirements. As far as the resulting requirements allow, the requirements of the conventional VKF fire protection regulations take effect on the next level.

For classified buildings, a fire resistance duration of 90 minutes applies. Higher requirements apply to ceilings and walls forming fire compartments and to the vertical escape route. For non-nuclear buildings, the requirements of the VKF fire protection regulations apply.

As a rule, an extinguishing system is installed in a fire compartment if the fire load is high (> 1000 MJ/m^2). The design of the extinguishing systems in the individual fire compartments is determined by their size and type of use.

Walls and ceilings of the wet storage at fire compartment boundaries have a fire resistance duration of 90 minutes. Doors in fire compartment walls within the same building have a fire resistance rating of at least 30 minutes.

Leibstadt Nuclear Power Plant (KKL)

The fire resistances of the individual fire protection components were determined taking nuclear safety into account. In areas where nuclear safety is not affected, the regulations valid at the time of construction were used. By today's standards, these are the VKF fire protection guidelines. Thus, depending on the uses and installations defined in the fire compartments, fire resistance levels of EI 30 to REI180 are available in the KKL.

Within the buildings, the individual rooms are assigned to corresponding fire compartments. Several rooms can belong to one fire compartment. Different redundancies are separated from each other by means of fire compartments. Staircases form independent fire compartments. The fire compartment boundaries are designed structurally/technically so that a fire remains confined to the fire compartment for the fire resistance time assigned to the fire compartment.

All components at the fire zone boundaries have the following fire resistances:

- Walls and ceilings REI 180
- Doors EI 90
- Cable and pipe penetration seals EI 90
- Building joint seals EI 90
- Fire dampers EI 90

All components at the fire compartment boundaries have the following fire resistances:

- Walls and ceilings REI 90
- Doors EI 60
- Cable and pipe penetration seals EI 60
- Mounting openings EI 60
- Fire dampers EI60

Mühleberg Nuclear Power Plant (KKM)

Building materials and components used can be defined according to European standard (EN) or VKF regulations. The fire protection authority decides on equivalence in individual cases. Whenever possible, building materials and components are used in the KKM in accordance with the VKF fire protection guideline BSR 13-15de, which make no or only a low fire contribution (RF1/RF2).

The building envelope, the load-bearing walls and ceilings as well as elements are constructed exclusively with RF1 building materials. The majority of the buildings are of solid construction (reinforced concrete structures). Combustible materials may be used if they do not lead to an inadmissible increase in danger. The existing fire protection plans serve as a basis.

The minimum requirements for fire resistance of the building materials to be used at the KKM site result from the usage requirements of the vertical and horizontal escape routes as well as from other usage.

Cables with PVC insulation were used in the construction of the KKM. For new cables to be installed, cables with flame-retardant outer sheath are used where applicable. The insulation of these new cables consists of a halogen-free, low-smoke and flame-retardant material.

For thermal and sound-absorbing insulation, non-combustible materials and products of category RF1 are used. In electrical installations, flame-retardant components of category RF2 are used. With the exception of cables, cable ducts and shafts contain neither combustible material nor pipelines carrying gas, oil or combustible media. Pipelines with flammable media are routed in separate shafts/ducts.

The fire protection distances are complied with in accordance with the VKF fire protection guideline BSR 15-15en. Connected, safety-relevant buildings are separated from each other by structural fire protection measures. If the fire protection distances are not observed, this is declared in the building permit procedure and substitute measures are defined in accordance with the VKF fire protection guideline BSR 15-15de. The existing fire protection plans serve as a basis.

The formation of fire compartments is also based on the VKF fire protection guideline BSR 15-15en. The formation of fire compartments in buildings and facilities depends on their construction, location, extension, building geometry, use and existing fire loads. Above all, the aspects of radiation protection must also be taken into account. Separation criteria were ensured in the best possible way during the construction of the KKM. Vertical and horizontal escape routes are designed as separate fire compartments and ensure safe escape from the buildings in case of fire. Passages and other openings in building components that form fire compartments must be closed off with fire-resistant fire closures. Between fire compartments with a low fire risk or fire load, the fire resistance can be reduced appropriately.

For buildings that are connected via ventilation ducts, the ventilation concept must always be coordinated with the fire protection concept. The fire compartmentation at the site is based on the SP2 system list and is shown in the respective fire protection plans. Maintenance measures are planned and carried out according to the SP2 maintenance programme. Work on partitions is additionally documented by means of internal partition management.

Due to the decommissioning process and the resulting reductions in hazards, fire loads and ignition sources as well as the omitted safety significance, fire compartments can be reduced or completely omitted based on the system list and in agreement with the fire protection authority. Changes to fire compartments are checked and approved by the fire protection quality assurance department. If fire compartments can be cancelled due to structural changes, the fire protection plans are updated. The creation of temporary fire compartments is possible in coordination with the QAO.

All penetration seals are systematically recorded and labelled in the penetration seal management system. If fire compartments are removed in the course of dismantling, the penetration seals no longer need to be inspected/maintained. This is noted in the internal control system of the penetration seals.

Sufficient escape and rescue routes are ensured throughout the decommissioning phase.

3.3.1.3 Performance assurance through lifetime

Beznau Nuclear Power Plant (KKB) / Interim storage facility at Beznau NPP

Passive components forming fire compartments are regularly checked and repaired if necessary.

Gösgen Nuclear Power Plant (KKG) / Interim storage facility at Gösgen NPP

Professional maintenance and servicing ensure that the fire compartment boundaries, in particular fire partitions and fire compartment-forming components, are in a condition that meets the requirements. An inspection for conformity takes place regularly.

Leibstadt Nuclear Power Plant (KKL)

The inspection intervals specified by the manufacturer and in guidelines ensure that the corresponding fire protection components are functional for the duration of their use. In addition, for certain areas in fire protection, directives require periodic renewal of the relevant system.

Central interim storage facility Zwilag

The components at the fire compartment boundaries are periodically checked and repaired or replaced if necessary. The inspection of the total of more than 2,000 fire seals takes place annually and is mapped with the help of a software tool designed for this purpose. The software also enables systematic planning and analysis of pending or completed procedures.

Mühleberg Nuclear Power Plant (KKM)

Maintenance is carried out by qualified personnel in accordance with the maintenance programme. The fire protection measures are periodically checked by the fire protection quality assurance department.

3.3.2 Ventilation systems

3.3.2.1 Ventilation system design: segregation and isolation provisions (as applicable)

Beznau Nuclear Power Plant (KKB) / Interim storage facility at Beznau NPP

Ventilation ducts that connect several fire compartments with each other are fitted with fire dampers in the case of components that form fire compartments. The fire dampers are connected to the fire alarm system and have a fire control. In the event of a fire or power failure, the fire dampers close automatically and the associated air unit is switched off.

If ventilation ducts without openings lead through several fire compartments, they are provided with fire protection cladding that has the necessary fire resistance.

Gösgen Nuclear Power Plant (KKG)

The nuclear ventilation system comprises the ventilation systems of the reactor building, annulus, auxiliary plant building and wet storage facility.

The nuclear ventilation system is a coherent system, i.e. it partly has common supply and exhaust air systems. The fire dampers are controlled selectively. The tasks of the nuclear ventilation systems are:

- Compliance with the specified environmental conditions in the rooms (including temperature and humidity)
- Compliance with directional air flows and specified negative pressures in the buildings
- Removal of any radioactive substances contained in the room air and thus protection of the personnel in the plant.
- Limit the release of radioactive substances via the exhaust air stack through appropriate filtering

The emergency building has its own ventilation system, which is set up line by line. In the course of the reconstruction of the emergency building, the ventilation system will be adapted.

The switchgear building is equipped with a complex ventilation system. Circulating air systems of the four redundancies and the general part are supplied with air via a common supply air and exhaust air system.

Leibstadt Nuclear Power Plant (KKL)

Ventilation ducts are equipped with fire dampers to isolate fire compartments. The fire resistance duration of the ventilation ducts and the fire dampers is based on the building classification and the defined use.

The ventilation systems are designed accordingly based on the safety classification of the buildings. The ventilations in the controlled zone are independent systems and clearly separated from the other ventilations.

Central interim storage facility Zwilag

The ventilation ducts and the fire dampers are designed for a fire resistance of 90 minutes and for cold smoke extraction from the rooms affected by the fire. Smoke extraction can only take place after the temperature of the flue gases has dropped below 60 °C.

The fire dampers are installed in the ducts of the supply air and exhaust air system at the fire compartment boundaries and receive a signal from the fire alarm control panel to close in the event of a fire.

Interim storage facility at Gösgen NPP

The wet storage facility has a supply and exhaust air system that ensures air exchange and negative pressure maintenance in the building. The cooling and dehumidification of the plant rooms is carried out via recirculation air systems. The plant rooms in the cooling towers are supplied with air via separate ventilation systems.

Mühleberg Nuclear Power Plant (KKM)

In the event of a fire, the majority of the ventilation system in the affected fire compartment is switched off. Exceptions result from the negative pressure maintenance within the controlled zone; here the ventilation systems are not automatically switched off. Fire compartments are isolated by automatic fire controls and by means of fire dampers.

3.3.2.2 Performance and management requirements under fire conditions

Beznau Nuclear Power Plant (KKB)

In the event of a fire, ventilation systems with a pure comfort function are taken out of operation by the fire control system and the associated fire dampers are closed. The status of the ventilation systems and fire dampers is displayed in the fire alarm control system.

Special operating instructions apply to the air-conditioning system of the main command room and its adjoining rooms as well as to the ventilation system in the adjoining building in case of fire.

In electrical rooms with gas extinguishing systems, the ventilation is automatically stopped in case of fire. After a successful extinguishing process, the room can be cleared of smoke by the ventilation system and flushed free of extinguishing agent.

In the emergency building, fire detectors are located in the outside air duct. In the event of a major fire outside the operational buildings (e.g. forest fire, aircraft crash), triggering the fire detector automatically switches the ventilation to recirculation mode to prevent corrosive gases or smoke from being drawn in.

The main stairwell of the emergency building has a smoke protection pressure system, whereby the pressure in the stairwell is increased with the help of a positive pressure fan to prevent smoke from entering.

Gösgen Nuclear Power Plant (KKG)

In the case of fire detection in the interior of the reactor building, the reactor building is sealed off from the air. In the case of fire detection in the annular space of the reactor building, both the interior and the annular space of the reactor building are sealed off from the air.

If a fire is detected in the emergency building, the ventilation system is switched off line by line. Duct 7 is supplied with air from both ducts, i.e. in the event of a fire, the affected duct is disconnected.

If a fire is detected in the switchgear building, the affected fire Chapter is isolated. The associated air circulation system continues to operate.

Leibstadt Nuclear Power Plant (KKL)

A basic distinction is made as to whether the ventilation system is located in a classified or unclassified building. The requirements for the ventilation system and its behaviour in case of fire are derived from this. Due to the assurance of nuclear safety, there may be deviations in the ventilation behaviour compared to guidelines in the conventional area for ventilation systems. As a rule, individual affected fire compartments are isolated by installed fire dampers and the ventilation is shut off. The requirements (e.g. fire resistance, etc.) for the ventilation ducts and the fire dampers as well as the fire matrix also depend on the classification of the building and the uses defined on site.

Central interim storage facility Zwilag

Since the fire conditions are already taken into account in the design of the ventilation systems at Zwilag in accordance with the applicable regulations, no requirements are placed on the ventilation systems under fire conditions that go beyond the design of the ventilation system.

Interim storage facility at Beznau NPP

The fire dampers are connected to the fire alarm system and have a fire control. In the event of a fire, the fire dampers close automatically and the corresponding ventilation systems are switched off in accordance with regulations.

Interim storage facility at Gösgen NPP

A selective fire control system is installed in the wet storage area. If a fire is detected in the wet storage area, the corresponding fire Chapter is isolated by closing the fire dampers and ventilation systems are switched off as required.

Mühleberg Nuclear Power Plant (KKM)

The fire dampers are connected to the fire alarm system and have a fire control. In case of fire, the fire dampers close automatically and the corresponding ventilation systems are switched off.

3.3.3 Licensee's experience of the implementation of the passive fire protection

3.3.3.1 Overview of strengths and weaknesses identified

Beznau Nuclear Power Plant (KKB)

The passive fire protection was implemented according to the currently valid fire protection concept. From the previous operation of the facility, the concept of passive fire protection has proven itself overall. The facility was built more than 50 years ago. Fire protection has developed massively during this time. The challenges are to keep the fire protection requirements and their implementation state of the art.

Passive fire protection is taken into account appropriately during plant modifications and upgrades.

Gösgen Nuclear Power Plant (KKG)

The strengths of structural fire protection in the KKG include the most far-reaching consistent separation of redundancies, the use of extinguishing systems for higher fire loads and the formation of fire compartments for higher fire loads.

Tests with removed fire doors that have been in use since the beginning of operations have shown that the required fire resistance of old doors is generally met. A project to upgrade the fire doors is currently underway.

One of the weaknesses of the structural fire protection in the KKG in particular is that the facility was built about 45 years ago and thus components meet the requirements from that time.

Leibstadt Nuclear Power Plant (KKL)

Due to the increased requirements for ensuring nuclear safety, more periodic inspections of system parts relevant to fire protection are carried out than specified by the guidelines. This results in a more in-depth and up-to-date knowledge of the system condition.

It is seen as a challenge that the structural fire protection in the facility was planned and executed about 45 years ago. Thus, increased maintenance measures are necessary.

Central interim storage facility Zwilag

Passive fire protection was implemented in accordance with VKF guidelines under the supervision of the competent authority, the Aargauische Gebäudeversicherung. From the operation of the facility's HLW repository to date, there are no indications of general strengths or weaknesses in passive fire protection.

Interim storage facility at Beznau NPP

The passive fire protection was implemented according to the currently valid fire protection concept. From the previous operation of the ZWIBEZ, the concept of passive fire protection has proven itself overall. The intervals for the periodic inspection of fire controls correspond to the state of the art. They have proven to be purposeful and expedient. Passive fire protection is taken into account appropriately in the case of plant modifications and upgrades.

Interim storage facility at Gösgen NPP

The basis for the construction of the wet storage facility was the VKF fire protection regulations 2003, i.e. the wet storage facility corresponds to the state of the art.

Mühleberg Nuclear Power Plant (KKM)

The structural measures for passive fire protection planned and applied on the basis of the fire protection concept provide sufficient and targeted protection against fires and their impact on the site. The existing order or change procedures are applied with corresponding clear orders, measures and responsibilities.

In the course of the decommissioning, the applied ongoing sensitisation of staff and regular housekeeping with regard to fire safety is assessed as a strength.

The cost-intensive and time-consuming changeability is assessed as a weakness in structural fire protection. The passive fire protection measures are shaped by the decommissioning process and are continuously evaluated and, if necessary, adapted due to the constantly changing environmental conditions. In the event of corresponding changes, the fire protection authority is involved in the decision-making process.

During decommissioning, the proven maintenance process continues to be applied, which includes all measures to preserve and restore the target condition as well as to determine and assess the actual condition of electrical and mechanical components of the dismantling operation systems and of building structures. This proven process fulfils the requirement to maintain the functionality of the building structures as well as the operational capability of the systems and components through maintenance measures in compliance with the relevant regulations and guidelines.

3.3.3.2 Lessons learned from events, reviews, fire safety related missions

Beznau Nuclear Power Plant (KKB)

The events that have occurred in the past have confirmed the effectiveness of the existing passive fire protection measures. All events were detected very early by the fire alarm system and existing fire controls were triggered so that there was no impact on other parts of the facility.

Gösgen Nuclear Power Plant (KKG) / Interim storage facility at Gösgen NPP

Around 2200 fire doors are installed in the KKG. In 2013/2014, an inventory and status analysis was carried out. By 2019, 69 fire doors had been replaced, 79 fire doors converted and a further 882 upgraded.

The bulkheads and fire protection expansion joints have been or will be signposted on site and entered into a database. It has proved particularly useful that the signage is duplicated. This way, in case of a defect or when removing the bulkhead system, one signage can be removed and handed over to the person in charge. After the bulkhead system has been repaired, it is reattached.

After it was determined in 2016 that individual fire dampers were not closing completely and that the fire dampers used did not meet today's requirements, it was decided that all fire dampers from the time the power plant was built would be replaced and controlled via a fire damper control system.

Leibstadt Nuclear Power Plant (KKL)

Due to the increased periodic inspections, e.g. signs of ageing can be detected at an early stage and corresponding measures can be initiated even before the actual occurrence of defects.

Central interim storage facility Zwilag

In the operating history to date, there was one event that prompted an improvement in the inspection of fire partitions. A cable fire in an underground duct in the neighbouring PSI led to an automatic fire alarm in building N of the Zwilag, which was triggered by smoke gases that had passed through the duct and the bulkheads into building N. The fire alarm was triggered by a fire.

Interim storage facility at Beznau NPP

No fire incidents have occurred in the ZWIBEZ since commissioning.

Mühleberg Nuclear Power Plant (KKM)

Since the cessation of service operations at the end of 2019, no internal event has occurred at the KKM that has called passive fire protection into question.

3.3.3.3 Overview of actions and implementation status

Beznau Nuclear Power Plant (KKB) / Interim storage facility at Beznau NPP

As part of a renovation project of the fire protection measures, the existing fire dampers were replaced and additional fire dampers were installed over the years. Based on previous experience, no measures to improve passive fire protection are currently planned.

Gösgen Nuclear Power Plant (KKG) / Interim storage facility at Gösgen NPP

Since 2015, the fire doors have been inspected annually and repaired if necessary.

The on-site signage of the bulkheads and fire protection expansion joints has not yet been completed.

The replacement of the fire dampers began in 2019. The replacement is expected to be completed in 2025.

There are no open measures in the wet storage.

Leibstadt Nuclear Power Plant (KKL)

Any measures are transferred to a catalogue of measures, where they are recorded, assessed and prioritised accordingly.

Central interim storage facility Zwilag

The development of a software tool that lists all the bulkheads and checks them was correct and forward-looking.

Mühleberg Nuclear Power Plant (KKM)

All structural measures can be found in the fire protection concept. All corresponding changes in passive fire protection were planned, approved and implemented in coordination with the fire protection quality assurance and the fire protection authorities. The status of the changes can be seen in previous monthly reports of the site.

3.3.4 Regulator's assessment of the passive fire protection

3.3.4.1 Overview of strengths and weaknesses identified

Beznau Nuclear Power Plant (KKB) / Interim storage facility at Beznau NPP

The challenges of a facility built more than 50 years ago are to keep the fire protection measures up to the state of the art. At the time of construction of the KKB, the usual fire protection measures were taken. The reinforcement coverings correspond to the national regulations valid at that time. From ENSI's point of view, there are deviations in the original plant areas compared to the currently valid regulations, but these can be partially compensated for by the use of wet or dry extinguishing systems in critical areas.

Some of the fire compartments in the original plant areas no longer correspond to the current state of the art. At the time the facility was built, the redundancies of the safety systems were not accommodated in their own fire compartments. The individual redundancies are partly in common fire compartments separated only by fire protection curtains. From ENSI's point of view, a direct fire spread can be prevented, but the entire affected fire compartment will be contaminated with fire gases in the event of a fire.

With a view to adapting to the state of the art, an emergency building was retrofitted in each unit at the KKB. This building contains emergency systems that can be used to bring each unit into a safe state independently of the safety systems in the original plant areas. The emergency buildings are structurally separated from the other buildings in such a way that the passive fire protection requirements are met from ENSI's point of view. The supply air ducts in the emergency buildings are equipped with duct smoke detectors. If the smoke detectors are activated, the air supply from outside is interrupted and the ventilation is then continued in recirculation mode, so that self-sufficient operation of the emergency systems is ensured.

In the KKB, the fire dampers have been replaced so that the new dampers correspond to the current state of the art from ENSI's point of view. The fire resistance duration of the fire dampers generally corresponds to the fire resistance of the breached fire compartment.

Combustible filters in the exhaust air systems are mounted in non-combustible housings. In case of fire, the combustible filter systems can be bypassed with a bypass. The ventilation systems are switched off or continue to operate in a protection-target-oriented manner. By selectively controlling the fire dampers, the individual fire compartments can be isolated in a targeted manner.

Gösgen Nuclear Power Plant (KKG)

In the KKG, the redundancies of the safety systems and the emergency systems were already separated as far as possible during the construction phase when implementing structural fire protection, and the fire compartmentation was adapted for higher fire loads. Exceptions are, in particular, the annular space and the containment in the reactor building. Alternatively, appropriate extinguishing systems were retrofitted for higher fire loads. In ENSI's view, the fire protection measures implemented, depending on the type and scope of the plant modification, are appropriate.

In a few safety-relevant areas, the structural fire compartmentation is in place, but missing fire dampers mean that there are gaps in the fire compartmentation. These gaps are currently being closed by retrofitting the missing fire dampers.

From ENSI's point of view, the tests carried out in the KKG on the removed fire doors from the construction period provide valuable findings that will be taken into account in future assessments of fire protection measures.

Activated carbon filters are installed in non-combustible housings. In the event of a fire, the activated carbon filters can be bypassed via a bypass. The ventilation systems are switched off or continue to operate according to the protection goal. By selectively controlling the fire dampers, the individual fire compartments can be isolated in a targeted manner.

Leibstadt Nuclear Power Plant (KKL)

In the KKL, the redundancies of the safety systems and the emergency systems were already consistently separated structurally and accommodated in their own fire compartments during the implementation of structural fire protection in the construction phase. At the time of construction, the usual fire protection measures were taken. The reinforcement coverings correspond to the national regulations valid at that time. There are deviations from the currently valid regulations, but ENSI believes that these can be largely compensated for by the use of wet or dry extinguishing systems in critical areas.

Some of the fire compartments in the laundry no longer correspond to the current state of the art. The KKL is already planning plant modifications in this area.

ENSI considers the periodic inspections of passive fire protection equipment increasingly carried out by KKL to be a strength. Defects are recorded in a catalogue of measures and processed according to their importance. This increases knowledge of the current condition of the fire protection facilities so that maintenance measures can be initiated at an early stage.

Combustible filters in the exhaust air systems are mounted in non-combustible housings in the KKL. In the event of a fire, the combustible filter systems can be bypassed. The ventilation systems are switched off or continue to operate according to the protection goal. By selectively controlling the fire dampers, the individual fire compartments can be isolated in a targeted manner.

Central interim storage facility Zwilag

In the view of ENSI, passive fire protection was implemented at Zwilag during planning and construction in accordance with the corresponding requirements of the VKF guidelines. Based on operating experience to date, ENSI continues to assess the existing passive fire protection facilities as appropriate. Changes to passive fire protection are therefore not expected in the near future.

Interim storage facility at Gösgen NPP

One of the bases for the construction of the wet storage facility was the VKF fire regulations of 2003, which correspond to the state of the art in terms of content. Based on operating experience to date, ENSI continues to consider the existing passive fire protection facilities to be appropriate. Changes to passive fire protection are therefore not expected in the near future.

Mühleberg Nuclear Power Plant (KKM)

Since the start of the decommissioning of the KKM, it has become apparent from ENSI's point of view that the existing processes of the commissioning and modification procedure with the tasks, measures and responsibilities defined therein are assessed as a strength. This also continues to apply in the ongoing decommissioning process. Since the environmental conditions in the plant are constantly changing, also in the area of passive fire protection, a regular comparison between the TARGET and ACTUAL status is imperative. This requires regular findings and assessments of the situation on site. In this way, all employees remain sensitised to fire protection issues. The fire protection authorities and ENSI are involved in the decision-making process when appropriate changes are made.

As part of the deconstruction work, fire compartments must be adapted, and in this context adjustments will also be made to the ventilation systems. The adjustments will be supervised by the facility's fire protection officer and by an external QAO fire protection.

3.3.4.2 Lessons learned from inspection and assessment as part of the regulatory oversight

Beznau Nuclear Power Plant (KKB)

The existing passive fire protection equipment has proven to be fit for purpose in the events that have occurred in the past. All events were quickly detected and extinguished, so that there were no effects on other areas of the plant. In ENSI's view, the staggered protection principle has proved its worth here.

Gösgen Nuclear Power Plant (KKG) / Interim storage facility at Gösgen NPP

Based on the results of the tests carried out on removed fire doors, numerous closures were replaced or upgraded.

Furthermore, from ENSI's point of view, the double labelling introduced in the KKG for bulkheads and fire protection expansion joints has proven to be purposeful and practical. In the event of a defect or replacement of a component, a label can be removed and enclosed with the repair. In this way, the component is clearly marked regardless of its location and can then be repaired at the correct location.

In ENSI's view, the required installation of more than 500 new, state-of-the-art fire dampers was carried out by KKG very consistently and without any complaints.

Leibstadt Nuclear Power Plant (KKL)

KKL increasingly carries out periodic inspections of the passive fire protection equipment. This allows, for example, signs of ageing to be detected at an early stage. In this way, the necessary measures for repair can be initiated at an early stage. ENSI considers this procedure to be expedient. This ensures that the passive fire protection facilities remain functional throughout their entire service life.

Central interim storage facility Zwilag

All the existing passive fire protection equipment has proven to be fit for purpose. Only the inspection cycle of the installed fire partitions was adjusted after a fire event at the neighbouring PSI.

Interim storage facility at Beznau NPP

All existing passive fire protection measures have proven to be appropriate. There have been no fire incidents since commissioning.

Mühleberg Nuclear Power Plant (KKM)

Since the boundary conditions of the plant are constantly changing as dismantling progresses, ENSI regularly inspects the plant in order to be able to compare the TARGET and ACTUAL status of the passive fire protection facilities. From ENSI's point of view, this close monitoring is necessary in order to guarantee passive fire protection in all dismantling phases, and has proven to be purposeful and expedient.

3.4 Licensee's experience of the implementation of the fire protection concept

3.4.1 Overview of strengths and weaknesses identified

Beznau Nuclear Power Plant (KKB) / Interim storage facility at Beznau NPP

The fire protection concept for the Beznau nuclear power plant was drawn up in accordance with VKF fire protection guidelines under the supervision of the Aargau Building Insurance (AGV) and ENSI (formerly HSK). The plant's operation to date has not revealed any particular strengths or weaknesses in the fire protection concept. On the positive side, it can be noted that the regulations for avoiding fire loads have proven their worth.

Gösgen Nuclear Power Plant (KKG) / Interim storage facility at Gösgen NPP

The existing overarching fire protection concept was completely revised by the end of 2022 and approved by ENSI. In addition to the overarching fire protection concept, detailed fire protection concepts are currently being drawn up for each building. Despite the complexity of a nuclear power plant with around 35 different buildings and various requirements, the overarching fire protection concept provides a good overall view of the plant-specific fire protection measures.

A fire protection concept was drawn up for the construction of the wet storage facility when it was built, and this is still valid.

Leibstadt Nuclear Power Plant (KKL)

The fire protection organisation, the sensitisation of the employees for fire protection and the fire protection concept (which is periodically updated) have contributed significantly to the fact that no fire incidents with major consequential damage have occurred in the KKL.

The fire protection concept at the KKL describes the facility-specific fire protection requirements that must be met. In 2021, the KKL has decided to create a higher-level fire protection concept that will replace the current fire protection concept and update it at the same time. As in the previous fire protection concept, the future overarching fire protection concept will also refer to further documents in which the individual building-specific fire protection precautions are described in more detail. As a result, there are several documents relevant to fire protection in the KKL.

Central interim storage facility Zwilag

The Zwilag fire protection concept was implemented in accordance with VKF guidelines under the supervision of the AGV and ENSI (formerly HSK). The operation of the facility to date has not revealed any particular strengths or weaknesses in the fire protection concept. On the positive side, it can be noted that the regulations for avoiding fire loads have proven their worth.

Mühleberg Nuclear Power Plant (KKM)

Since the cessation of service operations at the end of 2019, the fire protection concept has been revised several times in accordance with the applicable decommissioning phase. These revisions were each carried out by the internal specialist departments and approved by the fire protection quality assurance department. Inspections, exchanges of experience and specific technical discussions with the fire protection authorities took place several times. Finally, the applicable fire protection concept is officially evaluated by the fire protection authority with the respective phase approval.

3.4.2 Lessons learned from events, reviews, fire safety related missions

Beznau Nuclear Power Plant (KKB) / Interim storage facility at Beznau NPP

The events to be dealt with over the last 20 years have confirmed the operational plans and processes to remedy identified deficiencies. These have been regularly adapted to changing situations.

Gösgen Nuclear Power Plant (KKG) / Interim storage facility at Gösgen NPP

During the revision of the overarching fire protection concept, deviations from the current VKF fire protection regulations were identified and evaluated. Based on this, improvements were made concerning, for example, the fire control of the ventilation system in the auxiliary and main cooling water buildings.

Leibstadt Nuclear Power Plant (KKL)

Based on internal evaluations of the existing fire protection concept, it was decided to optimise the fire protection concept and revise parts of it. The revised document forms the overarching fire protection concept.

Central interim storage facility Zwilag

In the entire operating history to date, there has not been a single fire incident except for one fire report due to a hot bearing of a ventilation fan. The emergency staff's journal on this matter shows that the staff had proceeded very precisely according to the checklists. All relevant units (fire brigade, emergency staff) were alerted in a timely manner.

Mühleberg Nuclear Power Plant (KKM)

Since the cessation of power operation at the end of 2019, no internal event has occurred at the KKM that would have led to a triggering or deployment of an extinguishing system

3.4.3 Overview of actions and implementation status

Beznau Nuclear Power Plant (KKB) / Interim storage facility at Beznau NPP

From the operation of the KKB and the ZWIBEZ so far, the concept for prevention or design against fire has proven itself overall in terms of availability, reliability and susceptibility to faults.

As part of a renovation project of the fire protection measures in the KKB, many new fire dampers were installed over the years, thus reducing the size of fire compartments. Furthermore, the fire alarm control system was replaced by a new system.

In the ZWIBEZ, additional fire detectors were retrofitted as part of an extended use of electrical cabinets.

The use of the individual buildings is periodically reviewed and the fire protection measures are adjusted. If necessary, reinforcements are identified and implemented according to the existing framework conditions. This is an ongoing, recurring process.

Based on previous experience, no measures to improve the fire protection concept are currently planned.

Gösgen Nuclear Power Plant (KKG) / Interim storage facility at Gösgen NPP

The detailed fire protection concepts for each building are currently being prepared. This is expected to be completed by the end of 2023.

In 2017, the mobile smoke extraction system was established. In the event of a fire, the room area affected by the fire is exhausted with mobile fans. This system proved its worth in an incident in 2019 (short circuit in a 10kV switchgear).

The retrofitting of an automatic ventilation closure of the emergency building in the event of a fire detection to improve the protection of the emergency systems against an external fire is in the implementation planning stage.

Based on previous experience, no measures to improve the fire protection concept are currently necessary or planned in the wet storage facility.

Leibstadt Nuclear Power Plant (KKL)

The new overarching fire protection concept is currently being coordinated with ENSI. Due to the approach of continuous improvement, new documents for fire protection are also being prepared for the overarching fire protection concept.

Central interim storage facility Zwilag

From the operation of Zwilag to date, the concept for precautionary measures and design against fire has proven itself overall in terms of availability, reliability and susceptibility to faults. Based on experience to date, no measures to improve the fire protection concept are currently necessary or planned.

Mühleberg Nuclear Power Plant (KKM)

All corresponding measures in connection with the valid fire protection concept were planned, approved and implemented in coordination with the fire protection authorities.

3.5 Regulator's assessment of the fire protection concept and conclusions

3.5.1 Overview of strengths and weaknesses identified

Beznau Nuclear Power Plant (KKB) / Interim storage facility at Beznau NPP

The employees of the KKB are trained in fire protection and are familiar with the existing fire protection concept. In ENSI's view, the level of safety awareness for fire protection issues at the KKB is therefore high. The important position of fire protection officer is filled by an experienced person who has sound fire protection training and knows the plant very well.

As part of the evaluation of the basic elements of the fire protection concept in Chapters 3.1 to 3.3, ENSI identified the following potential for improvement at the KKB (<u>National area for improvement</u>):

- The existing fire protection concept and, in particular, the associated plan bases are to be revised in accordance with the requirements laid down in the VKF fire protection regulations.
- In plant areas that were formerly free of fire loads, additional fire loads are stored that must be added to both the fire load management and the fire protection concept.
- The use of more battery-powered lifting and cleaning equipment must be added to the fire protection concept.

Gösgen Nuclear Power Plant (KKG) / Interim storage facility at Gösgen NPP

The employees of the KKG are trained in fire protection and are familiar with the existing fire protection concept. From ENSI's point of view, the level of safety awareness for fire protection issues at the KKG is therefore high. The important position of fire protection officer is filled by an experienced person who has sound fire protection training and knows the plant very well.

The KKG has drawn up a new overall fire protection concept which, from the KKG's point of view, largely reflects the current fire protection status of the facility. The KKG is vigorously pursuing the creation of detailed, building-specific fire protection concepts.

Leibstadt Nuclear Power Plant (KKL)

KKL employees are trained in fire protection and are familiar with the existing fire protection concept. From ENSI's point of view, safety awareness of fire protection issues at KKL can therefore be rated as high. The important position of fire protection officer has been filled by a new person who now has sound fire protection training and knows the plant well.

The existing fire protection concept is currently being revised at the KKL on the basis of a target/actual comparison. This revision is being carried out in close coordination with ENSI. The preparation of detailed, building-specific fire protection concepts has begun.

Central interim storage facility Zwilag

Zwilag employees are trained in fire protection and are familiar with the existing fire protection concept. ENSI therefore considers the level of safety awareness for fire protection issues at Zwilag to be high. The important position of fire protection officer is held by an experienced person who knows the plant very well.

As part of the evaluation of the basic elements of the fire protection concept in Chapters 3.1 to 3.3, ENSI identified the following potential for improvement at Zwilag (National area for improvement):

- The existing fire protection concept and, in particular, the associated plan bases must be revised in accordance with the requirements set out in the VKF fire protection regulations.

Mühleberg Nuclear Power Plant (KKM)

The employees of the KKM are trained in fire protection and are familiar with the current fire protection concept during the decommissioning phases. ENSI is therefore of the opinion that the level of safety awareness for fire protection issues at KKM is high. The important position of fire protection officer is filled by an experienced person who has sound training and knows the plant very well.

The fire protection conditions, which change almost daily due to the dismantling of the KKM, represent a particular challenge. From ENSI's point of view, the individual dismantling phases have so far been mapped in a targeted manner in the fire protection concept and also in the fire protection plans .

3.5.2 Lessons learned from inspection and assessment as part of the regulatory oversight

Nuclear facilities

The operational fire brigades at Swiss nuclear facilities comply with the specifications issued by the responsible cantonal building insurers with regard to crew size, capability, training, material and the number of exercise units per year. Exercises are regularly organised with the neighbouring fire brigades, which support the plant fire brigades when required, in order to train the behaviour of the members of the neighbouring fire brigades on the plants.

Due to the large number of different alarm systems in Swiss nuclear facilities, ENSI believes that additional regulatory requirements are needed for the design of alarm systems (National area for improvement).

Nuclear power plants in operation

From ENSI's point of view, the increasing age of Swiss nuclear power plants, in conjunction with the original design, means that the challenges with regard to fire protection are becoming ever greater. For example, a fire protection inspection by ENSI at KKB clearly showed that deficiencies had arisen in the formation of fire compartments in non-safety-relevant areas in connection with the increased heat loads over the years, which have to be dissipated through ventilation. Furthermore, the old age of the original components has led to higher oil consumption. In order to ensure smooth operation, mobile fire loads are therefore increasingly brought into the fire compartments.

In the KKG, the fire dampers had to be replaced for ageing reasons. Some of the cables in the KKG still contribute too much to a fire and develop corrosive gases. In the course of replacement, these are exchanged for cables that comply with current SN-EN standards (including halogen-free, flame-retardant, self-extinguishing behaviour).

The outages require increased attention because there are many people in the facilities. Established processes (e.g. fire load management) can sometimes no longer be adhered. In the KKL, for example, some fire doors were locked open during the annual overhaul and considerable fire loads were temporarily stored in some connecting corridors.

At the KKL, it was found that the maintenance work required for the extinguishing systems had not been documented and it was therefore not evident whether the prescribed maintenance work had also been carried out.

In construction projects, fire protection should be included in the approval process at an early stage so as not to delay this process.

Dedicated spent fuel storage facilities

ENSI has not carried out any fire protection inspections at the interim storage facilities ZWIBEZ and Zwilag or at the wet storage facility KKG for quite some time. ENSI will intensify its inspection activities at these facilities as a potential area for improvement (National area for improvement).

Facilities under decommissioning

Due to the deconstruction, the situations in the KKM are constantly changing. Formerly established processes can no longer be applied, so that more personnel and flexible processes adapted to the progress of dismantling are needed to maintain fire protection. From ENSI's point of view, close monitoring of the dismantling work with regard to the assessment of the adjustments to the fire protection measures has proven to be purposeful and expedient.

With regard to organisational fire protection in particular, ENSI found that fire loads had been introduced into the turbine building that had not been accounted for, and that KKM had no knowledge that an external company had introduced highly flammable liquids. Furthermore, the items of mobile extinguishing equipment such as hand-held fire extinguishers were not systematically recorded during the dismantling work. As a result, some portable fire extinguishers were not properly maintained.

4 Overall Assessment and General Conclusions

In the previous chapters of the National Assessment Report NAR), ENSI has used the reports submitted by the Swiss licensees to assess the scope, methologies and results of the fire safety analyses performed and the implementation of the fire protection concept in the Swiss nuclear installations which are to be addressed in the Topical Peer Review. In the chapters below, these assessments are summarized, and general conclusions are drawn from them.

4.1 National Regulatory Framework

The structural, technical and organisational requirements for fire protection in Switzerland are laid down in the standard and the associated guidelines of the Association of Cantonal Fire Insurers (VKF) /12/. These legal requirements must also be implemented in nuclear facilities, as far as reasonably applicable. Due to the specific requirements in nuclear legislation, additional fire protection requirements in the supervisory area of ENSI are required in addition to the VKF and cantonal fire protection requirements.

The previous requirements for fire protection in Swiss nuclear facilities are currently still laid down in guideline HSK-R-50. /13/. This guideline will be replaced in 2024 by the new guideline ENSI-G18 /14/ which contains more comprehensive and detailed fire protection requirements and is harmonised with the corresponding international requirements of the IAEA and WENRA. The basic fire protection requirement in both directives is compliance with the nuclear and radiological protection objectives in the event of a fire by means of staggered fire protection precautions (defence in depth principle).

For the Swiss nuclear power plants in operation, the review of fire protection measures in accordance with guidelines ENSI-A01 /20/ and ENSI-A05 /23/ must be updated every 10 years at the latest as part of the periodic safety review. For other nuclear installations, graded requirements for fire analyses apply depending on the hazard potential (graded approach).

In the context of the self-assessment of the implementation of the revised WENRA Safety Reference Level (SRL) /27/ ENSI concluded that the overriding requirements of the new Issue SV "Internal Hazards" are covered in particular by the legal requirements in Switzerland and the guidelines ENSI-A01 and ENSI-A05. The additional, specific requirements for fire protection (SRL SV6.1-6.14) are covered with the publication of the new guideline ENSI-G18.

4.2 Fire Safety Analyses

Nuclear power plants in operation

In accordance with the requirements of the guidelines ENSI-A01 and ENSI-A05, both deterministic and probabilistic fire analyses are performed at Swiss nuclear power plants. The deterministic fire analysis is based on the fire occurrence frequencies and relevant fire compartments determined in the probabilistic fire analysis and also includes exclusively radiologically relevant plant areas with activity-carrying components. Both analyses serve to review the fire protection concept implemented in the facility from different perspectives and to assess the effectiveness of the fire protection measures.

The probabilistic fire analyses carried out in the Swiss nuclear power plants cover the main plant areas and plant conditions, and the effects of both internally and externally triggered fires are systematically investigated using the analysis steps specified in the guideline ENSI-A05.

In addition to direct fire-related failures, the analyses also include multiple spurious operations (MSO) according to internationally recognised methods. For more refined analyses of the fire effects within a fire compartment, proven fire simulation programs are used, with which multi-compartment analyses (MCA) are also carried out, taking into account the main fire phenomena. During the plant inspections carried out by ENSI to verify the boundary conditions of the probabilistic fire analyses, a need for improvement was identified in individual cases, particularly with regard to the assumptions for the distribution of the fire loads and the possible fire effects.

From ENSI's point of view, the probabilistic fire analyses of the Swiss nuclear power plants are of high quality and largely correspond to the international state of the art. This assessment was explicitly confirmed for the PSA of the Leibstadt nuclear power plant (KKL) as part of an IAEA peer review mission (IPSART). From the review of the fire PSA of the Gösgen nuclear power plant, ENSI identified a need for improvement, among other things, due to the further development, in particular, of the methods for determining fire occurrence frequencies and for handling fire-related short circuits (National area for improvement, ChapterChapter 2.1.7.1). ENSI will continue to pursue the implementation of this need for improvement in the ongoing supervisory process.

In ENSI's view, the deterministic fire analyses of the Beznau (KKB) and Gösgen (KKG) nuclear power plants submitted as part of the last periodic safety reviews do not yet comprehensively fulfil the requirements newly specified in guideline ENSI-A01 in 2018 and require appropriate updating (National area for improvement, ChapterChapter 2.1.7.1). The deterministic fire analysis submitted by the Leibstadt nuclear power plant (KKL) in 2022 is currently being reviewed by ENSI. The first impression is that this analysis is closely oriented to the new methodological requirements laid down in guideline ENSI-A01.

From ENSI's point of view, the results of the probabilistic fire analyses show that, due to the extensive fire protection measures taken in the Swiss nuclear power plants, the fire risk does not make a dominant contribution to the core damage frequency (CDF) and the fire-related CDF contribution is also below the target value defined in guideline ENSI-A05 for concrete measures to reduce the risk contribution. Due to the project-accompanying evaluation of plant modifications, significant changes in the area of fire protection are also included in the update of the probabilistic fire analyses, so that they reflect the current plant condition. From ENSI's point of view, the significantly lower fire-related CDF contribution of KKL compared to the fire-related CDF contributions of KKB and KKG is due to the very consistent fire protection separation of the individual redundancies of the safety and emergency systems in all safety-relevant plant areas.

Even though there is still a need for methodological improvement in the deterministic fire analyses, the results of the fire simulations confirm that in the newer plants KKG and KKL, due to the structural and spatial separation in most plant areas, no more than one redundancy of the safety or emergency systems can be endangered by a fire and thus the shutdown paths for transferring the plants to a safe state remain intact. In the KKB, the fire simulations show that at least two independent shutdown paths remain available in the event of a fire and thus the single fault criterion is fulfilled as a basic design requirement. The main steam blowdown station was identified as a critical plant area at the KKB due to the lack of fire protection separation of the individual safety lines under narrow spatial conditions (National area for improvement, Chapter 2.1.7.1). Concrete measures are planned here to further reduce the probability of a fire.

The new earthquake verifications to be performed show in all Swiss nuclear power plants that the shutdown paths credited in the deterministic fire analyses are not affected by seismically induced fires, since the equipment of the shutdown paths is sufficiently seismically robust and no ignition sources have been identified that pose a fire hazard to this equipment.

Dedicated spent fuel storage facilities

In accordance with the requirements of the guidelines ENSI-A01 and ENSI-A05, a decision must be made on a case-by-case basis for interim storage facilities in Switzerland as to the level of detail of deterministic fire analyses and whether probabilistic fire analyses should also be carried out. Based on the results of the deterministic fire analyses, ENSI has decided that no probabilistic fire analyses need to be carried out for the interim storage facilities in Switzerland.

High-active spent fuel elements are stored in all the interim storage facilities dealt with in the NAR. Regardless of the different types of storage, both in the wet storage facility of the KKG and in the dry storage facilities Zwilag and ZWIBEZ, the storage areas are passively cooled and there are only very low fire loads and ignition sources.

Internal fires as well as externally caused fires do not lead to inadmissible activity releases in the storage areas for high-level waste of the Zwilag and ZWIBEZ interim storage facilities due to the transport and storage containers designed to withstand the effects of fire as a result of an accidental aircraft crash and the design of the buildings to withstand earthquakes.

This assessment is to be applied analogously to the wet storage facility of the KKG. The protection goals "residual heat removal" and "subcriticality" are not endangered in the case of internal and externally caused fires due to the fire protection measures implemented there (including fire protection separation of the building areas and the redundant heat removal systems as well as a fire alarm system) and the design of the building against a safe shutdown earthquake and aircraft crash.

The waiver of a detailed fire analysis is thus justified from ENSI's point of view for the HAW storage facilities.

In accordance with the acceptance conditions, no radioactive waste containing spontaneously combustible or explosive substances is stored in the interim storage facilities Zwibez and ZWILAG. The waste is in sealed containers, encapsulated and conditioned, or in the case of raw waste, compressed and encapsulated. From ENSI's point of view, the only hazard assumptions to be taken into account for the fire analyses are a hypothetical spontaneous combustion of a waste package or external impacts. A fire caused by spontaneous combustion has not yet occurred in either interim storage facility.

Building M of the interim storage facility ZWIBEZ, in which only intermediate-level waste is stored for the long term, is protected against impacts from a safe shutdown earthquake and an impacting aircraft, just like the wet storage facility of the KKG. An impermissible release of activity due to externally caused fires is therefore not to be expected.

Since combustible, solidified radioactive waste is also stored in Building M, the radiological effects of a covering fire scenario, namely spontaneous combustion of a waste package stored there, were analysed. The fire analysis carried out shows that, due to the existing fire protection measures (including fire protection separation of the building areas and suppression systems), there is no inadmissible release of activity. The permissible dose value according to the regulatory requirements is clearly undercut.

The buildings or building areas in which low-level waste is stored are designed against the safe shutdown earthquake in both interim storage facilities, but not against an aircraft crash. The storage containers are also secured against tipping over in the event of a an earthquake. The fire analyses carried out for these buildings therefore include internal fires caused by self-triggering and as a result of the impact of an aircraft.

The fire analyses carried out for several fire scenarios that ENSI considers to be covered show that, due to the existing passive fire protection measures (including fire protection separation of the building areas and separation of the containers), there is also no inadmissible release of activity. The permissible dose value according to the regulatory requirements is clearly undercut.

The fire analyses in the Swiss interim storage facilities were carried out in each licensing phase of the individual storage buildings and checked by ENSI. Up to now, the fire analyses have mainly been updated in the event of applications for changes to the acceptance conditions, conversion of the storage buildings or an increase in the number of casks stored. A comprehensive periodic safety review (PSR) has so far only been required for nuclear power plants. In accordance with an IRRS recommendation from 2021, an extension of PSR to other nuclear facilities, such as the interim storage facilities discussed here, is currently being considered.

As part of the evaluation of the fire analyses updated due to an adjustment of the acceptance conditions for low-active waste at the ZWIBEZ interim storage facility, ENSI requested that the possibility of seismic induced fires be investigated and evaluated (National area for improvement, ChapterChapter 2.4.7.1). This need for improvement is being pursued in the ongoing supervisory process.

Facilities under decommissioning

After final decommissioning, the Mühleberg nuclear power plant (KKM) was transferred to decommissioning phase 1 (SP1) in September 2020. As of 30 June 2022, the plant was still in decommissioning phase 1 and some of the fuel assemblies were still stored in the spent fuel pool inside the containment. Since September 2023, decommissioning phase 1 has been completed, the plant is free of nuclear fuel and has been transferred to decommissioning phase 2 (SP2).

Although not explicitly mentioned in the guidelines ENSI-A01 and ENSI-A05, the same principles regarding the level of detail of deterministic fire analyses apply to nuclear facilities in decommissioning as to the interim storage facilities.

The probabilistic fire analysis developed for the decommissioning phase of the KKM was adapted to the specific boundary conditions of SP1. The focus was on the analysis of fire effects on the cooling of the spent fuel pool. With the transition to SP2, there was no longer any need for a probabilistic safety analysis.

From ENSI's point of view, the fire scenarios considered in the deterministic fire analyses cover the dismantling and decommissioning conditions specific to SP1 and SP2. The effects of internal fires in buildings and on the plant site as well as fires triggered by earthquakes were analysed. The fire analyses carried out show that there is no inadmissible release of activity due to the existing fire protection measures. The dose value is significantly below the permissible dose value according to the regulatory requirements.

4.3 Fire Protection Concept and its Implementation

Every Swiss nuclear facility has a fire protection concept that defines the objectives and principles of fire protection. The fire protection concepts set out the structural, technical and organisational measures implemented in the facilities.

However, for the Beznau nuclear power plant and the interim storage facilities ZWIBEZ and Zwilag, ENSI considers it necessary to update and supplement the fire protection concepts and associated documentation in accordance with the national fire protection regulations (National area for improvement, Chapters 3.1.4.1 and 3.5.1).

In addition, ENSI has recognised that its inspection activities in the interim storage facilities need to be expanded (National area for improvement, Chapters 3.1.4.2 and 3.5.2).

Fire prevention

During the construction of the nuclear facilities, care was taken to ensure that only non-combustible or hardly combustible materials were used. The choice of materials also took into account the possible corrosive effects of fire gases and vapours. In ENSI's view, these principles will continue to be followed.

In all nuclear facilities, the existing mobile and immobile fire loads are systematically recorded in a fire load inventory from ENSI's perspective and monitored as part of fire load management. For this purpose, regular fire protection walkdowns are carried out to check compliance with the maximum permissible fire loads per fire compartment.

The existing ignition sources are also systematically recorded and evaluated. From ENSI's point of view, there are established processes for any necessary hot work, in which the substitute measures to be taken are specified. The operating personnel receive regular training in this regard.

From ENSI's point of view, there are clear acceptance conditions for the delivery of radioactive waste to the interim storage facilities Zwilag and ZWIBEZ. Accordingly, the radioactive waste must generally not contain any spontaneously combustible or explosive substances. Spent fuel elements from the nuclear power plants are only stored in transport and storage containers with specific approval. Other waste must be delivered conditioned or compressed in non-combustible containers. The permissible quantity of stored, combustible raw waste is administratively limited.

The storage area concept in the storage areas for high-level waste of Zwilag and ZWIBEZ was developed in such a way that inadmissible ambient conditions (temperatures) are prevented by natural ventilation in both storage areas. In the storage areas for low- and intermediate-level waste, artificial ventilation ensures that no inadmissible ambient conditions (temperatures, gas formation) arise.

In the wet storage facility of the Gösgen nuclear power plant, spent fuel elements are handled exclusively under water. Inert gas monitors are used at the edge of the pool and in the exhaust air from the ventilation systems to monitor possible gas leaks from the fuel assemblies.

At the Mühleberg nuclear power plant, which is currently being decommissioned, the major ignition sources and fire loads resulting from power operation have already been removed. These are being continuously reduced through the ongoing decommissioning and dismantling of systems. The new fire loads and ignition sources introduced as a result of the dismantling work have been recorded and taken into account in the fire protection measures.

From ENSI's point of view, operating experience to date confirms that the goal of minimising fire loads and ignition sources is consistently pursued in Swiss nuclear facilities. The requirements specified in this regard in WENRA Safety Reference Levels SV 6.11, S-26 and S-27 are met in Swiss nuclear facilities.

Active fire protection

Fire detection and alarm

Swiss nuclear facilities are automatically monitored by fire alarm systems. The systems are designed in accordance with the national regulations of the Association of Cantonal Fire Insurances (VKF) and the Association of Swiss Installers of Security Systems (SES). In the controlled zone, every room is monitored by fire detectors regardless of the existing fire load. Rooms with a high radiation load are excluded. Manual alarm buttons are installed at the entrance to escape and rescue routes.

Alarm, fault and status signals are transmitted via the fire alarm control systems to the main control room of the nuclear power plants or to a permanently stuffed position in the other nuclear facilities. Based on these signals, the status of the fire protection equipment (e.g. triggering of fire detectors and extinguishing systems, position of fire dampers) can be recognised at any time. To ensure high availability, the fire alarm centres in the individual plant areas are connected to an uninterruptible emergency power supply in addition to the internal battery supply for 12 hours.

In the event of a fire, the operating personnel in the nuclear power plants are alerted via the main command room or the control centre; in the other nuclear facilities, they are alerted via a permanently stuffed office. Various technical alarm options are available for this purpose.

Due to the large number of different alarm systems in Swiss nuclear facilities, ENSI believes that additional regulatory requirements are needed on how the alarm systems are to be designed (National area for improvement, Chapters 3.2.5.1 and 3.5.2).

At the Mühleberg nuclear power plant, the plant areas to be monitored by the fire alarm system will be adjusted during decommissioning in consultation with ENSI and in accordance with the fire protection concept, depending on the progress of dismantling and protection of the plant areas.

The fire alarm systems in Swiss nuclear facilities are continuously maintained in accordance with the SES national regulations. In ENSI's view, appropriately trained personnel are available for this purpose.

From ENSI's point of view, operating experience to date shows that targeted monitoring of possible fire locations in Swiss nuclear facilities and timely alerting are guaranteed. The requirements specified in this regard in WENRA Safety Reference Levels SV 6.8 and 6.11 are met in the Swiss nuclear facilities.

Fire suppression

The Swiss nuclear facilities have adequately dimensioned stationary extinguishing systems for firefighting, which are used fully automatically, remotely (controlled) or manually on site. From ENSI's point of view, the type of extinguishing equipment is matched to the existing fire hazard and the use of the appropriate extinguishing agent.

Fire-fighting water can be drawn from several diverse sources. Depending on the plant, these are the power plant's own high reservoir facilities, groundwater pumping stations or drinking water supplies from neighbouring communities. The extinguishing water is fed into the individual buildings and consumers via the connected distribution network. From ENSI's point of view, sufficient supply options are available for all plant areas in an emergency case. In addition, sufficient retention systems for extinguishing water are installed in all Swiss nuclear facilities in order to prevent the negative effects from extinguishing operations or a false triggering of extinguishing water systems.

At the Mühleberg nuclear power plant, the permanently installed extinguishing systems will be dismantled and the fire protection plans adapted in consultation with ENSI and in accordance with the fire protection concept, depending on the progress of dismantling and protection of the plant areas.

From ENSI's perspective, the extinguishing systems in Swiss nuclear facilities are maintained and tested in accordance with national regulations. In addition, employees are periodically trained in the use of the extinguishing systems, which have to be operated manually on site.

From ENSI's point of view, operating experience to date shows that the extinguishing systems in Swiss nuclear facilities are operational. The requirements specified in WENRA Safety Reference Levels SV 6.9 to 6.11 are met in Swiss nuclear facilities.

Administrative and organisational firefighting issues

ENSI is not responsible for the supervision of the operational fire brigades of Swiss nuclear facilities. The operational fire brigades are monitored and inspected by the responsible cantonal building insurers.

The cantonal building insurances carry out annual exercise inspections and a material inspection every five years. Furthermore, the operational readiness of the fire brigade is also checked every five years with an unannounced alarm inspection. The company fire brigades are required to carry out an unannounced operational exercise every year.

All operational fire brigades in Swiss nuclear facilities meet the requirements issued by the responsible cantonal building insurers with regard to crew size, skills, training, material and the number of exercises per year. Exercises are regularly organised in the nuclear facilities with the neighbouring fire brigades, which support the plant fire brigades when required, in order to train the coordination of both fire brigades. In addition, several exercises are also held with the fire protection equipment stored in the external Reitnau storage facility for all nuclear power plants. Once a year, each plant fire brigade has to request the various pumps from the Reitnau external storage facility and practise their use.

From ENSI's point of view, compliance with the requirements specified in WENRA Safety Reference Levels SV 5.10 and 6.11 to 6.14 can be concluded on the basis of the known evaluations of the exercises carried out.

Passive fire protection

Fire barriers

The safety-relevant buildings in the Swiss nuclear facilities are basically divided into fire compartments. The fire compartments were defined taking into account conventional fire protection requirements (including existing fire loads, room use and room size), but above all the aspects of nuclear safety and radiation protection were decisive.

In the oldest nuclear power plant Beznau, the fire compartments in the original plant areas no longer correspond to the current state of the art. For example, at the time of construction, the redundancies of the safety systems were not accommodated in their own fire compartments. Extinguishing systems are installed in the critical areas as partial compensation measures. However, ENSI considers the most effective measure to be the retrofitting of emergency systems, which are housed in separate buildings and are independent of the original safety systems. In the other nuclear power plants, a cross-redundancy fire event is largely prevented by the fire protection separation of the safety systems.

The fire resistance duration of the fire compartments in Swiss nuclear facilities varies between 30 and 90 minutes, depending on the fire closure. Higher requirements apply to ceilings and walls forming fire compartments and to escape and rescue routes. In ENSI's view, the fire spread simulations carried out in the fire analyses confirm that the fire resistance duration of the fire compartments in the Swiss nuclear power plants is sufficient. Based on operating experience to date, ENSI assesses the existing passive fire protection facilities in the interim storage facilities as appropriate.

From ENSI's point of view, professional maintenance in all Swiss nuclear facilities ensures that the fire compartment boundaries, in particular fire partitions and fire compartment-forming components, are in a condition that meets the requirements.

Due to the reduction in fire loads and ignition sources during the decommissioning of the Mühleberg nuclear power plant and the loss of safety significance of the remaining systems, fire compartments may also be reduced, provisionally created or completely omitted in agreement with the fire protection authority. From ENSI's point of view, such changes will be systematically updated in the fire protection plans.

The requirements for fire barriers specified in WENRA Safety Reference Levels SV 6.5 and 6.11 are met in Swiss nuclear facilities.

Ventilation systems

The general rule for ventilation systems in Swiss nuclear facilities is that ventilation ducts connecting several fire compartments are fitted with fire dampers at fire compartment boundaries. In the past, deviations from this principle were only found in individual cases in Swiss nuclear facilities. The fire dampers are selectively activated via the fire controllers. In the event of a fire, the fire dampers close automatically and the affected fire compartment is isolated in a targeted manner. In ENSI's view, this effectively prevents the spread of fire.

If ventilation ducts without openings lead through several fire compartments, these are provided with fire protection cladding. The fire resistance of the fire protection cladding corresponds to that of the fire compartments. The ventilation ducts and the fire dampers have a fire resistance of at least 60 minutes and are in most cases designed for cold smoke extraction from the fire compartment affected by the fire.

In the event of a fire, depending on the design of the ventilation system, the type of components housed in the fire compartment and its use, as well as the nuclear and radiological protection objectives pursued, the ventilation systems are switched off or continue to operate.

From ENSI's point of view, operating experience to date shows that in the few cases in which a request was made, the fire compartments were isolated in a targeted manner by fire dampers. The requirements for ventilation systems specified in WENRA Safety Reference Levels SV 6.6 and 6.7 are met in Swiss nuclear facilities.

4.4 General conclusions

Fire Safety Analyses

Nuclear power plants in operation

Overall, from ENSI's point of view, the probabilistic and deterministic fire analyses performed by the Swiss nuclear power plants in operation fulfil the requirements specified in WENRA SRL SV 6.1 and E 6.1. The analyses show the high level of protection of Swiss nuclear power plants against internally and seismically triggered fires by demonstrating the shutdown to a safe state with the safety or emergency systems even under conservative boundary conditions. The findings from the analyses of fire effects as a result of an aircraft crash have not been dealt with in the NAR for reasons of information protection.

Manual fire extinguishing by the fire brigade has only been considered in a few fire scenarios in the fire analyses of the Swiss nuclear power plants, since the critical fire sections are mostly protected by automatic extinguishing systems. In accordance with regulatory requirements, manual fire extinguishing was also only taken into account if there was sufficient time available for intervention on the basis of the fire spread simulations. WENRA SRL SV 6.2 is thus also fulfilled.

From ENSI's point of view, it has been possible to derive specific measures for improving fire protection in Swiss nuclear power plants from the fire analyses carried out to date.

Dedicated spent fuel storage facilities

Overall, from ENSI's point of view, the deterministic fire analyses performed for the Swiss interim storage facilities fulfil the requirements specified in WENRA SRL S-30 and E 6.1. Due to the existing specific protective measures against fires resulting from earthquakes and aircraft crashes, there is no need for detailed fire analyses for the repositories with high-level waste.

Fire scenarios covering internal fires and externally triggered fires were analysed for the storage facilities with low- and intermediate-level waste. The fire analyses show that no inadmissible activity releases occur due to the existing fire protection measures. The permissible dose values according to the regulatory requirements are clearly undercut.

Facilities under decommissioning

Overall, from ENSI's point of view, the deterministic fire analyses carried out for the Mühleberg nuclear power plant (KKM), which is currently being decommissioned, meet the requirements set out in WENRA SRL S-30 and E 6.1.

The fire analyses show that there are no inadmissible releases of activity due to the existing fire protection measures. The permissible dose values according to the regulatory requirements are clearly undercut.

Due to the continuous changes in plant configurations during decommissioning, the fire protection measures implemented in the original plant design can no longer be fully complied with everywhere. From ENSI's point of view, the fire analyses carried out show that comprehensive protective measures against internal fires are still being maintained at the KKM, or that alternative measures have been taken.

Fire Protection Concept and Its Implementation

Overall, from ENSI's point of view, the concept of staged fire protection precautions, which includes the prevention and control of fires and the mitigation of the consequences of fires, is being consistently pursued in all Swiss nuclear facilities. The requirements set out in the WENRA Safety Reference Levels are met.

The following fire protection principles are implemented in all Swiss nuclear facilities:

- The facilities have a fire protection concept that contains the most important principles of fire protection. The associated documentation is reviewed regularly and adapted if necessary.
- The facilities have a fire load management tool with which the existing fire loads are systematically recorded and evaluated.
- The facilities have a fire alarm system whose monitoring scope is designed as full monitoring in accordance with national fire protection regulations. The fire alarm systems have been upgraded to state-of-the-art technology in recent years or the projects are currently being implemented.
- Fire protection equipment in the plants is regularly checked using internal processes.
- The principle of forming fire compartments is consistently applied in the facilities, which is based on national fire protection regulations.
- In the facilities, the ventilation systems are designed so that each fire compartment can be separated in the event of a fire by the targeted closing of fire dampers.
- In the plants, the fire protection officer has a commissioning function, which is linked to sound training.

From ENSI's point of view, the particular challenge in fire protection is to bring the current state of the art into line with the existing design of nuclear facilities, some of which are already over 50 years old in Switzerland. The design criteria that corresponded to the state of the art 50 years ago are no longer up to date today, but in some cases cannot be adapted either.

5 Abbreviations

AGV:	Aargau Building Insurance
BFW:	Company fire brigade
FAS:	Fire alarm system
FACP:	Fire alarm control panel
BWR:	Boiling Water Reactor
CDF:	Core Damage Frequency
CAD:	Computer Aided Design
CFAST:	Consolidated Fire and Smoke Transport
DIN:	German institute for standardization
DECT:	Digital Enhanced Cordless Telecommunications
DETEC:	Federal Department of the Environment, Transport, Energy and Communications
ENSI:	Swiss Federal Nuclear Safety Inspectorate
EPRI:	Electric Power Research Institute
ESK:	German Disposal Commission
FDF:	Fuel Damage Frequency
FDS:	Fire Dynamics Simulator
FDT:	Fire Dynamics Tool
GVB:	Building Insurance Bern
HAW:	High Active Waste
IAEA:	International Atomic Energy Agency
I&C:	Instrumentation & Control
ISRAM:	Information System for Radioactive Materials
IvG:	Intervention group
KKB:	Beznau Nuclear Power Plant
KKG:	Gösgen Nuclear Power Plant
KKL:	Leibstadt Nuclear Power Plant
KKM:	Mühleberg Nuclear Power Plant
KTA:	Nuclear Safety Standards Commission (Germany)
LAW:	Low Active Waste
LERF:	Large Early Release Frequency

MAW:	Medium Active Waste
MCA:	Multi-Compartment Analyses
MSO:	Multiple Spurious Operations
Nagra:	National Cooperative for the Disposal of Radioactive Waste
NAR:	National Assessment Report
NEA:	Nuclear Energy Act
NEI:	Nuclear Energy Institute
NEO:	Nuclear Energy Ordinance
NUREG:	Nuclear Regulatory Commission (gov.)
OECD/NEA:	Organisation for Economic Co-Operation and Development/Nuclear Energy Agency
PSA:	Probabilistic Safety Assessment
PSI:	Paul Scherrer Institute (Switzerland)
PSR:	Periodic Safety Review
PTS:	Pressurised Thermal Shock
PWR:	Pressurised Water Reactor
QAO:	Quality Assurance Officer
RSD:	Remote Shutdown Area
SES:	Association of Swiss Installers of Security Systems
SMS:	Short Message Service
SRL:	Safety Reference Level
SSC:	Structures, Systems and Components
TPR:	Topical Peer Review
VKF:	Association of Cantonal Fire Insurances
U.S. NRC:	United States Nuclear Regulatory Commission

6 References

/1/ WENRA Report Topical Peer Review 2023, Fire Protection, Technical Specification for the National Assessment Reports , June 2022

/2/ ENSREG, Terms of Reference for the Topical Peer Review Process on Fire Protection, June 2022

/3/ Gösgen Nuclear Power Plant, Report BER-M-93201, Contribution to the National Assessment report, Topical Peer Review 2023 'Fire-protection', June 2023

/4/ Leibstadt Nuclear Power Plant, Technical Report BET/22/0292, Rev. 1, 'Fire Protection 2023 (TPRII)', August 2023

/5/ Mühleberg Nuclear Power Plant, Note AN-MUA-2023/040, Contribution to the National Assessment report, Topical Peer Review 'Fire Protection', June 2023

/6/ Beznau Nuclear Power Plant, Technical Report TM-076-SW2300, Topical Peer Review 2023 'Fire Safety: KKB 1 and KKB 2', June 2023

/7/ Beznau Nuclear Power Plant, Technical Report TM-076-SW23002, Topical Peer Review 2023 'Fire Safety: ZWIBEZ', June 2023

/8/ Central Interim Storage Facility Zwilag, Report ZWI 2621/D00089, Topical Peer Review 2023 'Fire Protection - Zwilag Building H', June 2023

/9/ Central Interim Storage Facility Zwilag, Report ZWI 2621/D00090, Topical Peer Review 2023 'Fire Protection - Zwilag', June 2023

/10/ Nuclear Energy Act (NEA) of 21 March 2003 (Status as of July 2023), 732.1

/11/ Nuclear Energy Ordinance (NEO) of 10 December 2004 (Status as of January 2022), 732.11

/12/ Fire Protection Regulations of the Association of Cantonal Fire Regulations, 1 January 2015

/13/ Guideline HSK-R-50, Safety Requirements for Fire protection in Nuclear Facilities, March 2003

/14/ Guideline ENSI-G18, Fire Protection, Draft November 2022 (still in consultation)

/15/ Guideline ENSI-A04, Application Documents for Modifications in Nuclear Installations requiring Approval, September 2021

/16/ Guideline ENSI-B10, Basic Training, Recurrent Training and Continuing Education of Personnel in Nuclear Installation, October 2010

/17/ Guideline ENSI-B12, Emergency Preparedness in Nuclear Installations, January 2023

/18/ Guideline ENSI-G23, Design Requirements for other Nuclear Installations, October 2021

/19/ DETEC Ordinance on the Hazard Assumptions and the Assessment of the Protection against Accidents in Nuclear Installations, SR 732.112.2

/20/ Guideline ENSI-A01, Technical Safety Analysis for Existing Nuclear Installations: Scope, Methodology and Boundary Conditions, May 2020

/21/ Guideline ENSI-A03, Periodic Safety Review of Nuclear Power Plants, October 2018

/22/ Guideline ENSI-A08, Source term analysis: scope, methodology and boundary conditions, February 2010

/23/ Guideline ENSI-A05, Probabilistic Safety Analysis (PSA): Quality and Scope, January 2018

/24/ Guideline ENSI-A06, Probabilistic Safety Analysis (PSA): Applications, November 2015

/25/ IAEA Specific Safety Requirements, No. SSR-2/1 (Rev. 1), Safety of Nuclear Power Plants: Design, 2016

/26/ IAEA Specific Safety Requirements, No. SSR-2/2 (Rev. 1), Safety of Nuclear Power Plants: Commissioning and Operation, 2016

/27/ WENRA RHWG, Safety Reference Levels for Existing Reactors 2020, February 2021

/28/ NUREG/CR-6850, Fire PRA Methodology for Nuclear Power Facilities, Final Report, March 2021

/29/ NUREG-2169, Nuclear Power Plant Fire Ignition Frequency and Non-Suppression Probability Estimation Using the Updated Fire Events Database, January 2015

/30/ NUREG-1805, Fire Dynamics Tool (FDTs): Quantitative Fire Hazard Analysis Methods for the U.S. Nuclear Regulatory Commission Fire Protection Inspection Program, December 2004.

/31/ EPRI 3002012980, Methodology for Seismically Induced Internal Fire and Flood Probabilistic Risk Assessment, June 2018

/32/ Nuclear Energy Institute , NEI 00-01, Guidance for Post Fire Safe Shutdown Circuit Analysis, December 2019

/33/ Federal Office for Radiation Protection, BfS-SCHR-37/05, Methods for Probabilistic Safety Analysis for Nuclear Power Plants, August 2005

/34/ Guideline ENSI-G05, Transport and storage casks for interim storage, November 2015, October 2021

7 Appendices

Appendix 1: Comparison of the content of Guidelines HSK-R-50 and ENSI-G18

Content	Content
1 Objective of the Directive 2 Legal basis 3 Scope of application 4 Supervisory procedure 5 Overriding objectives of fire protection 6 Applicable provisions and regulations 7 Important aspects of fire protection 7.1 Imputed effects due to fire 7.2 Protection of the safety devices, Redundancy separation 7.3 Staggered protection principle (defence in depth) 7.4 Danger to the operational safety of the plant due to fire protection equipment 7.5 Acceptance of the structural and technical fire protection equipment 8 Required fire protection documents 8.1 General 8.2 Fire protection concept 8.2.1 Brief description of the nuclear installation 8.2.2 Fire protection objectives 8.2.3 Fire protection measures 8.2.4 Applied control and trusses 8.3 Technical documentation 8.3.1 Fire protection plans 8.3.2 List of fire compartments withfire loads 8.3.3 List of fire compartments with radioactive inventory 8.3.4 Fire brigade plan, fire brigade operation 8.3.5 Extinguishing water supply and -retention 8.4 Accident regulations 8.5 Maintenance, updating of documents, training 8.6 Safety verification with regard to fire protection 8.7 Verification of the fire protection equipment used 8. Review of fire protection measures during operation 8.1 Internal review by the operator	1 Introduction 2 Legal foundations 3 Subject matter and scope 4 Basic fire protection requirements 4.1 Protection goals 4.2 Overriding fire protection requirements 4.3 Proof procedures in fire protection 4.4 Emergency instructions 4.5 Quality assurance 5 Building fire protection 5.1 Buildings 5.2 Fire Chapters 6 Technical fire protection 6.1 Fire alarm system 6.2 Extinguishing devices 6.3 Smoke and heat extraction systems (SHEVS) 7 Fire protection on technical installations 7.1 Ventilation systems 7.2 Flammable equipment 7.3 Electrotechnical equipment 8 Dangerous substances 8.1 Storage of flammable substances 8.2 Storage of flammable radioactive substances 9 Fire protection organisation 9.1 General requirements 9.2 Safety organisation fire protection 9.3 Organisational fire protection 10 Fire prevention 10.1 Fire brigade 10.2 Extinguishing water supply 10.3 Extinguishing water retention 11 Review and changes to fire protection measures 11.1 Internal reviews 11.2 Periodic review and assessment 11.3 Fire protectionsystem modifications 11.4 Safety analyses for fires 12 List of references 13 Amendments to other directives Appendix 1: Terms Appendix 2: Fire protection concept Appendix 3: Fire protection documentation

8.2 Inspections by authorities 9 Terms Appendix 1: Addressing fire safety aspects Appendix 2: Checking fire compartments with radioactive inventory	

Editor:
Swiss Federal
Nuclear Safety
Inspectorate ENSI
CH-5201 Brugg

+41 (0)56 460 84 00
info@ensi.ch
www.ensi.ch

ENSI-AN-11728

ENSI
Industriestrasse 19
5201 Brugg
Schweiz

+41 56 460 84 00
info@ensi.ch
www.ensi.ch