Topical Peer Review II on Fire Protection

Participation of the Joint Project – Nuclear Risk & Public Control in the stakeholder consultation of the Topical Peer Review II

Report

Author: Oda Becker, nuclear expert

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Introduction

In the Nuclear Safety Directive, a European system of Topical Peer Reviews (TPR) is included. In these TPRs, the EU member states shall work together on nuclear safety issues by peer reviewing and exchanging information on the given topics. The ENSREG, the European Nuclear Safety Regulator Group, organizes these TPRs.

The most recent TPR II looked into the level of fire protection of the European nuclear facilities.

The Joint Project – Nuclear Risk & Public Control participated in the most recently conducted TPR and commissioned the independent nuclear expert Oda Becker to review the TPR documents, raise questions and analyze the answers. The report at hand summarizes the results of this participation in the TPR.

For further information, please go to https://www.joint-project.org/2025/03/19/ensreg-answers-on-our-comment-on-the-topical-peer-review-ii-on-fire-protection/

1 Summary of the TPR II Summary Report "Fire Protection"

In most countries, specific nuclear safety requirements related to fire protection that complement the conventional fire safety requirements (e. g. Bulgaria) are in place. In some countries, the requirements for fire protection in nuclear installations are limited to the conventional fire safety requirements, applicable to any industry or industrial building.

Nuclear safety requirements are primarily aimed at protecting structures, systems and components relevant for nuclear safety and radiation protection from fire and ensuring safety functions, whereas conventional fire safety requirements are more focused on the protection of people and property.

It can be noticed that the nuclear fire safety requirements are applicable in most countries specifically to nuclear power plants (NPP), and not to other types of nuclear installations. In such cases, the non-NPP nuclear installations are regulated by conventional fire requirements.

Most of these countries mention that the WENRA Safety Reference Levels (SRL) for NPPs are included either in their regulations or in guidance.

However, the TPR II team highlighted the following challenge: *"[d]evelopment of guidelines to convert high-level objectives mentioned in the standards into detailed requirements for carrying out safety analyses, especially for some type of installations or conditions of operation"*.

Operating experience feedback from nuclear installations and activities is a key means of enhancing nuclear safety. Many countries use operational experience feedback to replace or upgrade fire protection provisions, such as fire dampers or doors, fire suppression systems, and maintenance procedures. It was highlighted that improvements related to human factors and safety culture are less frequently shared internationally.

Information sharing on fire safety lessons takes place both nationally and internationally through databases, forums, and expert groups. However, a challenge was identified concerning the need for a unique, centralized database for fire events from all types of nuclear installations, including sufficient information on these events to enhance its usefulness.

Fire analyses aim to demonstrate compliance with nuclear fire protection goals, qualify safety-critical structures, systems and components (SSCs), and ensure safety for workers and assets. While nuclear power plants focus mainly on nuclear safety, other facilities such as research reactors and waste facilities place greater emphasis on protection of workers and assets.

Countries use **various deterministic approaches**, such as Fire Hazard Analysis (FHA) and Fire Safe Shutdown Analysis (FSSA), to assess fire impacts on SSCs important to safety. While the guidelines of the International Atom Energy Agency (IAEA) are widely referenced, countries may follow different standards and assumptions, with some adopting more conservative or realistic assumptions.

The fire protection means aim at mitigating secondary fire effects and maintaining safety functions, including mitigation of the **radiological consequences** of the fire. Indeed, in the presence of radioactive materials, a fire can disperse the materials and thereby lead to radioactive releases to the environment.

To limit the consequences of a fire that could lead to the release of radioactive material into the air, specific fire designed containment equipment has been implemented, in particular dedicated ventilation management, multiple containment barriers, reinforced ventilation equipment resisting to temperature. These features need adequate qualification to prove their effectiveness in case of fire.

The estimated radiological consequences of releases could show a wide variation. The relevance of the calculated radiological consequences therefore deserves further consideration. As a result, further research and knowledge-sharing on the phenomena and key parameters for estimating radiological consequences in the event of a fire could be beneficial.

Fire Probabilistic Safety Assessment (Fire PSA) is important in identifying and implementing plant modifications to improve fire safety. Deviations in assumptions related to plant layout, fire barriers, and detection systems can impact fire safety analysis (FSA) results, making continuous monitoring essential.

The scope of Fire PSA varies across countries, with most of them performing Level 1 PSA for full power operations, some extending to all plant operational states and Level 2 for all reactor states. Bulgaria, e. g., said their PSAs are full scope (all plant operational states, all plant internal events, internal and external hazards) up to Level 2.

In this regard, the use of conservative assumptions (instantaneous failure of equipment, conservative time of failure of fire protection features, etc.) versus more realistic ones can significantly impact Fire PSAs results, thereby influencing decisions related to corrective actions and the prioritization of modifications.

There is a large variation in the contribution of fires to the overall damage estimates (core and, in some countries, also fuel damage frequencies) and to the radioactive release frequencies (large and/or large early release frequencies) within PSA. The contribution of fires to core damage results varies significantly, ranging from 1 % to 60 %. The information in the national action reports (NAR) did not allow to further analyze the reasons behind these differences, which exist even for similar reactor technologies.

The availability of detailed Fire PSA may allow to identify specific scenarios or locations in the plants that are particularly sensitive to fire risk. Screening criteria, such as fire-induced core damage frequency (CDF) thresholds, affect the range of scenarios considered, influencing low-probability scenario interpretation’s frequency. Some countries have reported plant modifications derived from Fire PSAs aiming at reducing the fire risk in specific scenarios or locations.

The consideration of **hazard combinations**, including fires and other events, varies across countries and installations, using both deterministic and probabilistic approaches. Many countries assess credible combinations (e.g., fire with seismic events or explosions) based on engineering judgment. However, some have developed a more comprehensive and systematic screening process to identify credible hazard combinations, particularly for NPPs and high-risk research reactors. Some countries also perform detailed FSAs for non-reactor installations (spent fuel or waste storage facilities) focusing on scenarios like aircraft crashes causing fires.

The systematic identification and management of ignition sources, such as hot work, chemical reactions, and mechanical failures, is critical for **fire prevention**. Additionally, the introduction of emerging technologies like lithium-ion batteries at nuclear installations has been recognized as an ongoing challenge requiring further research and fire safety guidelines development by the TPR II team.

Countries have implemented various inspection and test procedures for the **ageing managing** of **fire protection components** such as penetration seals, fire doors, and hydrant networks. Visual inspections of seals and doors are common, with regular checks (10 – 20 % annually) and specific tests are carried out for degradation, cracks, and functionality. Fire hydrant networks undergo visual checks and advanced methods like endoscopy and ultrasonic testing. Lessons learned emphasize the importance of continuous monitoring and the need for upgrades to address obsolescence and ensure fire protection reliability. The primary cause for modifications and replacements is ageing degradation (e.g. corrosion, cracking, and material wear).

In all countries, **fire hydrant networks and fire hydrants** have been at least partly replaced due to ageing degradation (e.g., corrosion, cracking, damage). Several countries have replaced fire doors and seals based on safety significance.

Most countries acknowledge that originally certified **penetration seals** and their fire resistance ratings may degrade over time due to various factors, such as ageing effects (e.g. corrosion, cracking, elastomer degradation, material loss, hardening), inadequate maintenance procedures, and poorly implemented modifications.

The correct, effective, and reliable operation of **fire dampers** is crucial to prevent the spread of fire between compartments. To ensure this, inspections and tests are conducted as part of the installation's maintenance program.

Strategies for installing **fire detectors** in nuclear installations vary by country, with some aiming for full protection in all rooms and others focusing on high-risk areas based on fire hazard analysis. Older plants often lack complete coverage, though upgrades allow for the addition of more detectors. Some rooms were initially excluded from fire detection due to high radioactivity, but new technologies now offer solutions for these areas. Addressable fire detectors, which precisely locate fires, are increasingly used in newer plants or upgraded systems. Older systems may lack detailed location information.

The consideration of **harmful water effects from pipe breaks** or inadvertent operation of fire extinguishing systems is essential to ensure the safety and prevent contamination. Potential risks include flooding, electrical short-circuiting, and criticality, especially in fuel cycle facilities.

In most countries, **firefighting operations** in installations are organized at multiple levels to efficiently manage fire risks. However, the fire intervention teams are organized differently between countries and types of installations. There are some common practices and as well specificities due to the process or the types of risk of the installations. Most licensees rely on a quick response from the second intervention team to successfully limit the propagation of fire and to extinguish it successfully.

2 Bulgaria

In Bulgaria, five nuclear facilities at the Kozloduy NPP site were included in the analysis:

- NPP Kozloduy unit 5, reactor type VVER-1000/ 320, year of commissioning: 1987;
- Wet Spent Fuel Storage Facility (SFSF), year of commissioning: 2001;
- Dry SFSF, year of commissioning: 2011;
- Kozloduy unit 4 (under decommissioning), shut down 2002 and 2006;
- Storage Facility for Conditioned RAW (SFCRAW), year of commissioning: 2003.

2.1 Regulatory framework

For the NPPs, the requirements of the regulation are supplemented by a regulatory guide on protection against internal fires. The NAR indicates that the WENRA SRLs for Existing Reactors (2021), for Waste and Spent Fuel Storage (2014) and for Decommissioning (2015) are included in the regulatory framework. (ENSREG BG 2025)

2.2 Kozloduy unit 5

The following **weaknesses** related to fire protection were reported in the NAR (ENSREG BG 2025)**:**

- The existing fire detectors are technology. There is a need for replacement of fire detectors due to the ageing management, which is planned to take place by 2027. This is the only weakness for Bulgaria with is highlighted by the TPR II team. The TPR II team recommend addressing this for the national action plan.
- There is a lack of an automatic fire extinguishing system for the diesel fuel tanks in circulation water pumping stations 3 and 4. The corrective measure is planned for implementation by the end of 2025.

In the NAR (NRA 2023), it is said that *"[i]n connection with a registered defect of a pipeline from an automatic fire extinguishing system of the safety systems and a conducted analysis, decisions were made to replace the pipelines with corrosion-resistant austenitic steel. The developed design is in the process of implementation. In this regard, a long-term schedule for operational control (thickness measurement) of the pipelines has been developed*."
The ANSWER (BG 2024) added: Not all pipelines of fire extinguishing systems are replaced with austenitic steel pipelines.

It is stated that 84 defects that impact on the design availability of the components of the fire safety systems of the Kozloduy 5 and 6 have occurred. (ANSWER BG 2024)

The ANSWER (BG 2024) provides some results of the Probabilistic Safety Analyses (PSA): the contribution of internal fires to the core damage frequency (CDF) is 8%, while in terms of the spent fuel pool, the share of internal fires is large and accounts for 26% of the contribution.

The ANSWER (BG 2024) explains that aircraft crash scenarios are analyzed in PSA Level 1. It is explained that the NPP site fire probability due to the amount of fuel carried by large commercial aircraft (LCA) is an event with a relatively high probability - 2.68E-07. However, the questions about the possible radiological consequences are not answered either for the possible airplane crash or for any other event. (ANSWER BG 2024)

2.3 Wet Spent Fuel Storage Facility at the Kozloduy site (PSFSF)

The following **weakness** related to fire protection was reported:

- From an inspection of the insurance risk in 2023, a report was received, in which a recommendation was made to revise the Fire Hazard Analysis (FHA) of the PSFSF.

Kozloduy NPP has decided to carry out a FHA of the PSFSF by the end of 2025. In the ANSWER (BG 2024), it is added that the FHA has not been completed yet.

2.4 Other nuclear facilities

For Kozloduy unit 4 (NPP under decommissioning), the Storage Facility for Conditioned RAW (SFCRAW) and the Dry Spent Fuel Storage Facility no weaknesses are reported in the NAR (NRA 2023).

2.5 Conclusions

It is welcomed that WENRA-SRL have been included in the existing regulatory framework for all nuclear installations. At least for nuclear power plants, there is a regulatory guide for protection against internal fires.

The identified weaknesses will be solved in a timely manner. Modernization measures are reported for Kozloduy; the existing obsolete fire detectors must be replaced by 2027, and the missing automatic fire extinguishing systems are to be installed by the end of 2025.

Internal fires account for 8% of core damage frequency (CDF), while internal fires account for a significant 26% of spent fuel pool damage. It is not mentioned if there is a measure envisaged to reduce the risk for the spent fuel pool.

It is explained that the probability of a fire at the nuclear power plant site is an event with a relatively high probability of 2.68E-07 due to the amount of fuel transported by large commercial aircraft (LCA). However, the possible radiological consequences are not mentioned. (ANSWER BG 2024)

Based on a review of the insurance risk in 2023, a recommendation was made to revise the fire hazard analysis (FHA) of the wet spent fuel storage facility (PSFSF). The results are not yet available, so a reliable assessment of fire protection cannot be made.

3 Czech Republic

The following nuclear facilities were included in the NAR (SUJB 2023):

- NPP Temelín reactor type VVER 1000/320, years of commissioning: 2000, 2004;
- NPP Dukovany, reactor type VVER 440/213, years of commissioning: 1985-1987;
- Research reactor LVR-15, year of commissioning: 1957;
- NPP Temelín Dry Spent Fuel Storage, year of commissioning: 2010.

3.1 Regulatory Framework

The NAR states that the legal framework of fire protection requirements for nuclear installations in the Czech Republic consists of two basic acts (the Atomic Act and the Fire

Protection Act). The NAR indicates that the implementing legislation to the Atomic Act imposes additional obligations to operators of nuclear installations, "that are provided in various Decrees. (ENSREG CZ 2025) According to the ANSWER (CZ 2024), the WENRA SRLs for NPPs and Research Reactors are appropriately implemented in the Czech nuclear legislation since 2017.

3.2 Temelín and Dukovany NPPs in general

According to the ANSWER (CZ 2024), the aircraft crash is included in the external events considered for all nuclear facilities in the Czech Republic. However, the ANSWER (CZ 2024) does not provide any information about possible radiological consequences. No information was provided on radiological consequences for possible beyond-design-basis fires. It is only mentioned that in the FHA the most complicated fire is assessed.

The regulator SÚJB recorded in its data base approximately three fire protection related events per year per NPP; the majority of the fire protection equipment's malfunctions consist of false activation. Inspections focused on internal feed-back system are performed quarterly at both NPP. The investigation and analyses of selected operational events are reviewed. In several cases the SÚJB requires further investigation of the event and root causes or the additional corrective measures. In rare cases, a new analysis of the operational event is required. (ANSWER CZ 2024)

The following weakness related to fire protection was reported in the NAR as generic for NPPs Dukovany and Temelín (ENSREG CZ 2025):

- The modifications and changes are not easily implemented, considering the complexity and timeframe in complying with all legally binding requirements applicable as the Czech state is the majority owner of the utility ČEZ.

3.3 Temelín NPP

The contribution of internal threats, and thus also the contribution of internal fires, to the overall risk is evaluated annually and reported in the Operational Safety Analysis Report. For 2022, the contribution from internal fires to FDF (Fuel Damage Frequency) was 12.95%. (ANSWER CZ 2024)

Since start of operation in 2001, nine fires occurred in Temelín NPP, the majority was caused by technical failure or personnel carelessness. (ANSWER CZ 2024)

According to the ANSWER (CZ 2024), 68 failures were recorded on the Electric Fire Detector (EFD) system, 10 failures were recorded on the fire water system and 19 malfunctions were recorded in the air-conditioning system in 2023. Due to the scale of these systems and the number of components, there are one per thousand failures.

A large modernization of fire detection system has been carried out with the use of new generation, multi-criteria detectors.

No weaknesses related to fire protection were specifically reported for Temelín NPP (SUJB 2023).

3.4 Dukovany NPP

In the NAR (SUJB 2023) it is stated that *"[t] he overall contribution to the unit operating risk to internal initiation events from internal fires is at 20.3% level*." According to ANSWER (CZ 2024), the PSA model is updated regularly as part of the Living PSA, and the risk assessment is carried out continuously. The above mentioned value is the share of internal events caused by fires in the total value of Core Damage Frequency (CDF) = 3,42E-06. Contribution to large early release frequency (LERF) value is 5,8% (2,4E-08).

The following issue is mentioned in the NAR as weaknesses and acknowledged as such by the TPR II Team (ENSREG CZ 2025):

- The water fire extinguishing system which protects the cable compartments is obsolete.

The TPR II team recommends that the Czech Republic addresses this issue in the National Action Plan. At present, the Dukovany NPP has developed a requirement for the selection of the most suitable method of securing the cable compartments. A working group has been set up to evaluate the different options.

The following further weaknesses were reported in the NAR (ENSREG CZ 2025):

- The number of fire safety relevant changes to the buildings are improperly reflected in the relevant documents. The original documentation and subsequent changes are now being incorporated into one document.
- The impact of the human factors, in particular violations of fire regulations when using electrical appliances, failure to comply with the obligations and conditions of the permit when working with open flames (welding) or handling flammable materials.
- The difficulty of modifying some fire systems is due to design features of construction.

The main cause of fires in Dukovany NPP (5 during the entire period of operation of almost 40 years) was a technical fault.

According to the SUJB (2023), the safety important equipment is protected by stable extinguishing equipment with seismic resistance.

A large professional fire brigade ranging from 12 to 18 men depending on the NPP, is deployed on a permanent basis on the NPP site providing fire prevention, firefighting and rescue services.

3.5 Research Reactor LVR-15

The following weaknesses related to fire protection were reported in the NAR for LVR-15 (ENSREG CZ 2025):

- The original design of the equipment does not have the exact qualification requirements, or their certificates documented.
- Constraints given by the original building design limit the application of selected physical separation practices to prevent common cause failure (CCF) events (typically fire) particularly in relation to cable lines.
- The limitation of the use of some automated extinguishing agents due to the specific use of a nuclear research facility.

According to the ANSWER (CZ 2024), the firefighting equipment and electronic fire detectors (EFD) are not seismically qualified.

The requirements of the Aging Management Program (AMP) for research reactors were introduced by legislation in 2016. The program includes the EFD in buildings, fire dampers and fire water distribution of the building. For these devices, the AMP defines condition monitoring methods, acceptance criteria and selected preventive measures to minimize aging.

In 2019, the central switchboard, located in the Fire Rescue Service (FRSU) building, was replaced; in 2020, the main hydrant water supply (service) was reconstructed and part of the horizontal distribution lines up to the supply to the reactor hall were reconstructed. (ANSWER CZ 2024)

3.6 Conclusions

It is stated that the WENRA SRL for nuclear power plants and research reactors have been "appropriately" implemented in Czech legislation since 2017. What this exactly means is not explained, and furthermore the WENRA SRL for storage facilities are not mentioned.

According to the ANSWER (CZ 2024), aircraft crashes are included in the external events that are considered for all nuclear facilities in the Czech Republic. No information is provided on possible radiological consequences, either following an aircraft crash or any other potential fire. It is explained that the most typical causes of fires are carelessness and technical defects. What is being done to counteract these causes is not explained. It is important to note that the NAR explains that changes and modifications are not easy to implement, among other things because the Czech state is the majority owner of the energy supplier ČEZ (ENSREG CZ 2025).

For 2022, internal fires contributed 12.95% to the CDF (core damage frequency) for the Temelín NPP. For the Dukovany NPP, the total contribution of internal fires to the operational risk per unit due to internal initiating events is 20.3%.

A particular weakness of the Dukovany NPP is the outdated water extinguishing system for protecting the cable rooms. No solution has yet been presented, but a working group has been set up to evaluate the various options. In addition, it is generally difficult to modify certain fire protection systems due to existing design features. An outdated design cannot provide the required structural fire protection. Another fundamental problem is that a number of changes to the buildings relevant to fire protection has not yet been properly documented.

The following fire safety vulnerabilities have been identified for the LVR-15 research reactor: Due to the original design of the building, physical separation measures to prevent events with a common cause are limited, particularly regarding cable lines.

4 Hungary

The following four nuclear facilities were included in the NAR (HAEA 2023):

- Paks NPP (unit 1-4); reactor type VVER 440/213, electric power: 500 MW/unit, year of commissioning: 1982 -1987, year of operational license expiring: 2032–2037;
- Budapest Research Reactor (BKR): thermal power: 10 MW, year of commissioning: 1959, operating license extended until 2033;
- Training Reactor of the Budapest University of Technology and Economics (BME OR); thermal power: max. 100 kW; year of commissioning: 1971; operational license until 30.06.2027;
- Spent Fuel Interim Storage Facility (KKAT): Modular dry storage with vertical storage vaults, year of commissioning: 1997.

The TPR Board´s recommendation to evaluate the on-site NPP waste storage was not taken into account in the NAR (HAEA 2023).

4.1 Regulatory Framework

The current legal regulatory environment regulates the operational requirements of existing facilities, with general fire protection rules, complemented by special nuclear requirements in the Nuclear Safety Codes, and the Nuclear Fire Protection Codes and the Radioactive Waste Storage Fire Protection Codes. Besides, the HAEA Decree 1/2022 stipulates fire protection requirements for the design and operation of nuclear facilities. The NAR mentions that "[*t]o date, no dedicated official guidance for the assessment of nuclear fire safety has been developed by the HAEA.*" (HAEA 2023)

For nuclear power plants the Hungarian regulations are in line with the WENRA RLs. In the case of research reactors and interim spent fuel storages however several gaps were identified in the Hungarian regulations during and even prior the TPR II as part of a regulatory self-assessment. (ENSREG HU 2025) The gaps will be resolved during the next scheduled amendment of the Nuclear Safety Codes (December 2025). These new requirements will become active requirements during the next PSR. (ANSWER HU 2025)

4.2 Paks NPP

As there were no fire protection requirements for nuclear power plants during the construction period in the 1980's, improvements were implemented gradually. In particular, the cable room under the control rooms was equipped with fireproof coating against the spreading of flame and built-in fire extinguishers were installed to protect the diesel generators and the main circulation pumps. Additional measures were implemented to address deviations identified in the fire risk analyses, for example in cable rooms where the cables of safety systems are functionally not completely separable, the cables have been equipped with flame-retardant coating along their entire length.

The following issue is mentioned in the NAR as a weakness and acknowledged as such by the TPR II Team (ENSREG HU 2025):

- The lack of detectors for an area with combustible materials temporary storage.

The TPR team recommends that Hungary addresses this issue in the National Action Plan.

In addition to the weaknesses identified Hungarian nuclear authority (HAEA), there are two more issues concerning detectors identified by the TPR II team (ENSREG HU 2025):

- There is a need to reassess the detection strategy in area/rooms with harsh environment, in particular high radiation, and consider the adoption of appropriate fire detection solutions where needed. The TPR II team explained that the situation is not in line with the WENRA SRL that requires a dedicated fire detection system that allows for an early and reliable fire detection and localization, in those areas/rooms for which this need has been identified by the FSA.
- Fire detection systems for buildings other than the reactor buildings, the turbine buildings and water extraction plant are not seismically qualified and not independent between adjacent compartments. The TPR II team explained that there is inadequate justification of seismic qualification of this fire detection system and the lack of information on how the level of independence between fire detection systems is achieved and sustained under hazard conditions.

Concerning the adequacy of the seismic design, it is stated only that the fire water network ensures the fire water supply of the main buildings after an earthquake. (ANSWER HU 2025)

According to the ANSWER (HU 2025), in the last 10 years there was only one single INES 0 classified fire event in 2017 in the auxiliary building, at a pump station of a water chemistry/treatment system presumably due to a minor hydrogen peroxide leakage. The fire was detected and extinguished via hand-held fire extinguishers by the operator personal.

4.3 Research Reactors

The following weaknesses were reported in the NAR for the Research Reactors (ENSREG HU 2025):

- They were constructed on sites which include various facilities and activities, where different stakeholders and organizations need to coordinate. The responsibilities in the facilities are in many cases conflicting. (BKR and BME OR) This complicates the approval processes for certain modifications or corrective actions. (BME OR)
- There is a persisting issue regarding the sufficiency of staffing which poses a continuous obstacle to carrying out scheduled tasks on time. (BKR and BME OR)
- Insufficient availability of certified nuclear fire safety experts in Hungary, which poses a continuous obstacle to carry out certain tasks, such as the completion of the fire risk assessment. (BME OR)
- Lack of personnel specifically focusing on the changes in laws and regulations, which would ensure that both the fire risk analyses, and the internal Fire Protection Regulation is kept up to date. (BKR)
- In relation to the age of the buildings, there is a need to check the installation of materials complying with the fire protection requirements. (BKR)
- In certain areas within the facility a large amount of unnecessary flammable materials was detected in close proximity to cables relevant from the point of nuclear safety. (BME OR).

In addition to the weaknesses the HEAE identified, the TPR II team points to another weakness (ENSREG HU 2025):

- Insufficient physical separation between redundant safety-related components (i. e. diesel generators, ventilators). The TPR II team explained that the insufficient physical separation between redundant safety-related components creates a risk of common cause failure due to potential propagation of a fire. (BKR)

In the NAR (HAEA 2023) it is explained: "*Regarding the fire risk assessment of the BME OR training reactor facility the issue of the lack of submitted and approved fire risk assessment is persistent, therefore in-depth regulatory review or evaluation of assessment cannot be carried out at this point*." The HAEA set the now a deadline as a regulatory order, rather than self-imposed corrective action by the Licensee. (ANSWER HU 2025)

According to the ANSWER (HU 2025), in the case of the BME OR facilities the fire suppression systems include only manual fire extinguishers, therefore seismic design in not applicable in these facilities. In the case of the BKR facility the seismic resistance of the facility in general is under review as part of the PSR process.

4.4 Spent Fuel Interim Storage Facility (KKAT)

For Interim Spent Fuel Storage Facility (KKAT), there were no weaknesses related to fire protection reported in the NAR (HAEA 2023). According to ANSWER (HU 2025), in the case of the KKÁT the fire suppression systems include only manual fire extinguishers, therefore seismic design in not applicable in these facilities.

4.5 General Aspect

The document ANSWER (HU 2025) claims that the question of fire protection equipment event/failures is outside of the scope of the TPR II Technical Specifications. This is surprising because other nuclear authorities answered these questions. It is an example of the Hungarian authorities' unwillingness to answer questions. Also, the TPR II team states that the replies to their written questions during the TPR II did not allow them to clarify all the issues they had raised.

4.6 Conclusions

During the construction of the Paks NPP in the 1980s, no specific fire safety requirements for nuclear power plants were in place. The improvements made later (fireproof coating and fire extinguishers) cannot achieve the level of fire safety required by today's design standards, which call for physical separation of the cables of different safety systems.

It is noteworthy that the TPR II team points to further significant deficiencies regarding the fire detectors, which were not noted by HAEA: There are no fire detectors in all safety relevant rooms and in addition not all fire detectors are designed to withstand earthquakes.

The cause of the fire in 2017 at the Paks NPP is not mentioned, nor are any corrective measures that may have been taken.

For nuclear power plants, Hungarian regulations comply with the WENRA SRL. However, several gaps were identified in the Hungarian regulations for research reactors. These are to be closed in the next scheduled amendment to the radiation protection regulations (December 2025). However, compliance will only be verified in the next PSR. For this reason, there are a number of fundamental weaknesses in the two very old research reactors: Responsibilities are unclear and there is a lack of experts in Hungary.

In addition to the weaknesses identified by the HEAE, the TPR II team points to another weakness in the Budapest research reactor (BKR) resulting from its outdated design. The physical separation between redundant safety-related components is insufficient, posing a risk of a common failure due to the possible spread of fire.

The problem with the BME-OR training reactor facility is that no fire risk assessment has been submitted, meaning that no official review can be carried out.

In addition to all the weaknesses of the nuclear facilities, there is a lack of willingness of the Hungarian authorities to answer questions in the TPR II.

5 Poland

The research reactor Maria, the only nuclear facility in Poland, is considered in the NAR. The National Centre for Nuclear Research operates the 30 MW (thermal) multi-purpose research reactor since 1974 at Swierk, south of Warsaw.

5.1 Regulation Framework

The NAR mentions that “*the fire safety system of the MARIA reactor is primarily based on national requirements, regulations, and guidelines.”* The regulations are principal for the protection of buildings against fire; however, they are not specific to nuclear installations.

Regarding the WENRA safety reference levels (SRLs) for research reactors related to protection against internal fires, the analysis showed compliance of only 10 out of a total of 19 of the SRLs with national regulations. Another 4 SRLs were not reflected in Polish law, while 5 SLRs were considered as partially met. (ANSWER PL 2025)

The NAR does not mention which and how international safety standards are used in developing the overall fire safety program. (ENSREG PL 2025)

5.2 Research Reactor Maria

According to the NAR (PAA 2023), one of the most important weaknesses is the lack of automatic extinguishing systems, wherever there is a risk of fire that could threaten critical infrastructure for nuclear safety and radiological protection. This weakness is also acknowledged by the TPR team. (ENSREG PL 2025) In ANSWER (PL 2025) it is stated that in accordance with applicable national law, automatic fire extinguishing systems are not required at the MARIA reactor facility.

Furthermore, there is the weakness of the lack of internal specialized fire brigade unit. The TPR II team also mentioned this weakness. (ENSREG PL 2025) However, there are no plans to establish a company fire brigade unit in the near future. (ANSWER PL 2025),

The system of automatic fire detectors is unable to report the location of the fire, which is another weakness. The construction of a modern addressable fire detection and alarm system able to determine the place of fire (building number, floor number, room number, detector number) is ongoing.

The most important weakness of passive fire protection is that the construction building and reactor installations were designed using old standards and technical solutions, preventing its full adaptation to the requirements of current regulations. Some improvements are possible, but they need modernization efforts. (PAA 2023) It is explained in the ANSWER (PL 2025) that the actions recommended in the expert opinion on fire protection are currently implemented. These include, among others, the replacement of door parts with fire-resistant doors. Moreover, a costly modernization has recently been carried out, consisting in replacing the basic power supply systems and cabling of the MARIA reactor. The TPR II team highlighted the already implemented and still ongoing improvements program. (ENSREG PL 2025)

According to the ANSWER (PL 2025), the fire protection system components are not covered by the MARIA reactor aging program. This is another important weakness.

The TPR II team highlighted furthermore, the scope of the fire safety analyses performed does not cover scenarios involving combinations of various events; uncertainties are not taken into account in the fire safety analyses. (ENSREG PL 2025)

The TPR II team noted there is a process for updating procedures and efforts to strengthen safety culture, so as to minimize the presence of fire loads. The TPR II team also noted that the results from 2024 PSR expected soon and has potentially identified further improvements to be evaluated. (ENSREG PL 2025)

In addition to the weaknesses mentioned by the nuclear authority in Poland, the TPR II team highlighted a further weakness: the lack of compartmentation or compensatory measures between redundant structures, systems and components (SSCs). In particular the separation in the diesel generator room to prevent potential fires spreading should be improved. The TPR team explained that the insufficient compartmentation between redundant safety-related components creates a risk of common cause failure due to potential propagation of a fire. (ENSREG PL 2025)

5.3 Conclusions

There are several weaknesses in the fire safety of the more than 50-year-old research reactor in Poland. In addition, there are no specific regulatory requirements for fire safety in nuclear facilities. Not even the WENRA SRLs are included in the national regulations. There is no indication of when the missing WENRA SRL will be implemented in the regulations.

The missing requirements have an impact on the fire protection of the reactor: One of the most significant weaknesses is the lack of automatic extinguishing systems in safety-related buildings, which is not required by national regulations. In addition, there is no internal specialized fire brigade, and there are no plans to establish a fire brigade unit in the near future.

Only one of the significant weaknesses is to be remedied: the installation of an addressable automatic fire alarm system. (ANSWER PL 2025)

Although modernization programs are in place, the system was designed according to old standards and technical solutions that prevent full compliance with current regulations. Only a few improvements are possible. In addition to the weaknesses identified by the Polish Nuclear Regulatory Authority, the TPR II team highlighted another weakness: the lack of physical separation between redundant structures, systems, and components (SSCs), which poses a risk of common failure due to the possible spread of fire.

The components of the fire protection system in the Maria research reactor are not covered by the aging management program, which represents another significant weakness, as experience shows that all such facilities show signs of the negative aging effect.

6 Conclusions

Appropriate legal requirements in national regulations are a prerequisite for adequate fire protection. However, such requirements do not exist in all countries. The most evident example is Poland, where even the WENRA Safety Reference Levels have not been incorporated into national regulations. Consequently, the fire protection measures implemented in Poland do not meet international standards.

Fire protection measures are designed to maintain safety functions to prevent or at least reduce the release of radiological substances. ENSREG states that the calculated or estimated radiological releases can vary widely and require further consideration. Therefore, additional research could be valuable in estimating the potential radiological consequences in the event of a fire. Understanding these consequences is particularly important for the public and political decision-makers, enabling them to assess the risks associated with nuclear installations.

Probabilistic Fire Safety Assessment (Fire PSA) can provide insights into possible radiological consequences. A detailed Fire PSA can help identify specific scenarios or plant areas that are especially vulnerable to fire. However, some countries do not consider low-frequency, high-impact scenarios in their assessments.

Lessons learned emphasize the importance of continuous monitoring and the need for upgrades to address obsolescence and ensure the reliability of fire protection systems. The primary cause for modifications and replacements is aging degradation, such as corrosion. Signs of ageing are evident in fire protection systems across all nuclear facilities.

The results of TPR II have reaffirmed that, in older nuclear facilities, fire protection is not sufficiently ensured by physical separation of redundant safety systems, particularly concerning the associated cables. Active fire protection systems can only achieve the required safety levels to a limited extent. Moreover, these fire protection components are vulnerable to failures caused by aging effects.

The main objective of TPR II is for countries to learn from each other and improve their respective fire protection measures. Notably, in the case of research reactors, fire safety considerations often have not been adequately addressed or have been only minimally considered. The implementation of effective fire protection in nuclear facilities will primarily depend on the National Action Plans. The experience gained from the EU stress tests following the Fukushima disaster revealed numerous weaknesses; however, not all identified issues were addressed. It remains to be seen how ENSREG will act this time to ensure that fire safety is genuinely improved—or whether the lack of appropriate fire protection measures might even lead to the shutdown of facilities.

7 References

ANSWER BG 2024: BG-Answers to the questions to NAR of Bulgaria; 2024

ANSWER CZ 2024: TPR II answers Czech; 2024

ANSWER HU 2024: all question collated TPR2 Hungary: 2024

ANSWER PL 2024: Answers to questions and comments raised to TPR II NAR of Poland

ENSREG 2025 2nd Topical Peer Review Summary Report "Fire Protection" European Nuclear Safety Regulators Group (May 2025)

ENSREG BG 2025: 2nd Topical Peer Review – 'Fire Protection' Country Review Report Bulgaria; European Nuclear Safety Regulators Group; January 2025

ENSREG CZ 2025: 2nd Topical Peer Review – 'Fire Protection' Country Review Report Czech Republic; European Nuclear Safety Regulators Group; January 2025

ENSREG HU 2025: 2nd Topical Peer Review – 'Fire Protection' Country Review Report Hungary; European Nuclear Safety Regulators Group; January 2025

ENSREG PL 2025: 2nd Topical Peer Review – 'Fire Protection' Country Review Report Poland; European Nuclear Safety Regulators Group; January 2025

HAEA 2023: National Assessment Report of Hungary for the Topical Peer-Review "Fire Protection" under Council Directive 2014/87/EURATOM; Hungarian Atomic Energy Authority; October 2023

NRA 2023: EU Topical Peer Review 2023, Fire Safety; National Report Republic of Bulgaria; Nuclear Regulatory Agency; October 2023

PAA 2023: National Assessment Report of Poland, Topical Peer Review 2023, Fire Protection; Polish 2nd TPR national report prepared in accordance with the Nuclear Safety Directive 2014/87/EURATOM; National Atomic Energy Agency

SUJB 2023: National Assessment Report of the Czech Republic, For the purposes of Topical Peer Review "Fire Protection"; under the Nuclear Safety Directive 2014/87/EURATOM; State Office for Nuclear Safety; October 2023