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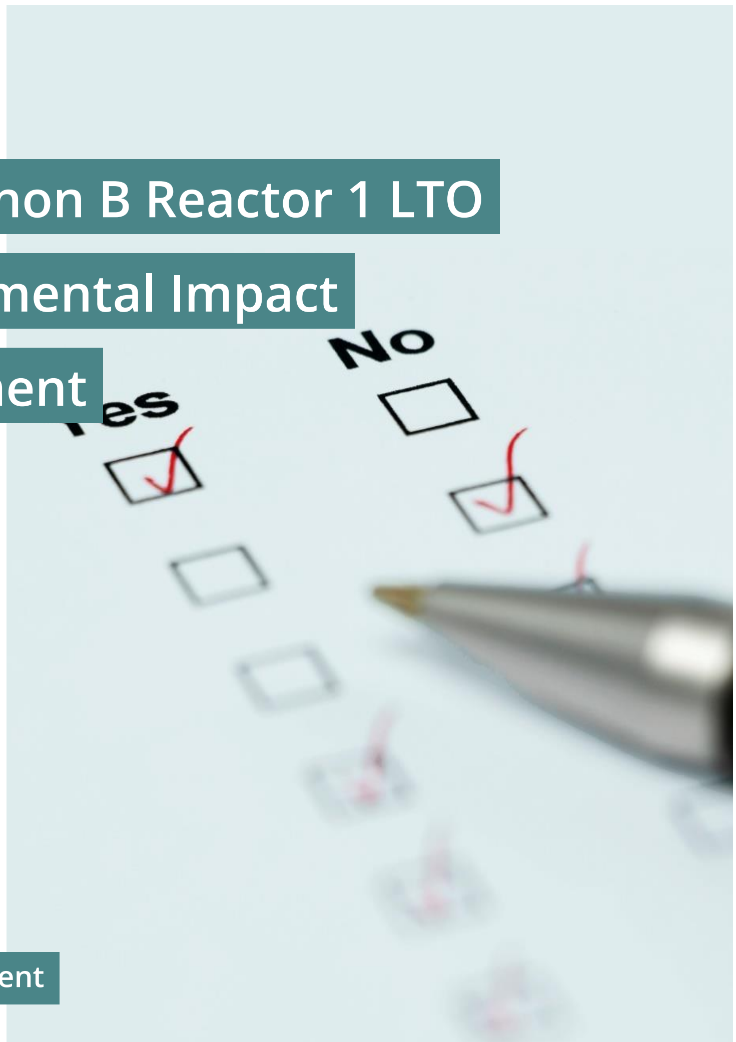
NPP Chinon B Reactor 1 LTO Environmental Impact Assessment



Expert Statement

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NPP CHINON B REACTOR 1 LTO ENVIRONMENTAL IMPACT ASSESSMENT

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SUMMARY

The Chinon B NPP consists of four pressurized water reactors with a capacity of 900 MWe each. These reactors were commissioned between 1982 and 1987. France notified the 4th periodic safety review of the Chinon B nuclear power plant (reactor 1), which is to be considered as a lifetime extension in accordance with the UNECE Espoo Convention on Environmental Impact Assessment (EIA) in a Transboundary Context. The competent authority is the French department of Indre-et-Loire. The project applicant is Électricité de France (EDF).

Austria is participating in this transboundary EIA, as significant impacts of an accident cannot be excluded. The aim of Austria's participation in the process is to give recommendations to minimize, and in the best case eliminate, possible significant adverse impacts on Austria.

Procedure

The operating authorization of French nuclear power plants is not limited in time. However, every ten years, French NPPs are subject to a Periodic Safety Review (PSR). The fourth PSR plays a special role, as it marks the regulatory process for the Long-Term Operation (LTO) of an NPP beyond 40 years. The French PSR framework mandates a comprehensive safety assessment in two phases: generic and plant specific.

For the 4th PSR of the 900-MWe nuclear power plants, EDF has set as a general guideline the objective of achieving the nuclear safety targets of the latest generation of reactors, whose reference reactor for EDF is the EPR-Flamanville 3. This guideline has been confirmed by the ASNR. The generic phase ended with the publication of the ASNR's opinion on February 23, 2021, which contained general regulations that had previously been the subject of a public consultation. (ASN 2021) Once the generic phase is complete, inspections of all 32 reactors at the 900 MWe nuclear power plants should follow over a period of approximately ten years (from 2019 to 2031).

There is a high degree of public involvement in the process of the life-time extension of the French NPP fleet. However, an EIA according to the EIA Directive is not performed.

Long-Term operation and operational experience

Based on the information provided in the EIA documents, it can be concluded that a comprehensive aging management program was implemented to ensure operation. This is also indicated by the results of the first Topical Peer Review (TPR) as set out in Article 8e of Directive 2014/87/EURATOM. However, addressing the problems associated with the aging of structures, systems, and components (SSCs) poses a major challenge for the plant, which has been in operation for more than 40 years. Since most SSCs were originally designed for a nominal operating lifetime of 40 years, the 4th PSR can be considered the necessary approval to operate the nuclear power plant beyond its original design life. Therefore, the 4th PSR requires a more detailed consideration of aging management.

The EIA documents do not clearly indicate whether there has been a comprehensive expansion of the scope of aging management compared to the 3rd PSR. Only a few examples of preventive component replacement are presented. As far as is known, ASNR proposed expanding the scope of aging management during the general phase of the 5th PSR. This should also be performed for the 4th PSR.

The implementation of the Program for Complementary Investigations (PIC) is an approach that aims to confirm the absence of operational failures in areas that are not regularly inspected. Without justification, it is stated that no checks are to be carried out for Chinon B1 as part of the supplementary investigation program.

In the framework of the generic phase of the 5th PSR of 900 Mwe reactors, the ASNR requires EDF to define, by December 31, 2025, the strategy for taking into account the findings from the discovery of stress corrosion cracking and, more generally, the risk of unexpected degradation of components in the primary and main secondary circuits through the checks required by the additional inspection and maintenance programs. The cause of the cracks, inter-crystalline stress corrosion, is a well-known corrosion phenomenon, but it was not expected in the relevant areas and therefore the pipes were not inspected for it either. This means that the aging management concept for components in the primary and main secondary circuits is called into question.

The ASNR's proposal during the general phase of the 5th PSR to extend aging management beyond the 4th PSR is supported. As proposed by the ASNR, the focus must be on components that are necessary for controlling accident situations. However, the scope of the program "qualification of materials under accident conditions" in the 4th PSR is very limited for Chinon B1.

An evaluation of the safety-related incidents at the Chinon B1 NPP over the past five years (2020-2025) published by the ASNR revealed a number of incidents that were related to non-compliance with the general operating rules (RGE). The reason for the large number of violations of the RGE is unknown.

In recent years, significant deficiencies in the seismic resistance of various components of the Chinon B1 and other 900 MW reactors have been identified. It cannot be ruled out that there are others, as to date unidentified, deficiencies. Deficiencies in earthquake protection are of particular interest for Chinon B1, as there are doubts about the adequacy of its design with regard to earthquakes (see Chapter 4).

External hazards

The EIA documents provide comprehensive information on hazard types considered in the safety demonstration for Chinon B1 and measures already implemented or decided to be implemented in order to strengthen the robustness of the NPP with respect to external hazards. The documents, however, do not provide clear evidence if the processes of the PSR and LTO follow WENRA requirements as stipulated by ASNR. For most external hazards, the methods, data and assumptions used in the hazard assessment are not specified in detail. It remains particularly unclear if design basis events with exceedance frequencies not higher than 10^{-4} per annum have been determined for all external hazards and how Design Extension Conditions (DEC) are addressed for the identified hazards.

Non-conformity with WENRA Reference Levels is observed for earthquake and seismic ground shaking. The Design Basis Earthquakes (DBE) for Chinon B1 is still based on deterministic analyses. This approach is no longer state of the art. The EIA documents clarify that a Probabilistic Safety Hazard Assessment (PSHA) for the Chinon site was conducted to derive the Seismic level for the hardened safety core (SND) which is relevant to the design of the Hardened Safety Core (ND). The PSHA revealed a ground acceleration of 0,34 g for the SND which corresponds to an average earthquake return period of 20,000 years. The deterministically derived seismic design basis value for Chinon B is 0,2 g. It therefore remains to be demonstrated that the seismic resistance of all SSCs important to safety is sufficient to conservatively ensure the fundamental safety functions for a DBE with an average recurrence interval of 10,000 years as required by WENRA (2021).

With respect to safety upgrades of Chinon B, it is evident that one of the most important measures to provide protection against external hazards is the implementation of the Hardened Safety Core (ND). However, its implementation is still pending. Implementation is announced for Phase B of the 4th PSR 900. The timeline prescribed by ASNR envisages implementation of the ND for Chinon B1 is 2029. The fundamental decision to implement the ND has been made in 2012 in the aftermath of the European Stress Tests (ASN 2012). The fact that the implementation of the ND is pending for 17 years thereafter appears remarkable given that WENRA requires the "timely implementation of the reasonably practicable safety improvements identified" (WENRA 2021). This suggests that the announced implementation schedules do not comply with the WENRA requirement.

Terrorist attacks and acts of sabotage can have a significant impact on nuclear facilities and cause serious accidents. Nevertheless, they are only mentioned in very general terms in the EIA documents submitted. Similar EIA reports have covered such events to a certain extent. Even if precautions against sabotage and terrorist attacks cannot be discussed in detail for reasons of confidentiality, the necessary legal requirements should be set out in the EIA documents.

Information regarding the issue of terror attacks would be of great interest, considering the far-reaching consequences of potential attacks. In particular, the EIA documents should include information on the requirements for the design against the targeted crash of a commercial aircraft. This topic is particularly important, because the reactor building as well as the spent fuel building of the Chinon B1 NPP is vulnerable against airplane crashes. It is important to mention that the EPR's 1.8-meter-thick outer reinforced concrete shell is designed to withstand the impact of a large passenger aircraft. However, the wall thickness at the Chinon B1 NPP is less than 1.0 m. Furthermore, the increasing availability and performance of drones is raising the potential threat to nuclear facilities. A recent assessment of the nuclear security in the France points to shortcomings compared to necessary requirements for nuclear security in regard to “security culture”, “cybersecurity” and “protection against insider threats”.

Safety aspect of accident without core-melt and spent fuel pools

The analysis utilizes both Deterministic Safety Analysis (DSA) and Probabilistic Safety Analysis (PSA) to re-evaluate operational transients, Design Basis Accidents (DBA), and Design Extension Conditions (DEC).

Significant safety enhancements have been implemented or are planned to reduce radiological consequences and improve defense-in-depth across the plant. An Augmented Ultimate Heat Sink Connection was implemented by diversifying the connection of the Steam Generator (SG) Auxiliary Feedwater System (ASG) to the Fire Fighting Water Reservoir; this secures long-term heat removal capability during accident sequences involving loss of normal and emergency feedwater. For thermal-hydraulic control, the capacity of the Main Steam Line Safety and Relief Valves (GCT-a) was uprated (PNPE1141) to accelerate the Reactor Coolant System (RCS) cooldown and depressurization following various transients. Furthermore, a lower permissible concentration of Iodine-131 (I-131) in the RCS water was enforced to reduce the potential radiological source term during accidents.

Regarding the Spent Fuel Pool (SFP), its integrity is supported by the implementation of mobile cooling capabilities (PTR bis), which align with post-Fukushima requirements for diverse, long-term cooling. The water supply to the SFP was strengthened, and the installation of flame arrestors in the SFP building is planned to prevent fire propagation. Finally, two key requirements set by the ASNR are currently outstanding: the validation of the Critical Heat Flux (CHF) correlation for deformed fuel assemblies (Study-B) and the final integration of findings regarding the Fuel Assembly Grid Buckling Limit (Study-D).

Safety aspects of core melt accidents

Severe accidents (SA) involving core meltdown were not taken into account in the design of the French 900 MWe reactors. However, as a result of previous Periodic Safety Reviews (PSRs), facilities and measures for SA management have been implemented. According to the ASNR, the objective of the fourth PSA for the 900 MWe reactors is to bring the safety level of the reactor closer to that of the EPR in Flamanville, a third-generation reactor. In third-generation reactors, features to mitigate the effects of core melt accidents are already implemented in the design; these cannot be fully transferred to second-generation reactors such as Chinon B1. The EIA documents do not contain a systematic comparison between the safety level of the 900 MWe reactors and the safety level of the EPR in order to identify the remaining gaps.

The modifications planned as part of the 4th PSR in the event of a core-melt accident focus on heat removal from the containment without opening the filtered pressure relief system and on stabilizing and cooling the corium on the basement. Based on current knowledge, a failure of the containment cannot be ruled out after the modification to stabilize and cool the molten core has been implemented. On the one hand, not all important modifications have been implemented yet, and on the other hand, it is not possible to assess whether the modifications (especially the reinforcement of the basement) are sufficient, based on the available information.

The planned modifications for heat removal without using the filtered pressure relief system in the event of a core-melt accident have not yet been fully implemented. In addition, the reinforcement of the filtered pressure relief system (U5 system) against severe earthquakes has not yet been carried out. This means that even after completion of all Phase A measures of the 4th PSR, a core-melt accident with a major release of radioactive substances is still possible at Chinon B1. The EIA documents do not provide a complete overview of which of the planned modifications meet the ASNR requirements published at the end of the generic phase of the 4th PSR. Most of the measures are not scheduled to be implemented until the end of phase B and the supplementary phase (2029). The EIA documents do not indicate whether this schedule will be adhered to.

Radiological impact of accidents / Transboundary effects

The EIA documentation considers events and accident sequences corresponding to three categories of design-basis events and an additional category representing beyond-design-basis accidents, including core-melt and spent fuel pool scenarios.

The analysis of radiological consequences presented in the document lacks technical information. Key elements required for independent verification, such as radionuclide inventories, source-term assumptions, release fractions, and detailed dispersion modelling methodology, are not provided. As a result, the transparency of the radiological impact assessment is limited as well as reproducibility of the assessment results.

For design-basis accidents, the EIA concludes that consequences remain below national reference levels and do not pose transboundary risks. For beyond-design-basis accidents, including core melt scenarios, the EIA does acknowledge potential long-range impacts, but again without providing sufficient technical data to allow validation of these results. Quantitative assessments to confirm statements regarding food contamination remaining below EU limits at a distance of more than 5 km after 7 days and less than 1 km after 1 year are not provided. The EIA also omits any information on ground deposition, despite its relevance for long-term consequences and food-chain contamination.

Modelling of atmospheric dispersion and deposition conducted by the expert team demonstrates that, under certain meteorological conditions, a severe accident at Chinon B could lead to ground deposition of Cs-137 in Austria above the national threshold value for triggering agricultural measures of 650 Bq/m^2. Although the study does not assess the probability of such conditions, the results indicate that transboundary impacts greater than those implied in the EIA cannot be excluded.

Overall, the EIA provides an assessment of radiological consequences without providing complete information on assessment methodology and underlying data to support the claims, particularly for severe accidents with potential transboundary effects. More detailed source-term information, dispersion modelling inputs, and food-chain contamination assessments would be needed to fully evaluate the potential impact on Austria and to support the claims made in the EIA documents.

Assessment of the time frame

The timeframe for implementing all measures of the 4th PSR (6 years after publication of the PSR report = 2029/2030) is not unusual in principle. However, as the period following the 4th PSR corresponds with the start of Long-Term Operation (LTO), some of the specific measures require special attention. It is important that the agreed implementation period is not extended. A lack of financial resources or the known problems with supply chain availability, including human resources, could affect the implementation period. It is particularly noteworthy that important safety modifications listed as part of the 4th PSR modifications were already considered necessary as part of the EU stress test (2012), and their implementation had been agreed upon.

ZUSAMMENFASSUNG

Das Kernkraftwerk Chinon B besteht aus vier Druckwasserreaktoren mit einer Leistung von jeweils 900 MWe. Diese Reaktoren wurden zwischen 1982 und 1987 in Betrieb genommen. Frankreich notifizierte die vierte Periodische Sicherheitsüberprüfung (PSÜ) des Kernkraftwerks Chinon B (Reaktor 1), die als Laufzeitverlängerung gemäß der UNECE Espoo Konvention über die Umweltverträglichkeitsprüfung (UVP) im grenzüberschreitenden Rahmen zu betrachten ist. Die zuständige Behörde ist das französische Departement Indre-et-Loire. Die Projektantragstellerin ist die Électricité de France (EDF).

Österreich beteiligt sich an dieser grenzüberschreitenden UVP, da erhebliche Auswirkungen eines Unfalls nicht ausgeschlossen werden können. Ziel der Beteiligung Österreichs an diesem Verfahren ist es, Empfehlungen zur Minimierung und im besten Fall zur Vermeidung möglicher erheblicher nachteiliger Auswirkungen auf Österreich abzugeben.

Verfahren

Die Betriebsgenehmigung für französische Kernkraftwerke ist zeitlich nicht begrenzt. Alle zehn Jahre werden die französischen Kernkraftwerke jedoch einer Periodischen Sicherheitsüberprüfung (PSÜ) unterzogen. Die vierte PSÜ spielt eine besondere Rolle, da sie den Genehmigungsprozess für den Langzeitbetrieb (Long-Term Operation, LTO) eines Kernkraftwerks über 40 Jahre hinaus markiert. Der französische PSÜ-Rahmen schreibt eine umfassende Sicherheitsbewertung in zwei Phasen vor: eine generische und eine anlagenspezifische Phase.

Für die 4. PSÜ der 900-MWe-Kernkraftwerke hat EDF als allgemeine Leitlinie das Ziel festgelegt, die nuklearen Sicherheitsziele der neuesten Reaktorgeneration zu erreichen, deren Referenzreaktor für EDF der EPR-Flamanville 3 ist. Diese Leitlinie wurde von der ASNR bestätigt. Die generische Phase endete mit der Veröffentlichung der Stellungnahme der ASNR am 23. Februar 2021, die allgemeine Vorschriften enthielt, die zuvor Gegenstand einer öffentlichen Konsultation gewesen waren. (ASN 2021) Nach Abschluss der generischen Phase sollen über einen Zeitraum von etwa zehn Jahren (von 2019 bis 2031) Inspektionen aller 32 Reaktoren der 900-MWe-Kernkraftwerke folgen.

Die Öffentlichkeit ist in hohem Maße in das Verfahren der Laufzeitverlängerung der französischen Kernkraftwerke eingebunden. Ein UVP-Verfahren gemäß der UVP-Richtlinie wird jedoch nicht durchgeführt.

Langzeitbetrieb und Betriebserfahrung

Auf der Grundlage der in den UVP-Unterlagen enthaltenen Informationen kann der Schluss gezogen werden, dass ein umfassendes Alterungsmanagementprogramm zur Gewährleistung des Betriebs durchgeführt wurde. Dies geht auch aus den Ergebnissen des ersten Topical Peer Review (TPR) gemäß Artikel 8e der Richtlinie 2014/87/EURATOM hervor. Das Management der mit der Alterung von Strukturen, Systemen und Komponenten (SSCs) verbundenen Probleme stellt jedoch eine große Herausforderung für das Kernkraftwerk dar, das seit mehr als 40 Jahren in Betrieb ist. Da die meisten SSCs ursprünglich für eine nominelle Betriebsdauer von 40 Jahren ausgelegt waren, kann die 4. PSÜ als die erforderliche Genehmigung für den Betrieb des Kernkraftwerks über seine ursprüngliche

Auslegungsdauer hinaus angesehen werden. Daher erfordert die 4. PSÜ eine detailliertere Betrachtung des Alterungsmanagements. Aus den UVP-Unterlagen geht nicht eindeutig hervor, ob der Umfang des Alterungsmanagements im Vergleich zur 3. PSÜ umfassend erweitert wurde. Es werden nur wenige Beispiele für den vorbeugenden Austausch von Komponenten angeführt. Soweit bekannt, hat die ASNR vorgeschlagen, den Umfang des Alterungsmanagements während der allgemeinen Phase der 5. PSÜ zu erweitern. Dies sollte auch für die 4. PSÜ durchgeführt werden.

Die Umsetzung des Programms für ergänzende Untersuchungen (PIC) ist eine Methode, die darauf abzielt, sicherzustellen, dass in Bereichen, die nicht regelmäßig inspiziert werden, keine Betriebsstörungen auftreten. Ohne Begründung wird angegeben, dass für Chinon B1 im Rahmen des ergänzenden Untersuchungsprogramms keine Kontrollen durchgeführt werden sollen.

Im Rahmen der generischen Phase der 5. PSÜ für 900-MWe-Reaktoren verlangt die ASNR von EDF, bis zum 31. Dezember 2025 eine Strategie zu definieren, um die Erkenntnisse aus der Entdeckung von Spannungsrisskorrosion und allgemeiner des Risikos einer unerwarteten Degradierung von Komponenten im Primär- und Hauptsekundärkreislauf durch Kontrollen im Rahmen zusätzlichen Inspektions- und Wartungsprogrammen zu berücksichtigen. Die Ursache der Risse, die interkristalline Spannungsrisskorrosion, ist ein bekanntes Korrosionsphänomen, das jedoch in den betreffenden Bereichen nicht zu erwarten war und daher diese auch nicht darauf untersucht wurden. Damit wird das Alterungsmanagementkonzept für Komponenten im Primär- und Hauptsekundärkreislauf in Frage gestellt.

Der Vorschlag der ASNR, das Alterungsmanagement während der 5. PSÜ gegenüber jener der 4. PSÜ zu erweitern, wird unterstützt. Wie von der ASNR vorgeschlagen, muss der Schwerpunkt auf Komponenten liegen, die für die Beherrschung von Unfallsituationen notwendig sind. Der Umfang des Programms „Qualifizierung von Werkstoffen unter Unfallbedingungen" in der 4. PSÜ ist für Chinon B1 jedoch sehr begrenzt.

Eine Bewertung der von der ASNR veröffentlichten sicherheitsrelevanten Vorfälle im Kernkraftwerk Chinon B1 in den letzten fünf Jahren (2020-2025) ergab eine Reihe von Vorfällen, die mit der Nichteinhaltung der allgemeinen Betriebsvorschriften (RGE) zusammenhingen. Der Grund für die große Anzahl von Verstößen gegen die RGE ist unbekannt.

In den letzten Jahren wurden erhebliche Mängel in der Erdbebensicherheit verschiedener Komponenten von Chinon B1 und anderer 900-MW-Reaktoren festgestellt. Es kann nicht ausgeschlossen werden, dass es weitere, bislang unbekannte Mängel gibt. Mängel im Erdbebenschutz sind für Chinon B1 von besonderem Interesse, da Zweifel an der ausreichenden Auslegung in Bezug auf Erdbeben bestehen (siehe Kapitel 4).

Externe Gefahren

Die UVP-Unterlagen enthalten umfassende Informationen über die Gefahrenarten, die beim Sicherheitsnachweis für Chinon B1 berücksichtigt wurden, sowie über die bereits umgesetzten oder beschlossenen Maßnahmen zur Erhöhung der Robustheit des Kernkraftwerks gegenüber externen Gefahren. Die Unterlagen liefern jedoch keine eindeutigen Belege dafür, dass die Methoden der PSÜ und LTO den WENRA-Anforderungen gemäß den Vorgaben der ASNR entsprechen. Für die meisten externen Gefahren werden die bei der Gefahrenbewertung verwendeten Methoden, Daten und Annahmen nicht im Detail angegeben. Insbesondere bleibt unklar, ob für alle externen Gefahren Auslegungsereignisse mit einer Überschreitungshäufigkeit von nicht mehr als 10^{-4} pro Jahr festgelegt wurden und wie die erweiterten Auslegungsbedingungen (DEC) für die identifizierten Gefahren behandelt werden.

Bei Erdbeben und seismischen Bodenerschütterungen wird eine Nichtkonformität mit den WENRA-Referenzwerten festgestellt. Das Auslegungserdbeben (DBE) für Chinon B1 basiert nach wie vor auf deterministischen Analysen. Dieser Ansatz entspricht nicht mehr dem Stand der Technik. Aus den UVP-Unterlagen geht hervor, dass eine Probabilistische Seismische Gefährdungsanalyse (PSHA) für den Standort Chinon durchgeführt wurde, um das Erdbebenrisiko für den „Hardened Safety Core" (SND) abzuleiten, das für die Auslegung des Hardened Safety Core (ND) relevant ist. Die PSHA ergab eine Bodenbeschleunigung von 0,34 g für den SND, was einem durchschnittlichem Wiederkehrintervall von 20.000 Jahren entspricht. Der deterministisch abgeleitete seismische Auslegungswert für Chinon B beträgt 0,2 g. Es bleibt daher nachzuweisen, dass die seismische Widerstandsfähigkeit aller sicherheitsrelevanten SSCs ausreichend ist, um die grundlegenden Sicherheitsfunktionen für ein DBE mit einem durchschnittlichen Wiederholungsintervall von 10.000 Jahren, wie von der WENRA (2021) gefordert, konservativ zu gewährleisten.

Im Hinblick auf die Sicherheitsnachrüstung von Chinon B ist es offensichtlich, dass eine der wichtigsten Maßnahmen zum Schutz vor externen Gefahren die Umsetzung des „Hardened Safety Core" (ND) ist. Die Umsetzung steht jedoch noch aus. Die Umsetzung ist für Phase B der 4. PSÜ angekündigt. Der von der ASNR vorgegebene Zeitplan sieht die Umsetzung des ND für Chinon B1 im Jahr 2029 vor. Die grundlegende Entscheidung zur Umsetzung des ND wurde 2012 im Anschluss an die europäischen Stresstests getroffen (ASN 2012). Die Tatsache, dass die Umsetzung des ND erst 17 Jahre später erfolgt, erscheint bemerkenswert, da die WENRA die „rechtzeitige Umsetzung der identifizierten, vernünftigerweise durchführbaren Sicherheitsverbesserungen" verlangt (WENRA 2021). Dies deutet darauf hin, dass die angekündigten Umsetzungszeitpläne nicht den Anforderungen der WENRA entsprechen.

Terroranschläge und Sabotageakte können erhebliche Auswirkungen auf kerntechnische Anlagen haben und schwere Unfälle verursachen. Dennoch werden sie in den vorgelegten UVP-Unterlagen nur sehr allgemein erwähnt. Ähnliche UVP-Berichte haben solche Ereignisse bis zu einem gewissen Grad behandelt. Auch wenn Vorsichtsmaßnahmen gegen Sabotage und Terroranschläge aus Gründen der Vertraulichkeit nicht im Detail behandelt werden können, sollten die erforderlichen rechtlichen Anforderungen in den UVP-Unterlagen dargelegt werden.

Angesichts der weitreichenden Folgen potenzieller Anschläge wären Informationen zum Thema Terroranschläge von großem Interesse. Insbesondere sollten die UVP-Unterlagen Angaben zu den Anforderungen an die Auslegung gegen den gezielten Absturz eines Verkehrsflugzeugs enthalten. Dieses Thema ist besonders wichtig, da sowohl das Reaktorgebäude als auch das Gebäude für abgebrannte Brennelemente des Kernkraftwerks Chinon B1 durch Flugzeugabstürze gefährdet sind. Es ist wichtig zu erwähnen, dass die 1,8 m dicke äußere Stahlbetonhülle des EPR so ausgelegt ist, dass sie dem Aufprall eines großen

Passagierflugzeugs standhält. Die Wandstärken im Kernkraftwerk Chinon B1 betragen jedoch weniger als 1,0 m. Darüber hinaus erhöhen die zunehmende Verfügbarkeit und Leistungsfähigkeit von Drohnen die potenzielle Bedrohung für kerntechnische Anlagen. Eine kürzlich durchgeführte Bewertung der nuklearen Sicherung in Frankreich weist zudem auf Mängel im Vergleich zu den notwendigen Anforderungen an die nukleare Sicherung in Bezug auf die „Sicherungskultur“, die „Cybersicherheit“ und den „Schutz vor Insider-Bedrohungen“ hin.

Sicherheitsaspekte von Unfällen ohne Kernschmelze und Brennelementlagerbecken

Die Analyse nutzt sowohl deterministische Sicherheitsanalysen als auch probabilistische Sicherheitsanalysen (PSA), um Betriebstransienten, Auslegungsstörfälle (DBA) und erweiterte Auslegungsbedingungen (DEC) neu zu bewerten.

Es wurden erhebliche Sicherheitsverbesserungen umgesetzt oder sind geplant, um die radiologischen Auswirkungen zu verringern und das gestaffelte Sicherheitskonzept im gesamten Kernkraftwerk zu verbessern. Durch die Diversifizierung der Verbindung des Hilfs-Speisewassersystems (ASG) des Dampferzeugers (SG) mit dem Löschwasserreservoir wurde eine verbesserte Verbindung zur Wärmesenke geschaffen, die eine langfristige Wärmeabfuhr bei Unfällen mit Ausfall der normalen und Not-Speisewasserversorgung gewährleistet. Zur thermohydraulischen Steuerung wurde die Kapazität der Sicherheits- und Überdruckventile der Hauptdampfleitung (GCT-a) erhöht (PNPE1141), um die Abkühlung und Druckentlastung des Reaktorkühlsystems (RCS) nach verschiedenen Transienten zu beschleunigen. Darüber hinaus wurde eine niedrigere zulässige Konzentration von Jod-131 (I-131) im RCS-Wasser vorgeschrieben, um die potenzielle radiologische Freisetzung bei Unfällen zu reduzieren.

Die Integrität des Lagerbeckens für abgebrannte Brennelemente (SFP) wird durch die Implementierung mobiler Kühlkapazitäten (PTR bis) unterstützt, die den Anforderungen nach Fukushima für eine diversitäre, langfristige Kühlung entsprechen. Die Wasserversorgung des SFP wurde verbessert, und die Installation von Flammensperren im SFP-Gebäude ist geplant, um eine Ausbreitung von Bränden zu verhindern. Schließlich sind derzeit noch zwei wichtige Anforderungen der ASNR offen: die Validierung der Korrelation des kritischen Wärmeflusses (CHF) für deformierte Brennelemente (Studie B) und die endgültige Integration der Ergebnisse bezüglich des mechanischen Verhaltens der Brennelemente (Studie D).

Sicherheitsaspekte von Kernschmelzunfällen

Schwere Unfälle (SA) mit Kernschmelze wurden bei der Auslegung der französischen 900-MWe-Reaktoren nicht berücksichtigt. Als Ergebnis früherer periodischer Sicherheitsüberprüfungen (PSÜs) wurden jedoch Einrichtungen und Maßnahmen für das SA-Management implementiert. Laut ASNR besteht das Ziel der vierten PSÜ für die 900-MWe-Reaktoren darin, das Sicherheitsniveau des Reaktors näher an das des EPR in Flamanville, einem Reaktor der dritten Generation, heranzuführen. In Reaktoren der dritten Generation wurden bereits Einrichtungen zur Minderung der Auswirkungen von Kernschmelzunfällen in der Auslegung integriert; diese können nicht vollständig auf Reaktoren der zweiten Generation wie Chinon B1 übertragen werden. Die UVP-Unterlagen enthalten keinen systematischen Vergleich zwischen dem Sicherheitsniveau der 900-MWe-Reaktoren und dem Sicherheitsniveau des EPR, um die verbleibenden Lücken zu ermitteln.

Die im Rahmen des 4. PSÜ geplanten Modifikationen für den Fall eines Kernschmelzunfalls konzentrieren sich auf die Wärmeabfuhr aus dem Sicherheitsbehälter ohne Öffnung des gefilterten Druckentlastungssystems sowie auf die Stabilisierung und Kühlung des Coriums auf dem Fundament. Nach dem derzeitigen Kenntnisstand kann ein Versagen des Sicherheitsbehälters nach der Umsetzung der Modifikation zur Stabilisierung und Kühlung des geschmolzenen Kerns nicht ausgeschlossen werden. Zum einen sind noch nicht alle wichtigen Modifikationen umgesetzt, zum anderen lässt sich anhand der vorliegenden Informationen nicht beurteilen, ob die Modifikationen (insbesondere die Verstärkung des Fundaments) ausreichend sind.

Die geplanten Modifikationen zur Wärmeabfuhr ohne Einsatz des gefilterten Druckentlastungssystems im Falle eines Kernschmelzunfalls sind noch nicht vollständig umgesetzt. Darüber hinaus wurde die Verstärkung des gefilterten Druckentlastungssystems (U5-System) gegen schwere Erdbeben noch nicht durchgeführt. Das bedeutet, dass auch nach Abschluss aller Maßnahmen der Phase A der 4. PSÜ ein Kernschmelzunfall mit einer erheblichen Freisetzung radioaktiver Stoffe in Chinon B1 weiterhin möglich ist. Die UVP-Unterlagen geben keinen vollständigen Überblick darüber, welche der geplanten Modifikationen den am Ende der generischen Phase der 4. PSÜ veröffentlichten Anforderungen der ASNR entsprechen. Die meisten Maßnahmen sollen erst am Ende der Phase B und der Ergänzungsphase (2029) umgesetzt werden. Aus den UVP-Unterlagen geht nicht hervor, ob dieser Zeitplan eingehalten wird.

Radiologische Auswirkungen von Unfällen / Grenzüberschreitende Auswirkungen

Die UVP-Unterlagen berücksichtigen Ereignisse und Unfallabläufe, die drei Kategorien von Auslegungsstörfällen entsprechen, sowie eine zusätzliche Kategorie, die auslegungsüberschreitende Unfälle umfasst, darunter Szenarien mit Kernschmelze und im Lagerbecken für abgebrannte Brennelementen.

Der in dem Dokument dargestellten Analyse der radiologischen Folgen fehlen technische Informationen. Wichtige Elemente, die für eine unabhängige Überprüfung erforderlich sind, wie Radionuklidinventare, Annahmen zum Quellterm, Freisetzungsanteile und eine detaillierte Methodik zur Ausbreitungsmodellierung, werden nicht bereitgestellt. Infolgedessen sind sowohl die Transparenz der Bewertung der radiologischen Auswirkungen als auch die Reproduzierbarkeit der Bewertungsergebnisse begrenzt.

Für Auslegungsstörfälle kommt die UVP zu dem Schluss, dass die Folgen unter den nationalen Referenzwerten bleiben und keine grenzüberschreitenden Risiken darstellen. Für auslegungsüberschreitende Unfälle, einschließlich Kernschmelzszenarien, erkennt die UVP zwar potenzielle weitreichende Auswirkungen an, liefert jedoch erneut keine ausreichenden technischen Daten, um diese Ergebnisse zu validieren. Quantitative Bewertungen zur Bestätigung der Aussagen, dass die Lebensmittelkontamination in einer Entfernung von mehr als 5 km nach 7 Tagen und von weniger als 1 km nach 1 Jahr unter den EU-Grenzwerten bleibt, werden nicht vorgelegt. Die UVP enthält auch keine Informationen zur

Bodenkontamination, obwohl diese für die langfristigen Folgen und die Kontamination der Nahrungskette von Bedeutung sind.

Die vom Expert:innenteam durchgeführte Modellierung der atmosphärischen Ausbreitung und Bodenkontamination zeigt, dass unter bestimmten meteorologischen Bedingungen ein schwerer Unfall in Chinon B zu einer Bodenkontamination von Cs-137 in Österreich führen könnte, die über dem nationalen Schwellenwert von 650 Bq/m² für die Einleitung landwirtschaftlicher Maßnahmen liegt. Obwohl die Studie die Wahrscheinlichkeit solcher Bedingungen nicht bewertet, deuten die Ergebnisse darauf hin, dass grenzüberschreitende Auswirkungen, die über die in der Umweltverträglichkeitsprüfung dargestellten hinausgehen, nicht ausgeschlossen werden können.

Insgesamt liefern die UVP-Dokumente eine Bewertung der radiologischen Folgen, ohne vollständige Informationen über die Bewertungsmethodik und die zugrunde liegenden Daten zur Untermauerung der Behauptungen, insbesondere für schwere Unfälle mit potenziellen grenzüberschreitenden Auswirkungen, zu liefern. Um die potenziellen Auswirkungen auf Österreich vollständig bewerten und die in den UVP-Dokumenten gemachten Behauptungen untermauern zu können, wären detailliertere Informationen zum Quellterm, Angaben zur Ausbreitungsmodellierung und zur Bewertung der Kontamination der Nahrungskette erforderlich.

Bewertung des Zeitrahmens

Der Zeitrahmen für die Umsetzung aller Maßnahmen des 4. PSÜ (6 Jahre nach Veröffentlichung des PSÜ-Berichts = 2029/2030) ist grundsätzlich nicht ungewöhnlich. Da jedoch der Zeitraum nach der 4. PSÜ mit dem Beginn des Langzeitbetriebs (LTO) zusammenfällt, erfordern einige der spezifischen Maßnahmen besondere Aufmerksamkeit. Es ist wichtig, dass der vereinbarte Umsetzungszeitraum nicht verlängert wird. Ein Mangel an finanziellen Ressourcen oder die bekannten Probleme mit der Verfügbarkeit der Lieferkette, einschließlich der Humanressourcen, könnten sich auf den Umsetzungszeitraum auswirken. Besonders bemerkenswert ist, dass wichtige Sicherheitsmodifikationen, die als Teil der 4. PSÜ-Änderungen aufgeführt sind, bereits im Rahmen des EU-Stresstests (2012) als notwendig erachtet wurden und deren Umsetzung vereinbart worden war.

RÉSUMÉ

La centrale nucléaire de Chinon B comprend quatre réacteurs à eau pressurisée d'une puissance de 900 MWe chacun. Ces réacteurs ont été mis en service entre 1982 et 1987. La France a notifié le quatrième réexamen périodique de la centrale nucléaire de Chinon B (réacteur 1), qui doit être considéré comme une prolongation de durée de vie conformément à la Convention d'Espoo de la CEE-ONU sur l'évaluation de l'impact sur l'environnement (EIE) dans un contexte transfrontalier. L'autorité compétente est le département français d'Indre-et-Loire. Le demandeur du projet est l'Électricité de France (EDF).

L'Autriche participe à cette EIE transfrontalière, car des conséquences importantes en cas d'accident ne peuvent être exclues. L'objectif de la participation de l'Autriche à ce processus est de formuler des recommandations visant à minimiser, et dans le meilleur des cas à éliminer, les éventuelles conséquences négatives importantes pour l'Autriche.

Procédure

L'autorisation d'exploitation des centrales nucléaires françaises n'est pas limitée dans le temps. Cependant, tous les dix ans, les centrales nucléaires françaises sont soumises à un contrôle périodique de sûreté (RP). Le quatrième RP joue un rôle particulier, car il définit le processus réglementaire pour l'exploitation à long terme (LTO) d'une centrale nucléaire au-delà de 40 ans. Le cadre français du RP impose une évaluation complète de la sûreté en deux phases : générique et spécifique à chaque centrale.

Pour le quatrième RP des centrales nucléaires de 900 MWe, EDF a fixé comme ligne directrice générale l'objectif d'atteindre le niveau de sûreté nucléaire des réacteurs de dernière génération, dont le réacteur de référence pour EDF est l'EPR-Flamanville 3. Cette ligne directrice a été confirmée par l'ASNR. La phase générique s'est achevée avec la publication de l'avis de l'ASNR le 23 février 2021, qui contenait des réglementations générales ayant fait précédemment l'objet d'une consultation publique. (ASN 2021) Une fois la phase générique terminée, les inspections des 32 réacteurs des centrales nucléaires de 900 MWe devraient être effectuées sur une période d'environ dix ans (de 2019 à 2031).

Le public est fortement impliqué dans le processus de prolongation de la durée de vie du parc nucléaire français. Néanmoins, une EIE conforme à la directive EIE n'est pas réalisée.

Exploitation à long terme et expérience opérationnelle

Sur la base des informations fournies dans les documents d'EIE, on peut conclure qu'un programme complet de gestion du vieillissement a été mis en œuvre pour garantir le fonctionnement. C'est également ce qu'indiquent les résultats du premier examen thématique par les pairs (Topical Peer Review - TPR) prévu à l'article 8e de la directive 2014/87/ EURATOM. Cependant, la résolution des problèmes liés au vieillissement des structures, systèmes et composants

(SSC) représente un défi majeur pour la centrale, qui est en service depuis plus de 40 ans. Étant donné que la plupart des SSC ont été initialement conçus pour une durée de vie nominale de 40 ans, le 4e RP peut être considéré comme l'autorisation nécessaire pour exploiter la centrale nucléaire au-delà de sa durée de vie initiale. Par conséquent, le 4e RP nécessite un examen plus approfondi de la gestion du vieillissement. Les documents d'EIE n'indiquent pas clairement s'il y a eu une extension complète du champ d'application de la gestion du vieillissement par rapport au 3e RP. Seuls quelques exemples de remplacement préventif de composants sont présentés. À notre connaissance, l'ASNR a proposé d'étendre la portée de la gestion du vieillissement pendant la phase générale du 5e RP. Cela devrait également être réalisé pour le 4e RP.

La mise en œuvre du programme d'investigations complémentaires (PIC) est une approche qui vise à confirmer l'absence de défaillances opérationnelles dans les secteurs qui ne font pas l'objet d'inspections régulières. Il est précisé sans justification qu'aucun contrôle ne doit être effectué pour Chinon B1 dans le cadre du programme d'investigations complémentaires.

Dans le cadre de la phase générique du 5e RP des réacteurs de 900 MWe, l'ASNR demande à EDF de définir, d'ici le 31 décembre 2025, la stratégie visant à prendre en compte les conclusions tirées de la découverte de fissures de corrosion sous contrainte et, plus généralement, le risque de dégradation inattendue des composants des circuits primaire et secondaire principal à travers les contrôles requis par les programmes d'inspection et de maintenance supplémentaires. L'origine des fissures, la corrosion sous contrainte inter cristalline, est un phénomène de corrosion bien connu, mais il n'était pas susceptible de se produire dans les zones concernées et les tuyaux n'ont donc pas été inspectés à cet effet. Cela signifie que le concept de gestion du vieillissement des composants des circuits primaire et secondaire principal est remis en question.

La proposition de l'ASNR, visant à étendre la gestion du vieillissement au-delà du 4e RP pendant la phase générale du 5e RP est soutenue. Comme le propose l'ASNR, l'accent doit être mis sur les composants nécessaires au contrôle des situations accidentelles. Cependant, la portée du programme « qualification des matériels aux conditions accidentelles » du 4e RP est très limitée pour Chinon B1.

Une évaluation des incidents liés à la sûreté survenus à la centrale nucléaire de Chinon B1 au cours des cinq dernières années (2020-2025), publiée par l'ASNR, a révélé un certain nombre d'incidents liés au non-respect des règles générales d'exploitation (RGE). La raison du nombre élevé de violations des RGE est inconnue.

Au cours des dernières années, des d'importantes lacunes ont été identifiées dans la résistance sismique de divers composants de Chinon B1 et d'autres réacteurs de 900 MW. On ne peut exclure l'existence d'autres lacunes, non identifiées à ce jour. Les lacunes en matière de protection contre les séismes présentent un intérêt particulier pour Chinon B1, car des doutes subsistent quant à l'adéquation de sa conception en cas de séisme (voir chapitre 4).

Risques externes

Les documents d'EIE fournissent des informations complètes sur les types de risques pris en compte dans la démonstration de sûreté de Chinon B1 et sur les mesures déjà mises en œuvre ou dont la mise en œuvre a été décidée afin de renforcer la robustesse de la centrale nucléaire face aux risques externes. Cependant, ces documents ne fournissent pas de preuves claires que les processus de RP et de LTO sont conformes aux exigences de la WENRA telles que stipulées par l'ASNR. Pour la plupart des risques externes, les méthodes, les données et les hypothèses utilisées dans l'évaluation des risques ne sont pas précisées en détail. Il reste particulièrement vague si des incidents de dimensionnement dont la fréquence n'est pas supérieure à 10^{-4} par an ont été déterminés pour tous les risques externes et comment les conditions d'extension de conception (en anglais DEC) sont prises en compte pour les risques identifiés.

Une non-conformité avec les niveaux de référence de la WENRA est observée pour les séismes et les secousses sismiques. Les séismes de référence (SMS) pour Chinon B1 sont toujours basés sur des analyses déterministes. Cette approche n'est plus à la pointe de la technologie. Les documents d'EIE précisent qu'une évaluation probabiliste des risques pour la sûreté (EPS) a été réalisée pour le site de Chinon afin de déterminer le niveau sismique au Noyau Dur (SND), qui est pertinent pour la conception du Noyau Dur (ND). La EPS a révélé une accélération du sol de 0,34 g pour le SND, ce qui correspond à une période de retour moyenne des séismes de 20 000 ans. La valeur de SMS pour Chinon B est de 0,2 g. Il reste donc à démontrer que la résistance sismique de tous les SSC importants pour la sûreté est suffisante pour garantir de manière conservatrice les fonctions de sûreté fondamentales pour un SMS avec un intervalle de récurrence moyen de 10 000 ans, comme l'exige la WENRA (2021).

En ce qui concerne les améliorations de la sûreté de Chinon B, il est évident que l'une des mesures les plus importantes pour assurer la protection contre les risques aléas externes est la mise en œuvre du ND. Cependant, sa mise en œuvre est toujours en attente. La mise en œuvre est annoncée pour la phase B du 4e RP. Le calendrier prescrit par l'ASNR prévoit la mise en œuvre du ND pour Chinon B1 en 2029. La décision fondamentale de mettre en œuvre le ND a été prise en 2012 à la suite des tests de résistance européens (ASN 2012). Le fait que la mise en œuvre du ND soit en attente pendant 17 ans après cela semble remarquable étant donné que la WENRA exige « la mise en œuvre en temps utile des améliorations de sécurité raisonnablement réalisables qui ont été identifiées » (WENRA 2021). Cela suggère que les calendriers de mise en œuvre annoncés ne sont pas conformes à l'exigence de la WENRA.

Les attentats terroristes et les actes de sabotage peuvent avoir un impact significatif sur les installations nucléaires et provoquer des accidents graves. Néanmoins, ils ne sont mentionnés qu'en termes très généraux dans les documents d'EIE soumis. Des rapports d'EIE similaires ont couvert ces événements dans une certaine mesure. Même si les précautions contre le sabotage et les attentats terroristes ne peuvent être discutées en détail pour des raisons de confidentialité, les exigences légales nécessaires devraient être énoncées dans les documents d'EIE.

Les informations relatives aux attentats terroristes seraient d'un grand intérêt, compte tenu des conséquences considérables que pourraient avoir de telles attaques. Les documents d'EIE devraient notamment inclure des informations sur les exigences en matière de conception visant à prévenir le crash ciblé d'un avion commercial. Ce sujet est particulièrement important, car le bâtiment du réacteur ainsi que le bâtiment de stockage du combustible usé de la centrale nucléaire de Chinon B1 sont vulnérables aux crashs d'avion. Il est important de mentionner que l'enveloppe extérieure en béton armé de 1,8 m d'épaisseur de l'EPR est conçue pour résister à l'impact d'un gros avion de ligne. Cependant, l'épaisseur des murs de la centrale nucléaire de Chinon B1 est inférieure à 1,0 m. En outre, la disponibilité et les performances croissantes des drones augmentent la menace potentielle pour les installations nucléaires. Une évaluation récente de la sécurité nucléaire en France met en évidence des lacunes par rapport aux exigences nécessaires en matière de sécurité nucléaire en ce qui concerne la « culture de la sécurité », la « cybersécurité » et la « protection contre les menaces internes ».

Aspects liés à la sûreté en cas d'accident sans fusion du cœuret Piscine d'entreposage du combustible usé

L'analyse utilise à la fois l'analyse déterministe de sûreté et l'analyse probabiliste de sûreté (EPS) pour réévaluer les transitoires opérationnels, les accidents de conception (DBA) et les conditions d'extension de conception (DEC).

Des améliorations importantes en matière de sûreté ont été mises en œuvre ou sont prévues afin de réduire les conséquences radiologiques et d'améliorer la défense en profondeur dans l'ensemble de la centrale. Une connexion renforcée au dissipateur thermique ultime a été mise en place en diversifiant la connexion du Système d'alimentation auxiliaire en eau du générateur de vapeur (ASG) au réservoir d'eau d'extinction d'incendie ; cela garantit une capacité d'évacuation de la chaleur à long terme lors d'accidents impliquant une perte d'alimentation en eau normale et d'urgence. Pour le contrôle thermohydraulique, la capacité des vannes de sécurité et de décharge sur la conduite de vapeur principale (GCT-a) a a été augmentée (PNPE1141) afin d'accélérer le refroidissement et la dépressurisation du système de refroidissement du réacteur à la suite de divers transitoires. En outre, une concentration admissible plus faible d'iode 131 (I-131) dans l'eau du système de refroidissement a été imposée afin de réduire l'activité des éventuels rejets radioactifs en cas d'accident.

En ce qui concerne la piscine d'entreposage du combustible usé (en anglais SFP), son intégrité est renforcée par la mise en place de capacités de refroidissement mobiles (PTR bis), conformément aux exigences post-Fukushima en matière de refroidissement diversifié et à long terme. L'alimentation en eau de la SFP a été renforcée et l'installation de pare-flammes dans le bâtiment de la SFP est prévue afin d'empêcher la propagation du feu. Enfin, deux exigences clés fixées par l'ASNR sont actuellement encore en suspens : validité de la corrélation de flux critique en présence d'assemblages déformés latéralement (étude B) et l'intégration finale des conclusions concernant comportement mécanique des assemblages de combustible (étude D).

Aspects de sûreté des accidents de fusion du cœur

Les accidents graves (SA) impliquant une fusion du cœur n'ont pas été pris en compte dans la conception des réacteurs français de 900 MWe. Cependant, à la suite des examens périodiques de sûreté (RP) précédents, des installations et des mesures de gestion des SA ont été mises en place. Selon l'ASNR, l'objectif de la quatrième RP pour les réacteurs de 900 MWe est de rapprocher le niveau de sûreté du réacteur de celui de l'EPR de Flamanville, un réacteur de troisième génération. Dans les réacteurs de troisième génération, des dispositifs visant à atténuer les effets des accidents de fusion du cœur sont déjà intégrés dans la conception ; ceux-ci ne peuvent pas être entièrement transposés aux réacteurs de deuxième génération tels que Chinon B1. Les documents d'EIE ne contiennent pas de comparaison systématique entre le niveau de sûreté des réacteurs de 900 MWe et celui de l'EPR afin d'identifier les écarts restants.

Les modifications prévues dans le cadre du 4e RP en cas d'accident de fusion du cœur se concentrent sur l’évacuation de la puissance résiduelle du cœur sans ouverture du dispositif de décompression et filtration de l’enceinte (dispositif dit U5) et sur la stabilisation du corium sur le radier du bâtiment réacteur par son étalement et son renoyage.

Sur la base des connaissances actuelles, une défaillance de l'enceinte de confinement ne peut être exclue après la mise en œuvre de la modification visant à stabiliser et à refroidir le cœur fondu. D'une part, les modifications importantes n'ont pas encore toutes été mises en œuvre et, d'autre part, il n'est pas possible d'évaluer si les modifications (en particulier le renforcement du bâtiment réacteur) sont suffisantes compte tenu des informations disponibles.

Les modifications prévues pour sur l’évacuation de la puissance résiduelle du cœur sans ouverture du dispositif de décompression et filtration de l’enceinte en cas d'accident de fusion du cœur n'ont pas encore été entièrement mises en œuvre. En outre, le renforcement du système de décompression filtré (système U5) contre les séismes violents n'a pas encore été réalisé. Cela signifie que même après l'achèvement de toutes les mesures de la phase A du 4e RP, un accident de fusion du cœur avec un rejet important de substances radioactives est toujours possible à Chinon B1. Les documents d'EIE ne fournissent pas un aperçu complet des modifications prévues qui répondent aux exigences de l'ASNR publiées à la fin de la phase générique de la 4e RP. La plupart des mesures ne sont pas prévues avant la fin de la phase B et de la phase supplémentaire (2029). Les documents d'EIE n'indiquent pas si ce calendrier sera respecté.

Impact radiologique des accidents / Effets transfrontaliers

La documentation de l'EIE examine les événements et les séquences d'accidents correspondant à trois catégories de scénarios de base et à une catégorie supplémentaire représentant des accidents dépassant les limites de conception, y compris des scénarios de fusion du cœur et de piscine d’entreposage du combustible usé.

L'analyse des conséquences radiologiques présentée dans le document manque d'informations techniques. Les éléments clés nécessaires à une vérification indépendante, tels que les inventaires des radionucléides, les hypothèses relatives au terme source, les fractions de rejet et la méthodologie détaillée de modélisation de la dispersion, ne sont pas fournis. En conséquence, la transparence de l'évaluation de l'impact radiologique est limitée, tout comme la reproductibilité des résultats de l'évaluation.

Pour les accidents de base, l'EIE conclut que les conséquences restent inférieures aux niveaux de référence nationaux et ne présentent pas de risques transfrontaliers. Pour les accidents dépassant les limites de conception, y compris les scénarios de fusion du cœur, l'EIE reconnaît certes les impacts potentiels à longue distance, mais là encore sans fournir de données techniques suffisantes pour permettre la validation de ces résultats. Aucune évaluation quantitative n'est fournie pour confirmer les déclarations selon lesquelles la contamination alimentaire resterait inférieure aux limites de l'UE à une distance de plus de 5 km après 7 jours et de moins de 1 km après 1 an. L'EIE omet également toute information sur les dépôts au sol, malgré leur importance pour les conséquences à long terme et la contamination de la chaîne alimentaire.

La modélisation de la dispersion atmosphérique et dépôt réalisée par l'équipe d'experts démontre que, dans certaines conditions météorologiques, un accident grave à Chinon B pourrait entraîner des contaminations du sol de Cs-137 en Autriche supérieurs à la valeur seuil nationale de 650 Bq/m² déclenchant des mesures agricoles. Bien que l'étude n'évalue pas la probabilité de telles conditions, les résultats indiquent que des impacts transfrontaliers supérieurs à ceux impliqués dans l'EIE ne peuvent être exclus.

Dans l'ensemble, l'EIE fournit une évaluation des conséquences radiologiques sans donner des informations complètes sur la méthodologie d'évaluation et les données sous-jacentes à l'appui des affirmations, en particulier pour les accidents graves ayant des effets transfrontaliers potentiels. Des informations plus détaillées sur le terme source, les données utilisées pour la modélisation de la dispersion et les évaluations de la contamination de la chaîne alimentaire seraient nécessaires pour évaluer pleinement l'impact potentiel sur l'Autriche et justifier les affirmations contenues dans les documents de l'EIE.

Évaluation du calendrier

Le calendrier de mise en œuvre de toutes les mesures du 4e RP (6 ans après la publication du rapport RP = 2029/2030) n'est pas inhabituel en principe. Cependant, comme la période suivant le 4e RP correspond au début de l'exploitation à long terme (LTO), certaines mesures spécifiques nécessitent une attention particulière. Il est important que la période de mise en œuvre convenue ne soit pas prolongée. Le manque de ressources financières ou les problèmes connus liés à la disponibilité de la chaîne d'approvisionnement, y compris les ressources humaines, pourraient avoir un impact sur la période de mise en œuvre. Il convient de noter en particulier que d'importantes modifications de sécurité figurant dans la liste des modifications du 4e RP avaient déjà été jugées nécessaires dans le cadre du test de résistance de l'UE (2012) et que leur mise en œuvre avait été convenue.

1 INTRODUCTION

The Chinon B NPP consists of four pressurized water reactors with a capacity of 900 Mwe each. These reactors were commissioned between 1982 and 1987.

France notified the 4th Periodic Safety Review ("Public consultation procedure on the 4th safety review report") of the Chinon B nuclear power plant (reactor 1), which is to be considered as a lifetime extension in accordance with the UNECE Espoo Convention on Environmental Impact Assessment (EIA) in a Transboundary Context. The competent authority is the French department of Indre-et-Loire. The project applicant is Électricité de France (EDF).

Austria is participating in this transboundary EIA, as significant impacts of an accident cannot be excluded. The aim of Austria's participation in the process is to give recommendations to minimize, and in the best case eliminate, possible significant adverse impacts on Austria.

The Austrian Federal Ministry of Agriculture and Foresty, Climate and Environmental Protection, Regions and Water Management Action commissioned the Environment Agency Austria to coordinate the assessment of the submitted EIA documents in the framework of an expert statement.

2 PROCEDURE

2.1 Treatment in the EIA documents

The operating authorization of French nuclear power plants (NPPs) is not limited in time. However, every ten years, French NPPs are subject to a Periodic Safety Review (PSR), known in France as the Réexamen Périodique de Sûreté.

While NPPs are continuously inspected, a PSR involves a comprehensive evaluation of the state of structures, systems, and components (SSCs). It serves two main functions: a Conformity Check to verify plant components match their required safety standards, and a Safety Reassessment that compares the plant against current norms. The review aims to demonstrate that safety requirements will be fulfilled for at least ten years following the approval of the PSR.

The fourth PSR plays a special role, as it marks the regulatory process for the Long-Term Operation (LTO) of an NPP beyond 40 years. Since most SSCs were originally designed with a nominal 40-year lifespan in mind, the 4th PSR can be viewed as the authorization required to operate the NPP beyond its initial design life. Therefore, the 4th PSR includes a closer look at aging management and LTO-specific issues.

Aging affects not only the physical SSCs but also the regulatory framework. The safety standards according to which the NPP was designed often become superseded by more modern, stricter standards. Feedback from severe accidents has consistently driven the evolution of these standards, raising the bar for NPP design. Consequently, one aspect of the 4th PSR is to identify deltas (gaps) between the current design basis of the NPP and the modern state-of-the-art. The process requires proposing measures for backfitting (safety up-grades) the NPP to minimize these deltas as far as reasonably achievable. EDF and the ASNR have agreed to benchmark the safety levels of the French NPPs undergoing their 4th PSR against the standards applied to the EPR Flamanville 3 reactor, which is considered the current state-of-the-art reference.

The French NPP fleet can be broadly divided into three classes of NPPs. NPPs in each class were commissioned close to each other in time and share largely similar technology.

900 MWe reactors (32 units):

- Timeline: Construction largely spanned from the early 1970s to the late 1980s.
- Sub-types: Divided into type CP0, type CP1, and type CP2. The CP0 units were the earliest to be commissioned followed by the larger CP1 and CP2 series (e.g., Tricastin, Gravelines, Chinon).

1300 MWe reactors (20 units):

- Timeline: Construction periods generally started in the late 1970s and continued into the late 1990s.
- Sub-types: Divided into type P4 and type P'4. Plants include Paluel, Cattenom, and Belleville.

1450 Mwe Reactors (4 units):

- Timeline: Represents the latest series, with construction starting around the mid-1980s and concluding around 2000.
- Sub-types: Designated as type N4. Plants are Chooz B and Civaux.

The subject of this report is the 900 MWe fleet. The 900 MWe fleet consists of 32 reactors of the CP type, which are 3-loop pressurized water reactors. This fleet includes three sub-types: CP0, CP1, and CP2 (with CP1 and CP2 often jointly referred to as CPY). While Fessenheim units 1 and 2 were permanently shut down, EDF is planning to extend the operational life of all the other units beyond forty years. (ASN 2022)

France is conducting the 4th PSR in two phases, a generic and a specific phase. For the 4th PSR of the 900-MWe nuclear power plants, EDF has set as a general guideline the objective of achieving the nuclear safety targets of the latest generation of reactors, whose reference reactor for EDF is the EPR-Flamanville 3. This guideline has been confirmed by the ASNR. The generic phase ended with the publication of the ASNR's opinion on February 23, 2021, which contained general regulations that had previously been the subject of a public consultation. (ASN 2021)

Once the generic phase is complete, inspections of all 32 reactors at the 900 MWe nuclear power plants should follow over a period of approximately ten years (from 2019 to 2031). EDF submits a review report to the government and the ASNR. This is prepared after the ten-year reactor inspection, during which modifications and inspection and maintenance work are carried out. The following timeline shows the main stages of the 4th PSR for Chinon B1.

Figure 1: Main stages of the 4th PSR for Chinon B1 (EIA-REPORT P.1 2025)

Main stages of the 4th PSR

Source: Environment Agency Austria

Public Involvement in the PSR

Several steps were taken to involve the public in the generic phase of the 4th PSR of the 900 MWe reactors. These steps were designed to inform the public, facilitate the understanding of complex safety issues, explain the ASNR requirements associated with the review, and gather the expectations and positions of the various contributors.

The ASNR involved the public as early as 2016 in the development of its position on the "major objectives" of the 4th PSR of the 900 MWe reactors. This approach was continued in the development of its generic resolution on the 4th periodic safety review in early 2021. (ASN 2021)

While the public involvement process had similarities to an EIA, France always emphasized that the process is not to be seen as an EIA following the EU EIA Directive. Instead, France requested the High Committee for Transparency and Information on Nuclear Safety (HCTINS) to organize the process. Public comments for the specific phase for the NPP Chinon B, for instance, are possible until December 2025.

2.2 Discussion

There is a high degree of public involvement in the process of the lifetime extension of the French NPP fleet. However, an EIA according to the EIA Directive is not performed.

2.3 Conclusion

Since all the important elements of an EIA are present in the process, it is difficult to see why the last step, to implement the consultation in the frame of an EIA process, has not been taken.

3 LONG-TERM OPERATION AND OPERATIONAL EXPERIENCE

3.1 Treatment in the EIA documents

Ageing and obsolescence control

The EIA REPORT P.2 (2025) deals with the Ageing Management. The approach to controlling aging and dealing with obsolescence is based on three sustainable operational processes:

- the process for controlling the aging of structures, systems, and components (SSCs), which is being continued in the 4th PSR,
- the process of inspection during operation and maintenance,
- the process for addressing the obsolescence of materials and spare parts.

It is stated that the method used is in line with international best practices and consistent with the approach recommended by the IAEA in its Safety Guide No. NS-G-2.12 *"Ageing Management for Nuclear Power* Plants." (EIA REPORT P.2 2025)

The main measures taken or proposed by the operator in this area have two objectives:

<u>1 Proof of functionality of non-replaceable components after 40 years:</u>

- The operational reliability of the **reactor pressure vessel** has been proven using a conservative deterministic approach (neutron physics, materials, mechanics, etc.).
- The mechanical performance of the **containment** is continuously monitored by monitoring devices (e.g., deformation measurement). A pressure test of the containment is performed during each ten-year inspection. This test was carried out on the Chinon B1 containment from July 8 to 11, 2023, with the results meeting expectations.

<u>2 Proof of the functionality of replaceable materials after 40 years, which would otherwise be either replaced or modernized.</u>

Components whose performance may deteriorate due to aging and whose failure may have an impact on safety are documented and regularly inspected. In this context, inspections, checks, and maintenance work were carried out on the following SSCs during the 4th PSR: structures, control and monitoring systems, electrical cables, mechanical and electromechanical equipment, electrical equipment, and instrumentation.

Following completion of the aging control analysis of the SSCs of Chinon B1, maintenance and control measures were carried out, along with modifications to ensure the continued suitability of this unit for operation for a period of ten years after the 4th PSR shutdown.

Risk of obsolescence

Controlling the risk of component obsolescence is based in particular on monitoring the availability of spare parts, their procurement and, if necessary, ordering new identical or equivalent equipment. This equipment is then subjected to the same qualification tests as the original equipment. As part of the 4th PSR of the 900 MWe reactors, EDF plans, for example, to replace certain control and monitoring devices and certain components of switchboards.

Dossier of Suitability for Continued Operation" (DAPE)

The "Dossier of Suitability for Continued Operation" (DAPE) examines in detail the control of aging risks for a component or a structure. It describes the associated aging management program, including aspects such as in-service monitoring, regular and extraordinary maintenance, operating conditions, possible changes, supplementary studies, R&D programs, laboratory tests, particularly in the field of materials, quality assurance procedures, etc. The DAPEs are updated every five years. (EIA REPORT P.2 2025)

There are currently 12 DAPE for the following components for the 900 Mwe reactors:

- Reactor pressure vessel,
- Internal core components,
- Steam generators,
- Primary piping,
- Pressurizer,
- Primary motor pump group,
- Auxiliary lines of the primary main circuit,
- Power cables,
- Electrical penetrations,
- Control system,
- Containment,
- Structures.

Program for Complementary Investigations (PIC)

The implementation of the Program for Complementary Investigations (PIC) is an approach that aims to confirm the absence of operational failures in areas that are not regularly inspected. As part of the 4th PSR, the following areas were selected for the PIC:

- mechanical equipment of the primary and secondary circuit,
- other mechanical equipment: piping, heat exchangers, pumps, valves,
- containment.

Without justification, it is stated that no checks are to be carried out for Chinon B1 as part of the supplementary investigation program. (EIA-REPORT P.1 2025)

Stress corrosion of the auxiliary lines

As part of the proceedings initiated at the end of 2021 concerning "stress corrosion" on the auxiliary lines of the main primary circuit, investigations on the various reactors have shown that 900 MWe reactors such as those at Chinon B are hardly susceptible, if at all, to this phenomenon. In consultation with ASNR, a strategy for dealing with the nuclear power plants and a corresponding inspection program were established. With regard to the Chinon B1 reactor, inspections in 2023 led to the replacement of a weld joint connected to hot leg No. 2.

Objectives for the "continued operation after 40 years" of the 4th PSR

The 4th PSR of the 900 MWe reactors provides for a comprehensive work program on the aging of the plants as part of the continued operation of the plants after 40 years. The approach is based on aging management and maintaining the qualification of materials under accident conditions.

Qualification of materials under accident conditions

The objective of the "qualification of materials under accident conditions" is to verify that the organizational provisions required to ensure the sustainability of the qualification are in place. Verification of the organizational provisions was carried out and 257 materials qualified under accident conditions were physically inspected in Chinon B1. All checks required under this program were carried out. Anomalies were analyzed and/or corrected.

Maintaining qualification under accident conditions is subject to a procedure based on several verification methods, ranging from document analysis and sampling for testing to replacement. The result of this step-by-step and comprehensive procedure involves a considerable amount of work and makes it possible to guarantee the extension of the service life up to the 5th PSR.

The following two projects are mentioned:

- Ensuring the qualification under accident conditions of an activity measurement chain in the reactor building after more than 40 years of operation.
- Ensuring the qualification under accident conditions for distribution boxes and cabinets of the electrical components of the emergency power supply system that are more than 40 years old.

Safety relevant events

According to the EIA-REPORT P.1 (2025), between January 2012 and December 2021, the Chinon power plant reported 52 significant events. None of these had any noticeable impact on the environment. Each time, corrective and preventive measures were implemented and their effectiveness was verified. This analysis of ten years of operating experience confirms that the management of significant events is correctly integrated into the Chinon power plant's management system.

It is further explained that, at the time of publication of the EIA report, Chinon B1 has no specific safety-related events classified at Level 1 on the INES scale for which corrective measures are planned in accordance with the applicable regulations but have not yet been completed. (EIA-REPORT P.2 2025)

3.2 Discussion

As in any industrial plant, the quality of the materials used in a nuclear power plant deteriorates during operation, particularly as a result of physical aging[1]. Exposure to ionizing radiation, thermal and mechanical stresses, and corrosive, abrasive, and erosive processes cause the components to age. The consequences of the aging processes are embrittlement, hardening, creep, wall thickness reduction, crack formation and growth, fatigue, and changes in electrical and other physical properties.

The damage mechanisms associated with these phenomena are largely known as individual effects, but their actual long-term effects and, above all, their interaction under collective loads are often unknown. It is also to be expected that additional, previously unknown damage mechanisms will occur during prolonged use.

In the case of active components such as pumps and valves, whose function depends on switching operations and external energy supply, a reduction in functionality generally becomes clearly noticeable over the course of their operating life. Replacement can often be carried out as part of regular maintenance work.

The aging of passive components is difficult to detect during use. With a few exceptions (e.g., large-scale corrosion or rusting through), the aging processes of metals take place at the level of the microscopic lattice structure and are not directly visible from the outside.

The aging or deterioration of materials leads to a decrease in the functionality of SSCs as the operating life of a plant increases. To maintain plant safety, it is very important to identify the effects of aging on SSCs and to take corrective measures before integrity or functionality is lost.

Based on the information provided in the EIA documents, it can be concluded that a comprehensive aging management program was implemented to ensure continued operation. This is also indicated by the results of the first Topical Peer Review (TPR) as set out in Article 8e of Directive 2014/87/EURATOM. The first TPR focused on the Overall Ageing Management Programmes (OAMPs) and four thematic areas: electrical cables, concealed pipework, reactor pressure vessels and Calandria, and concrete containment structures and Pre-stressed Concrete

[1] Physical aging refers to the process by which the physical properties of structures, systems, or components (SSCs) change over time or through use (WENRA 2014).

Pressure Vessels. The French NPPs met for the evaluated area the "TPR expected level of performance" for the Ageing Management Program. This is the level of performance that should be reached to ensure consistent and acceptable management of ageing throughout Europe.

France has completed the implementation of all actions resulting from the follow-up of the first TPR. As a result, it issued its final report in June 2021, updating its National Action Plan (NAcP) published in September 2019. The 2019 report contained four actions for the NPP fleet. The findings issued from the self-assessment and the peer review concerned the OAMPs and concealed pipework. All actions were implemented and the NAcP is therefore closed.

However, addressing the problems associated with the aging of SSCs is a major challenge for the plant, which has already been in operation for more than 40 years.

Since most SSCs were originally designed with a nominal 40-years operation time in mind, the 4th PSR can be viewed as the authorization required to operate the NPP beyond its initial design life. Therefore, the 4th PSR includes a closer look at aging management. It becomes not clear from the EIA documents whether the comprehensive extension of the scope of the ageing management is performed compared to the 3rd PSR. There are only few examples for preventive exchange of components are considered.

The ASNR's proposal during the generic phase of the 5th PSR to extend aging management beyond 4th PSR is supported. As proposed by the ASNR, the focus must be on components that are necessary for controlling potential impacts. Because age-related effects can cause safety-relevant components to fail in the event of an external impact, which may be essential for successful accident management. (UMWELTBUNDESAMT 2024b)

Updating of regulatory reference documents for the primary and main secondary circuits

In the framework of the generic phase of the 5th PSR MWe, ASNR requires EDF to prepare regulatory reference documents justifying the maintenance of the integrity of components in the primary and main secondary circuits. These documents serve as input data for preventive maintenance programs.

EDF states that, for 900 MWe reactors, the analysis of the phenomena caused by stress corrosion cracking on auxiliary lines does not call into question the loads used in the reference documents and does not provide any additional information that would need to be included in the update of these files. In the ASNR's view, EDF's conclusion is called into question by the results of inspections carried out since the discovery of stress corrosion cracking. For example, the discovery of fatigue cracks in welds where they were not expected shows that current methods for estimating fatigue risk are not suitable for effective prevention of this risk. The challenges arising from this observation are compounded by the prospect of continued operation of 900-MWe reactors, which is likely to lead to new degradation phenomena or new sensitive areas.

The ASNR therefore requires EDF (within the framework of the 5th PSR) to define, by December 31, 2025, the strategy for taking into account the findings from the discovery of stress corrosion cracking and, more generally, the risk of unexpected degradation of components in the primary and main secondary circuits through the checks required by the additional inspection program and maintenance programs. The ASNR's requirement is in line with the high safety relevance of these cracks. The cause of the cracks, inter-crystalline stress corrosion, is a well-known corrosion phenomenon, but it was not expected in the relevant areas and therefore the pipes were not inspected for it either. This means that the aging management concept for unexpected damage to components in the primary and main secondary circuits is called into question.

Evaluation of significant effects

As part of this expert statement, an evaluation of safety-related events in reactor Chinon B1 between 2020 and 2025 was carried out based on reports from the ASNR.[2]

Non-compliance with the general operating rules (RGE)

An evaluation of safety-related incidents over the past five years (2020-2025) published by the ASNR revealed a number of incidents that were related to non-compliance with the general operating rules (RGE). The RGE are a collection of regulations approved by the ASNR that define the permissible operating range of the plant and the associated regulations for reactor operation. In particular, they specify the maximum repair periods in the event that the systems required for reactor safety are unavailable. The non-compliance was preceded, for example, by a component failure or a maintenance error. The reason for the large number of violations of the RGE is unknown. The reason could be a lack of safety culture combined with a large number of ageing related events.

The following paragraph lists these events for Chinon B1

- On March 1, 2025, while reactor 1 was shut down for refueling and maintenance operations since February 6, 2025, the operator noticed that a **valve had been closed improperly**. This closure resulted in the unavailability of path B of the radioactive iodine extraction system. Investigations conducted by the operator showed that the unavailability dated back to February 7, 2025. The RGE, which requires that no fuel movements be carried out in the event of partial unavailability of the radioactive iodine extraction system, were not complied with. Due to the late detection of the partial unavailability of the radioactive iodine extraction system, this event was classified as level 1 on the INES scale.
- On August 6, 2024, EDF reported a significant safety event relating to non-compliance with the procedures set out in the RGE for reactor 1 concerning the unavailability of a **pump in the chemical and volumetric**

[2] https://annual-report.asn.fr/controle/l-asnr-en-region/centre-val-de-loire/centrale-nucleaire-de-chinon-b/avis-d-incidents

control system of the primary circuit. Due to the late detection of the event and the failure to comply with the procedure required by the RGE, this event was classified as Level 1 on the INES scale.
- On May 5, 2024, EDF reported a significant safety event relating to non-compliance with the procedures set out in the RGE for reactor 1 concerning the unavailability of the **emergency power supply system**. Due to the operator's late detection and failure to comply with the RGE, this event, which affected the safety function related to the power supply to the control and command system, was classified as level 1 on the INES scale.
- On October 19, 2022, EDF reported a significant safety event relating to non-compliance with the procedures set out in the RGE for reactor 1 concerning the unavailability of one of the **isolation valves in the main steam circuit**. Due to the operator's late detection and non-compliance with the RGE, this event was classified as level 1 on the INES scale.
- On February 16, 2021, EDF reported a safety-related event involving non-compliance with the procedure specified in the RGE for reactor 1 with regard to **exceeding the required shutdown time** for this reactor. Due to the unavailability of the associated safety systems and non-compliance with the RGE, this event was classified as Level 1 on the INES scale.
- On April 2, 2020, EDF reported a safety-related event in connection with non-compliance with the rules of conduct set out in the RGE due to a **defect in a pressure sensor in the main steam circuit**. Due to the operator's delayed detection and non-compliance with the RGE, this event was classified as Level 1 on the INES scale.

Deficiencies of the seismic resistance of various components

In recent years, significant deficiencies in the seismic resistance of various components of the Chinon B1 and other 900 MWe reactors have been identified. It cannot be ruled out that there are others, as to date unidentified, deficiencies. Deficiencies in earthquake protection are of particular interest for Chinon B1, as there are doubts about the adequacy of its design with regard to earthquakes (see Chapter 4).

- On May 13, 2024, EDF reported a significant safety event concerning defects in the **civil engineering anchoring of certain safety-critical equipment**. These defects concern among other Chinon B1. As part of its facility inspections, EDF checks the compliance of anchors with the civil engineering of equipment that is important for safety. These discrepancies date back to the construction of the reactors and could have compromised the integrity of the supported equipment in the event of an earthquake. Given its potential consequences for these reactors, this event is classified as level 1 on the INES scale
- On March 24, 2023, EDF reported new seismic resistance defects in the **electrical sources** of its nuclear power plants. These defects were detected during inspections carried out in 2022 and early 2023, following the ASNR's decision on February 19, 2019, requiring verification of the

compliance of these systems. The inspections carried out since 2019 had already detected several discrepancies. At the end of 2019, beginning of 2020, and in the summer of 2022, EDF reported a significant safety event concerning the detection of earthquake resistance defects in certain equipment contributing to the operation of **diesel-powered emergency generators** in several of its reactors, also in Chinon B1. The new faults detected concern the emergency diesel generators and relate to incorrect assembly of elastomer pipe fittings and corrosion on certain sections of piping or their supports. The event is classified as level 1 on the INES scale.

- On September 29, 2020, EDF reported a safety-related event concerning the inadequate earthquake resistance of the **heat exchangers** in the intercooling system of the 900 MWe reactor, including Chinon B1. Given its potential consequences, this event is classified at level 1 on the INES scale for the 19 reactors concerned.
- On January 31, 2020, EDF reported a safety-related incident to the ASNR involving the risk of collision between **switch cabinets and relay housings** in 900 MWe reactors at nuclear power plants, including Chinon B1. Given the potential consequences for the safety of the reactors concerned in the event of an earthquake, this event is classified as level 1 on the INES scale.

Incomplete performance of a functional check

An example of deficiencies, which existed in all 900 MWe reactors and has been ongoing for 14 years is the following safety relevant event: On September 2, 2020, EDF reported a significant safety event to the ASNR relating to the incomplete performance of a functional check on a group of eight control clusters for the 900 MWe reactors at the Blayais, Chinon, Cruas, Dampierre, Gravelines, Saint-Laurent, and Tricastin nuclear power plants.

During a regular inspection of the protection system of a reactor at the Gravelines nuclear power plant in September 2019, EDF found that the inspection was not sufficient to fully verify the requirement regarding the blocking of specific fuel assemblies.[3] After analysis, EDF concluded that this safety case requirement had never been verified since 2006 for the reactors at the Blayais, Chinon, Cruas, Dampierre, Gravelines, Saint-Laurent, and Tricastin nuclear power plants.

Given the potential consequences, the failure to take into account the experience gained from the incident at the Bugey nuclear power plant in 2008, and the long time it took to assess the significance of the deviation identified at the Gravelines nuclear power plant in 2019, this incident is classified at level 1 on the INES scale for the 28 reactors concerned.

[3] In certain accident scenarios, it must be possible to block the removal of this group of eight fuel assemblies. If the blocking device malfunctions, these accident scenarios could lead to damage to the fuel, as there would be an increase in power in certain parts of the reactor core.

3.3 Conclusions

Based on the information provided in the EIA documents, it can be concluded that a comprehensive aging management program was implemented to ensure operation. This is also indicated by the results of the first Topical Peer Review (TPR) as set out in Article 8e of Directive 2014/87/EURATOM. However, addressing the problems associated with the aging of SSCs poses a major challenge for the plant, which has been in operation for more than 40 years.

Since most SSCs were originally designed for a nominal operating lifetime of 40 years, the 4th PSR can be considered the necessary approval to operate the nuclear power plant beyond its original design life. Therefore, the 4th PSR requires a more detailed consideration of aging management. The EIA documents do not clearly indicate whether there has been a comprehensive expansion of the scope of aging management compared to the 3rd PSR. Only a few examples of preventive component replacement are presented. As far as is known, ASNR proposed expanding the scope of aging management during the generic phase of the 5th PSR. This should also be performed for the 4th PSR.

The implementation of the PIC is an approach that aims to confirm the absence of operational failures in areas that are not regularly inspected. Without justification, it is stated that no checks are to be carried out for Chinon B1 as part of the supplementary investigation program.

In the framework of the generic phase of the 5th PSR of the 900 MWe reactors, the ASNR requires EDF to define, by December 31, 2025, the strategy for taking into account the findings from the discovery of stress corrosion cracking and, more generally, the risk of unexpected degradation of components in the primary and main secondary circuits through the checks required by the additional inspection and maintenance programs. The cause of the cracks, inter-crystalline stress corrosion, is a well-known corrosion phenomenon, but it was not expected in the relevant areas and therefore the pipes were not inspected for it either. This means that the aging management concept for components in the primary and main secondary circuits is called into question.

The ASNR's proposal during the generic phase of the 5th PSR to extend aging management beyond the 4th PSR is supported. As proposed by the ASNR, the focus must be on components that are necessary for controlling accident situations. However, the scope of the program “qualification of materials under accident conditions” in the 4th PSR is very limited for Chinon B1.

An evaluation of the safety-related incidents at the Chinon B1 NPP over the past five years (2020-2025) published by the ASNR revealed a number of incidents that were related to non-compliance with the RGE. The reason for the large number of violations of the RGE is unknown.

In recent years, significant deficiencies in the seismic resistance of various components of the Chinon B1 and other 900 MWe reactors have been identified. It cannot be ruled out that there are others, as to date unidentified, deficiencies. Deficiencies in earthquake protection are of particular interest for Chinon B1, as there are doubts about the adequacy of its design against earthquakes (see Chapter 4).

- The justification that no checks are to be carried out for Chinon B1 as part of the Program for Complementary Investigations (PIC) should be provided
- In-depth investigations on components relevant for preventing external events to affect the nuclear safety of the plant should be carried out, in particular concerning those components of the original systems that connect the newly installed "hardened safety core" and systems for mitigating the effects of core-melt accidents.
- A complete analysis of the causes of the cracks in the auxiliary line due to stress corrosion cracking should be carried out and taken into account in order to take preventive protective measures against such damage and its effects already within the framework of the 4th PSR.
- The modification of the ageing management for the secondary and primary circuit components to detect unexpected degradation should be considered. A systematic ageing control of the components safety relevant concerning the resistance with regard to earthquakes should be considered.

4 EXTERNAL HAZARDS

4.1 Treatment in the EIA documents

EIA-REPORT P.1 (2025, p. 32-37) provides a general overview of the external hazard types considered in the LTE process according to French regulations. The following external hazards (natural or human-made) are of concern: earthquakes, extreme weather or climatic conditions (flooding, snow, heat wave, drought, extreme cold, high wind, tornado), influences from rivers (ice drift, icing, siltation, oil spills, silting, low water), lightning and electromagnetic interference, fire, industrial hazards (explosion, release of hazardous substances), aircraft crash, and malicious acts. Hazard types conform to those identified by ASNR (ASN 2021). The EIA documents note that studies on external hazards take into account the international standards set by WENRA. It is also stated that *“the use of the " Noyau Dur " [hardened safety core] to handle extreme events (earthquakes, floods, etc.) exceeding previously assumed values helps to meet these requirements.”*

Hazard assessment

Earthquake: Earthquake, along with fire induced by electrical installations, is the most significant hazard contributing to core damage (EIA-REPORT P.1 2025, p. 37). The seismic design base for the NPPs of the 900 MWe fleet is deterministically derived from the maximum observed historical earthquake (SMHV) increased by one degree of intensity giving the so-called maximum safety earthquake (SMS) which is linked to a reference spectrum. Both determine the seismic design basis of the plant. Following the Fukushima Daiichi accident in 2011, a new seismic level (SND) was defined (EIA-REPORT P.1 2025, p. 36). The SND is required to (i) envelope the ground motion of an earthquake with a recurrence interval of 20,000 years, based on probabilistic seismic hazard assessment, (ii) envelop the SMS increased by 50%, and (iii) take site effects into account.

EIA-REPORT P.2 (2025, p. 124-126) states that the seismic hazard was re-assessed during the 4th PSR according to RFS 2001-01[4] and based on updated seismological findings (seismic-tectonic zoning, characterization of faults, etc.) and the historical seismicity data of the SisFrance 2012 database. Reference earthquakes for the Chinon NPP are the earthquakes of 15.02.1657 (epicentral intensity I_0=7,5), 25.06.1522 (I_0=7,5), and 11.03.1704 (I_0=7,5). It is noted that the reassessment of seismic hazard accounted for information on three major faults (Tours-Nevers, north of Châteauroux and south of the Paris basin) which are located at distances of 40 km, 5 km and 20 km from the Chinon NPP, respectively. The report claims that current findings underscore the absence of neotectonic evidence within a 25 km radius of the Chinon site. EDF has developed a stepwise approach to fault analysis, based on literature, geophysics, field geology, morphostructural and dating studies, and paleoseismology,

[4] Règle fondamentale de sûreté - RFS 2001-01 of 31st May 2001 concerning the determination of the seismic risk for the safety of surface basic nuclear installations

which, as a consequence of the 11.11.2019 Le Teil earthquake, is currently applied to the site of Cruas NPP. EDF, however, states that the approach will not be applied to the Chinon NPP. This is due to the absence of evidence for active faults in the area within 25 km from the site according to the active fault database by JOMARD et al. (2017).

As part of LTO process, EDF supplemented seismic hazard analyses by a Level 1 PSA with the following main steps (EIA-REPORT P.2 2025 p. 164-166):

- A probabilistic seismic hazard study determining the occurrence frequencies of seismic events as a function of their maximum ground acceleration (PGA)
- System analysis and functional analysis to identify model failures that could initiate accident sequences initiated by earthquake, and identify SSCs involved in mitigating these sequences
- Establishing fragility curves to determine the conditional probability of failure of SSCs as a function of seismic ground motion
- Risk quantification by combining seismic hazard, system analysis, functional analysis and the seismic fragility of SSCs, to estimate the Core Damage Frequency (CDF) and the probability to uncover spent fuel in the Spent Fuel Pool.

The ground motion corresponding to the occurrence probability of 10^{-4} per year is not stated in the EIA documents.

Seismic PSA. The Level 1 PSA estimated that the average contribution of seismic ground motion hazards to the CDF is on the order of 10^{-6} per reactor-year for *"a monitoring window corresponding to a return period of 150,000 years".* 90% of the CDF is contributed by seismic accelerations exceeding the Chinon hardened safety core earthquake (0.34 g).

High temperatures: The maximum long-time air temperature at which all safety-relevant materials are subject to acceptable environmental conditions, projected over the next 30 years (TLD; Température Longue Durée) was set at 34 °C, the exceptional air temperature (TE; Température Exceptionnelle) defining functional limits is 43.9 °C (EIA-REPORT P.2 2025, p. 124-126). Data used to determine the above temperatures include temperature values of the heat wave recorded in 2019. Methods and assumptions used to derive the TLD and TE values are not specified.

Extremely low temperatures: Protection requirements for extremely low temperatures were developed based on lessons learned from the coldest winters (notably 1984-1985 and 1986-1987) and implemented during the second Periodic Safety Reviews. Protection is said to be ensured for all Emergency Intervention Systems (EIPS) under cold conditions corresponding to the design cold level of the reactor platform, and beyond the design cold level for the EIPS. Assessments include IPCC forecasts indicating a reduction of the number of cold days per year. Methods and assumptions used to derive temperature values are not specified.

External flooding: As part of the 4th PSR, EDF was reviewing the robustness of the NPP with regard to hazards described in ASNR Guidance No. 13 on the protection against external flooding. EDF also analyzed the volumetric flood protection devices. Analyses for Chinon B, located on the Loire river, included the (re-) assessments of river floods including possible effects of upstream dam failure (Villerest, 5 km upstream of Chinon), local precipitation and groundwater rise (EIA-REPORT P.2 2025, p. 118-123).

High wind and tornado: The EIA documents state that the reassessment of hazards by storm do not require any update. No reference is made to a dedicated hazard assessment. With respect to tornadoes, hazard assessments reveal an occurrence probability of $1,1*10^{-5}$ per year for a tornado with velocities of 29 m/s (EF0 on the Enhanced Fujita tornado scale). Assessments consider the dynamic wind pressure, the sudden drop in pressure at the center of the vortex and projectiles. The EIA documents conclude that existing protection against high wind and wind-blown projectiles is sufficient to also protect the NPP against effects of the reference tornado (EF0 on the Enhanced Fujita tornado scale).

Availability of the ultimate heat sink: Analyses include the formation of frazil ice, clogging of the water intake by flotsam, low water level, sedimentation in the feeder channels (silting) and pollution of the cooling water with hydrocarbons.

Human-made hazards (industrial facilities, pipelines and transport of dangerous materials): Hazards associated with the industrial environment were deterministically addressed in the design of the facilities. Analyses include external explosions and hazards resulting from transportation of hazardous materials on the site.

Accidental aircraft crash: Analyses of the hazard of accidental airplane crash is based on Règle Fondamentale de Sûreté (RFS) I-2.a. The probabilistic assessment of air traffic hazards used updates of the following data: accident analysis parameter values, environmental data specific to each site (airport/airfield locations, air traffic data) and virtual surface area values (surface areas of structures exposed to aircraft impact risk). Results show that the probability of unacceptable release of radioactive substances at the Chinon nuclear power plant boundary due to air traffic is less than 10^{-6} / reactor year for the reactor and spent fuel storage. The EIA documents do not specify the airplane type for which the value was calculated.

Upgrades of protection measures

In general, EDF plans to achieve safety improvements by installing "hardened core" equipment to enhance the robustness of the NPP against hazards such as earthquakes, tornadoes, and floods (EIA-REPORT P.1 2025, p.58). In addition to this general measure, EIA-REPORT P.1 (2025, p. 32-37) and EIA-REPORT P.2 (2025) lists a number of specific improvements including the following measures to protect the NPP from external hazards:

Earthquake: Seismic reinforcement of venting of battery rooms, seismic reinforcement of some flood protection systems (watertight shafts), improving the earthquake resistance of the fuel of the emergency power generators and reinforcement of cable ducts and piping that support functionality, of the Hardened Safety Core to withstand the "Noyau Dur" earthquake (SND). The installation of the "Noyau Dur" will be completed in Phase B of the PSR. In addition, EDF determined the necessity to reinforce the Buildings for Nuclear Auxiliary Facilities (BAN) chimney to prevent it from damaging SSCs important to safety in the event of a collapse. This reinforcement is not due to a reassessment of the earthquake hazard (EIA-REPORT P.2 2025, p. 125).

Safety upgrades that have already been completed and those that are planned are comprehensively listed in the Annex of EIA-REPORT P.2 (2025).Table 1 lists the measures relevant for external hazards.

Regulatory requirements for the 4th PSR are summarized under [AGR-F] of ASNR (ASN 2021). This report cannot determine whether the relevant requirements have been fully implemented.

External flooding: Strengthening of volumetric protection, measures to allow refilling of water storage under flood conditions, protection of the site platform from flooding by a combination of sills, dams and concrete walls.

High temperatures: EIA-REPORT P.2 (2025, p. 137) notes that studies have identified the need for several modifications, which will be implemented during the 4th PSR. Decided measures include the replacement or protection of temperature-sensitive equipment with heat shields (diesel valves, current transformers, cables, sensors, fire alarm control panels, etc.), installation or replacement of cooling units, improvements of air conditioning of buildings containing SSCs important to safety by increasing ventilation performance and/or cooling capacity, installation of air conditioning systems. Measures set with respect to extreme temperatures appear to conform with the requirement [AGR-A] of ASNR (ASN 2021).

Low temperatures: EDF plans to install heating devices and thermal insulations for a number of SSCs.

High wind and tornado: Installation of protective devices on the filter systems of the cooling source for projectiles generated by strong winds, reinforcement of the BAN chimney against strong winds and tornadoes.

Availability of the ultimate heat sink: Measures to protect the availability of the ultimate heat sink include the installation of filtration devices (pre-filter screens, screens, chain filters) in the water intakes, managing the risk of siltation/siltation by implementing regular bathymetric monitoring and carrying out dredging operations. Protection against the formation of frazil ice is achieved is achieved by recirculating warm cooling water to the water intake of the emergency water system heat exchanger.

Lightning: The safety requirements applicable to the 4th PSR of the 900 MWe reactor fleet include new requirements for lightning protection. Accordingly, new lightning arresters are installed close to auxiliary transformers.

Human-made hazards (industrial facilities, pipelines and transport of dangerous materials): The EIA documents state that resistance to detonation-type explosions of buildings and civil structures housing or containing SSCs important to safety is provided by design. Analyses revealed no necessities for retrofitting. EIA-REPORT P.2 (2025, p. 152) further states that the transport of dangerous goods on the site has no impact on the safety of the NPP.

Table 1: Modifications of SSCs that are important for safety to withstand external hazards, which have been implemented and are planned for implementation at Chinon B1 (adapted from EIA-REPORT P.2 2025)

PNPE1049	Earthquake	Earthquake protection of fire doors	Completed
PNPE1118	Earthquake	Seismic reinforcement of the local system batteries	Completed
PNPE1191	Earthquake	Earthquake protection of cable shafts	Completed
PNPE1238	Earthquake	Reinforcement of the fuel tarp	Completed
PNPE1323	Earthquake /Tornado	Reinforcement of the BAN chimney to the SMS, strong winds and tornado	Completed
PNPE1355	Earthquake	Earthquake protection of watertightness	Completed
PNPE1447	Earthquake	Seismic reassessment Chinon B – Reinforcement of the cold source to the SMS	Completed
PNPP1679	Earthquake	Seismic reinforcement of the levels of the fuel pool BK	Completed
PNRL1933	Earthquake	Earthquake protection of the soda mixing pipeline	Completed
PNPE1115	Earthquake	Automatic reactor shutdown on earthquake and notification of a significant earthquake, retrofitting to SND	Open[1)]
PNPE1305	Earthquake	Implementation of a robust H1 earthquake detection system (SND)	Open[1)]
PNPE1332	Earthquake	Piping (SND)	Open[1)]
PNPE1358	Earthquake /Tornado	SND and tornado robustness of ND	Open[1)]
PNPE1478	Earthquake	Robustness of instrumentation for SND	Open[1)]
TCDI0120	Earthquake	Robustness of cable bridge for SND	Open[1)]
	Earthquake	Earthquake reinforcement of the primary circuit's main core, the secondary circuit's main core	Open[2)]
PNRL1846	Flooding	Elimination of the risk of bypassing volumetric protection in pumping stations	Completed
PNPE1069	High temperatures	Improvement of the air conditioning in the DEG refrigeration unit premises	Completed
PNPE1070	High temperatures	Improvement of the air conditioning in the ventilation and air conditioning systems of the "Bâtiment Electrique" building	Completed
PNRL1823	High temperatures	Replacement of the diesel air cooler engines	Completed
PNRL1835	High temperatures	Update of the parameters for the automatic monitoring of RRI/SEC heat exchanger fouling	Completed
PNPP1722	Low temperatures	Trace heating and thermal insulation of the ASG supply	Completed
PNRL1955	Low temperatures	Change of the setpoint setting of DVN air heaters	Completed
PNPE1119	Tornado	Protection of Noyau Dur against tornado	Open[1)]
PNPP1951	Lightning	Installation of surge protectors	Completed
PNPE1477	Lightning	Addition of a surge arrester to the secondary side of the Auxiliary Transformers or in the overhead substations	Completed

[1)] *Modifications that will be deployed on Unit 1 of the Chinon Nuclear Power Plant as part of Phase B of the modifications to the 4th PSR*
[2)] *Modifications that will be deployed on Unit 1 of the Chinon Nuclear Power Plant as part of a specific program*

Malicious acts

The EIA REPORT P.1 (2025) mentions that the events considered, which are specified in the regulations, also include external impacts due to malicious acts. No further information is provided.

The EIA-REPORT P.4 (2025) provides some general information: The security of nuclear power plants is subject to coordination between EDF and the state (including the Ministry of the Interior and the Ministry of Defense). In particular, the authorities ensure continuous monitoring of nuclear power plants and their airspace.

Nuclear power plants are divided into different areas in terms of their design and organization and are protected by a multi-level security system. The protective measures for nuclear power plants are diverse and must remain confidential in order to ensure their effectiveness. The security measures, which are subject to various nuclear safety regulations, are not part of the fourth periodic review. EDF is implementing a €750 million investment program for all nuclear power plants to further strengthen security measures against intruders and meet the requirements for robustness in the event of an attack.

4.2 Discussion

Generic aspects

The contents and procedures of a PSR are only loosely defined in the French legal framework, leaving it to the nuclear regulator to specify conditions and contents of the review. The objectives of the PSR of the 900 MWe fleet were defined by ASNR in a process that involved a proposal by EDF, a review and conclusive guidelines issued by ASNR. With respect to external hazards, ASNR stipulates that definitions of design basis events and design extension considerations must follow the requirements set by WENRA. The main implications of this requirement are:

- The mandatory contents of PSR including plant design, deterministic safety analyses, probabilistic safety analyses and hazard analyses are described in detail in Issue P, Reference Level P2.2 of WENRA (2021).
- Issue E, Reference Level E11.1 requires regular reviews of the actual design basis to determine whether the design basis is still appropriate.
- Issue F, Reference Level F5.1 requires the same regular review for Design Extension Conditions (DEC)
- Issue TU summarizes requirements for external hazard assessment, most importantly the definition of design basis events with exceedance frequencies not higher than 10^{-4} per annum, and the requirement to provide protection against design basis events. Protection shall be of sufficient reliability so that the fundamental safety functions are conservatively ensured.

- Issue TU, Reference Levels TU6.1 to TU6.3 list requirements for considering DEC.
- In addition to the requirements stipulated in the WENRA Safety Reference Levels, WENRA provides ample guidance on how to consider external hazards in safety demonstrations (WENRA 2020a-d).

In sum, WENRA requires that external hazards be addressed as part of the PSR. The design basis of existing plants is not considered fixed by the initial plant design but rather as a "floating" value that can change over the life of a reactor. The same applies to DEC.

The EIA documents provide no clear evidence if these WENRA requirements were followed by EDF. For most external hazards, the methods, data and assumptions used in the hazard assessment are not specified. Conformity with WENRA requirements and guidance can therefore not be assessed. It remains particularly unclear if design basis events with exceedance frequencies not higher than 10^{-4} per annum have been determined for all external hazards that apply to the site, if the assessment of design basis events is in line with WENRA regulations and guidance, and how DEC are addressed for the identified hazards.

Non-conformity with WENRA Reference Levels is observed for earthquake and seismic ground shaking. The Design Basis Earthquakes (DBE) for Chinon NPP and the other reactors of the French 900 MWe fleet are still based on deterministic analyses. Demonstration that the deterministically determined DBE can be defended against a PSHA-derived design basis earthquake with an average recurrence interval of 10,000 years is missing (see discussion below). It can therefore not be assessed if the seismic resistance of all SSCs important to safety is sufficient to conservatively ensure the fundamental safety functions for a DBE with an average recurrence interval of 10,000 years as required by WENRA (2021). The authors of this report assume that adequate protection against a probabilistically derived DBE, should it be higher than the deterministic value for which the plant was designed, is intended to be ensured by the Hardened Safety Core (Noyau Dur). This, however, would contradict the Defence-in-Depth (DiD) concept and the separation of DiD levels because the DEC equipment of the Noyau Dur could become necessary to protect the plant against design basis hazards, i.e., the probabilistically derived DBE. The Hardened Safety Core is classified as a 4th DiD level system which is required as an additional and independent level compared to the 3rd DiD level. The Hardened Safety Core can therefore not be used to compensate for existing deficits in terms of the protection against design basis events.

Site-specific aspects

Seismic hazard and definition of the design basis earthquake: Design basis ground motion values for the French 900 MWe reactors were established by a deterministic approach. The fact that the deterministic approach was originally stipulated in RFS 1.2.C (1981)[5] suggests that design basis values were only established after the start of construction of the Chinon B units. At the background of the standardized reactor series operated in France, EDF introduced the notion to define the DBE as the envelope spectrum of the various SMS spectra associated with the different sites of the same plant series (ASN 2011a). This approach allowed pooling the design studies for the reactors on the respective nuclear islands. All plants of a specific series consequently share the same seismic design. Other structures, referred to as "site structures", were specifically designed for each site.

Table 2: Design basis ground motions (PGA) of the Chinon B reactors (ASN 2011)

NPP	Start of construction	Start of commercial operation	DBE Nuclear island	DBE Site structure	SND
Chinon B1	1977	1982	EDF normalized to 0.2 g zero period	EDF normalized to 0.2 g zero period	PGA = 0,34 g
Chinon B2	1980	1983			
Chinon B3	1981	1986			
Chinon B4	1981	1987			

In 2001 the RFS 1.2.C (1981) was replaced by RFS 2001-01[6]. The replacement retained the general deterministic approach. The main changes concerned new definitions of seismotectonic zones, intensity-magnitude correlations, the replacement of a fixed response spectrum by a site spectrum, the consideration of site effects, and the account for paleo-earthquakes in addition to historical/instrumental earthquakes of the SISFRANCE earthquake catalogue. In addition, it was required that the DBE is higher than a minimum level that encompasses a M=4 earthquake at a distance of 10 km from the site, and a M=6.6 event at 40 km distance (ASN 2011a).

Defining the Design Basis Earthquake exclusively deterministically is not state of the art and does not conform with the WENRA Reference Levels (WENRA 2014; 2021). In the Stress Tests ENSREG (2012b) therefore recommended introducing probabilistic methods (Probabilistic Seismic Hazard Assessment - PSHA) to determine design basis earthquakes. The French National Action Plan (NAcP) consequently announced that probabilistic methods are to be used to determine the site-specific seismic hazard.

For Chinon B it is evident that a Probabilistic Seismic Hazard Assessment (PSHA) has been completed to define the ground motion parameters of the SND. The ground shaking level of the SND is relevant to the design of the Hardened Safety Core (Noyau Dur). The PSHA revealed a ground acceleration of 0,34 g for

[5] Règle fondamentale de sûreté - RFS 1.2.c of 1st October 1981 concerning the determination of the seismic motion to be taken into account for the safety of the facilities.

[6] Règle fondamentale de sûreté - RFS 2001-01 of 31st May 2001 concerning the determination of the seismic risk for the safety of surface basic nuclear installation.

the SND[7] (EIA-REPORT P.2 2025, p. 166). By definition of the SND, this value corresponds to an average earthquake return period of 20,000 years. No PSHA results other the single value characterizing the SND are communicated. Documents, in particular, do not show hazard curves and do not state a ground motion value characterizing the 10,000 years earthquake (occurrence probability of 10^{-4} per year) which, according to WENRA (2021), shall be used to define the seismic design basis of existing NPPs[8]. It is therefore unclear if the deterministically derived seismic design basis value for Chinon B, the SMS with 0,2 g, can be defended against a PSHA-derived design basis earthquake with an average recurrence interval of 10,000 years. The relatively high value for the SND (0,34 g) suggests that this may be not the case.

The EIA documents do not provide information on the methods, data and assumptions of the PSHA other than claiming that *"seismic studies [are] compliant with international best practices (Type 1 study)"*. The notion of type 1 study remains unexplained. With respect to methods and data it is worth noting that state-of-the art PSHA is based on both, earthquake and active fault data. EIA-REPORT P.2 (2025, p. 126) claims that no active faults exist in the area within 25 km from the site. This information is taken from the active fault database by JOMARD et al. (2017). Based on this evidence, EDF concluded that further investigation of faults is not necessary.

Contrary to EDF's assessment in the EIA documents, the map by JOMARD et al. (2017) shows numerous faults within a distance of 25 km from the site (near-region of the site to IAEA 2022) for which the ages of the last fault activity have not been determined, and several locations for which data exists in the Neopal neotectonic database (BAIZE et al. 2002; NEOPAL 2009). For such faults active faulting cannot be excluded. In such cases WENRA (2020b, p.11ff) suggests systematic fault mapping and collecting paleoseismologic information. Efforts should at least be made in the near-region of the site (not less than 25 km) to collect geological, geophysical, geomorphologic, geodetic and paleoseismological for identifying and characterizing active faults. Noteworthy, EDF developed a very similar approach for such investigations, based on literature, geophysics, field geology, morphostructural and dating studies, and paleoseismology for investigating the near-region of Cruas NPP. At this background it is remarkable that the approach is not applied to the near-region of the Chinon NPP.

The seismic safety of Chinon B was assessed by Level 1 seismic PSA which estimated that the average contribution of seismic ground motion hazards to the CDF is on the order of 10^{-6} per reactor-year. REPORT P.2 (2025, p. 166) adds the restriction that the value is valid for *"a monitoring window corresponding to a return period of 150,000 years".* To the authors of the current report this restriction suggests that strong earthquakes with recurrence periods longer than 150,000 years were not considered in the PSA. If this is the case, it cannot be excluded that the contribution of earthquakes with recurrence intervals >150,000 years

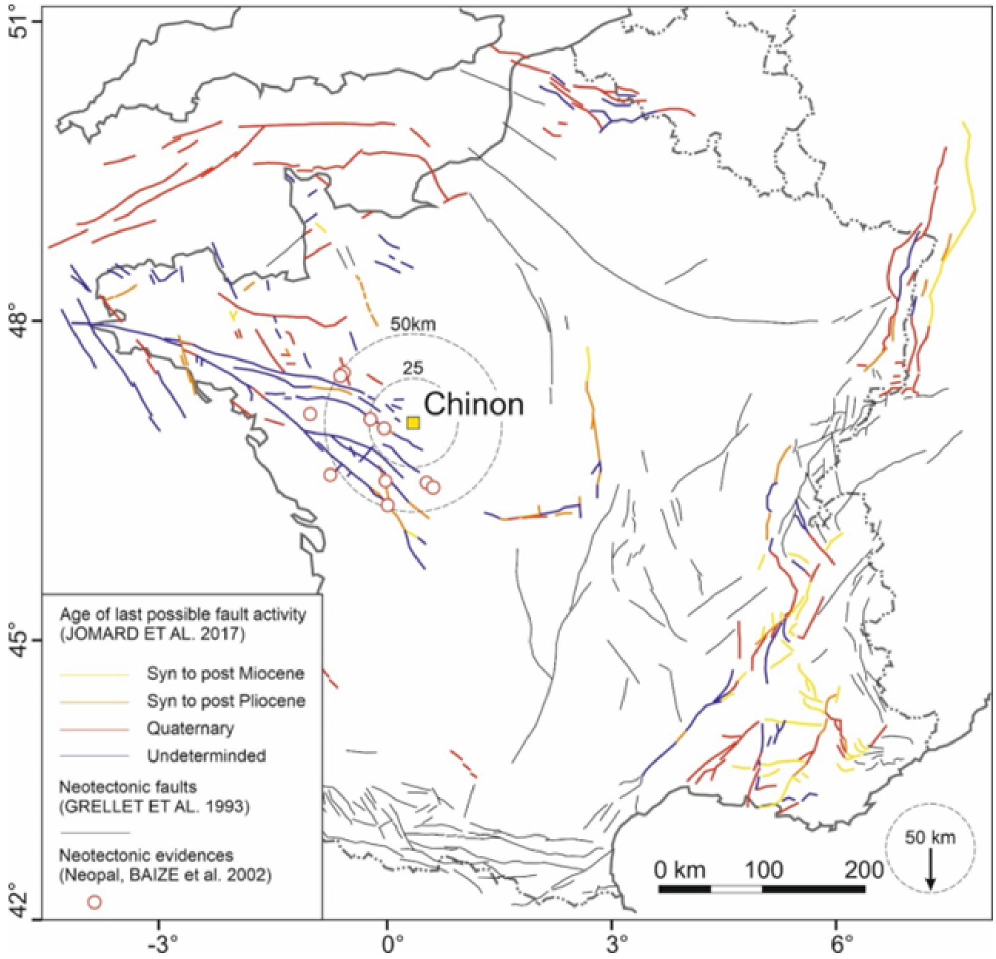
[7] The EIA documents leave open whether the value refers to Peak Ground Acceleration or Peak Horizontal Ground Acceleration.

[8] WENRA 2021, Issue TU, Reference Level TU4.2

to the total risk is significant or even higher than the contribution of the considered earthquakes. The observation suggests that because of the truncation at 150,000 years, the assessed risk may be incomplete, i.e., the CDF value is incorrect.

Figure 2: French active fault database and location of the Chinon NPP redrawn from: JOMARD et al. (2017); RITZ et al. (2021).

French active fault database and location of the Chinon NPP



Source: Environment Agency Austria umweltbundesamt

Circles around the Chinon NPP indicate the site near-region and site region according to IAEA (2022) (radius 25 and 50 km from the site, respectively).

Upgrades of protective measures: Safety upgrades that have already been completed and those that are planned are comprehensively listed in the Annex of EIA-REPORT P.2 (2025). The Annex does not contain a specific timetable for the implementation of the planned measures. Mandatory time schedules for individual upgrades, however, have been determined by ASNR (ASN 2021).

One of the most important measures to provide protection against external hazards is the implementation of the Hardened Safety Core (Noyau Dur). However, the implementation of the Noyau Dur is still pending as for example shown by measure no. PNPE1358 referring the earthquake and tornado robustness of the Noyau Dur (note that Table 1 contains several additional open actions that relate to the Noyau Dur). Implementation is announced for Phase B of the 4th PSR without adding concrete time schedules in the EIA documents. The fact that the implementation of the Noyau Dur is still pending appears remarkable at the background that the regulatory decision for its implementation dates back to 2012 and the European Stress Tests (ASN 2012).

It is concluded that the implementation of the Hardened Safety Core (Noyau Dur) as required by [ND-A], [ND-B] and [ND-C] of ASNR (ASN 2021, p. 14) is pending. ASNR requires the following implementation timeline for the Hardened Safety Core: Reactor B1 – 24.04.2029; Reactor B2: 21.3.2029; Reactor B3: 25.06.2035; Reactor B4: 15.03.2036. (ASN 2021)

Terrorist attacks and acts of sabotage

Terrorist attacks and acts of sabotage can have a significant impact on nuclear facilities and cause serious accidents—including at the Chinon B1 nuclear power plant. Nevertheless, they are only mentioned in very general terms in the EIA documents submitted. Similar EIA reports have covered such events to a certain extent. Even if precautions against sabotage and terrorist attacks cannot be discussed in detail for reasons of confidentiality, the necessary legal requirements should be set out in the EIA documents.

The nuclear power plants currently in operation have a certain degree of protection against possible terrorist attacks due to their design, e.g., through relatively thick outer walls and diverse and redundant safety systems. Accidental aircraft crashes have been taken into account in the design of nuclear power plants for several decades. However, only accidents involving smaller sports aircraft and/or military aircraft were considered. It was only after the attacks of September 11, 2001, that the consequences of a deliberate crash of a commercial aircraft were considered. Older nuclear power plants, such as the Chinon B1 NPP, are therefore not adequately protected against such massive attacks. A targeted aircraft crash could cause a serious accident with significant consequences for the population.

According to WENRA (2013), it is expected that a deliberate crash of a commercial aircraft will not lead to a core meltdown accident in new nuclear power plants and therefore, in accordance with WENRA safety objective (O2), should only have minor radiological consequences. To prove this, the effects of direct and secondary impacts of the aircraft accident must be considered (vibrations/shocks, burning and/or explosion of the aircraft fuel). In addition, buildings or parts of buildings containing nuclear fuel and safety-relevant safety equipment should be designed in such a way that no kerosene can penetrate.

The increasing risk due to aging effects must also be taken into account for Chinon B1: A study uses numerical simulations to investigate the influence of aging on the effects of a military aircraft impact on a nuclear power plant. The results show that the aging of a plant increases its susceptibility to large-scale or localized penetrations. The greater the degradation of the materials, the lower the residual resistance and the greater the risk of wall perforation. With the same impact force, the strength of the aged containment is reduced by approximately 30%. (FRANO 2021)

In addition to an attack with a commercial aircraft, a number of other attack scenarios are conceivable for a terrorist attack from the air. The drone flights over France in the fall of 2014 highlighted weaknesses in the air surveillance of French nuclear power plants and, above all, in the defense against such potential airborne attacks. In the fall of 2014, a total of 31 drone flights over 19 French nuclear facilities were recorded. (GP 2014)

Nuclear Threat Initiative (NTI)

In its Nuclear Security Index 2023, the US-based Nuclear Threat Initiative (NTI) assessed the measures taken by various countries to protect their nuclear facilities from terrorist attacks and sabotage. The index does not evaluate the specific measures taken by each facility, but rather the measures taken by the government and the legal requirements. In the NTI Index, 100 is the highest possible score and thus indicates compliance with current security requirements.

In the Nuclear Security Index 2023, France ranks only 20th out of 47 countries with a total score of 77 points. Low scores are shown for “security culture” (25), “cybersecurity” (63), and “protection against insider threats” (36). These low scores indicate weaknesses in protection against acts of sabotage and terrorist acts. (NTI 2025)

International Physical Protection Advisory Service (IPPAS)

The IAEA plays a key role in assisting States in protecting their civil nuclear materials and facilities. It supports States by conducting and organizing advisory security assessments and peer review missions through its International Physical Protection Advisory Service (IPPAS). An IPPAS mission is an assessment of existing practices in a State with the aim of strengthening a State's nuclear security organization, procedures, and practices. (IAEA 2021a)

The last IPPAS mission was completed in France with the follow-up mission in 2018. Due to the changed security situation in Europe and the low NTI Index score, another IPPAS mission should be considered to improve the security measures. (IAEA 2025a)

4.3 Conclusions

The EIA documents provide ample information on hazard types considered in the safety demonstration for Chinon B and measures already implemented or decided to be implemented in order to strengthen the robustness of the NPP with respect to external hazards. The documents, however, do not provide clear evidence if the processes of the PSR and LTE follow WENRA requirements as stipulated by ASNR. For most external hazards, the methods, data and assumptions used in the hazard assessment are not specified in detail. Conformity with WENRA requirements and guidance can therefore not be assessed. It remains particularly unclear if design basis events with exceedance frequencies not higher than 10^{-4} per annum have been determined for all external hazards that apply to the site, and how Design Extension Conditions (DEC) are addressed for the identified hazards.

Non-conformity with WENRA Reference Levels is observed for earthquake and seismic ground shaking. The Design Basis Earthquakes (DBE) for the Chinon NPP and the other reactors of the French 900 MWe fleet are still based on deterministic analyses. Defining the DBE on deterministic methods is no longer state of the art. Demonstration that the deterministically determined DBE can be defended against a PSHA-derived design basis earthquake with an average recurrence interval of 10,000 years is missing in the EIA documents.

The EIA documents clarify that a PSHA for the Chinon site was conducted to derive the SND which is relevant to the design of the Hardened Safety Core (Noyau Dur). The PSHA revealed a ground acceleration of 0,34 g for the SND which corresponds to an average earthquake return period of 20,000 years. No further PSHA results are communicated. Documents, in particular, do not state a ground motion value characterizing the 10,000 years earthquake (occurrence probability 10^{-4} per year) which, according to WENRA (2021), shall be used to define the seismic design basis of an existing NPP[9]. It is therefore unclear if the deterministically derived seismic design basis value for Chinon B, the SMS=0,2 g, can be defended against a PSHA-derived design basis earthquake with an average recurrence interval of 10,000 years. The relatively high value for the SND (0,34 g) suggests that this may be not the case. It therefore remains to be demonstrated that the seismic resistance of all SSCs important to safety is sufficient to conservatively ensure the fundamental safety functions for a DBE with an average recurrence interval of 10,000 years as required by WENRA (2021).

With respect to safety upgrades of Chinon B, it is evident that one of the most important measures to provide protection against external hazards is the implementation of the Hardened Safety Core (Noyau Dur). However, the implementation of the Noyau Dur is still pending. Implementation is announced for Phase B of the 4th PSR without announcing concrete time schedules in the EIA documents. The timeline prescribed by ASNR envisages implementation of the Noyau Dur for Chinon B1 2029. The fundamental decision to implement the Hardened Safety Core has been made in 2012 in the aftermath of the and the European Stress Tests (ASN 2012). The fact that the implementation of the Noyau Dur will be still pending 17 years thereafter appears remarkable at the background that WENRA requires the "timely implementation of the reasonably practicable safety improvements identified" (WENRA 2021, Issue A, Reference Level A2.3). This suggests that the announced implementation schedules violate the WENRA requirement.

[9] WENRA 2021, Issue TU, Reference Level TU4.2

Terrorist attacks and acts of sabotage can have a significant impact on nuclear facilities and cause serious accidents—including at the Chinon B1 nuclear power plant. Nevertheless, they are only mentioned in very general terms in the EIA documents submitted. Similar EIA reports have covered such events to a certain extent. Even if precautions against sabotage and terrorist attacks cannot be discussed in detail for reasons of confidentiality, the necessary legal requirements should be set out in the EIA documents.

Information regarding the issue of terror attacks would be of great interest, considering the far-reaching consequences of potential attacks. In particular, the EIA documents should include information on the requirements for the design against the targeted crash of a commercial aircraft. This topic is particularly important, because reactor building as well as the spent fuel building of the Chinon B1 NPP is vulnerable against airplane crashes. It is important to mention that the EPR's 1.8-meter-thick outer reinforced concrete shell is designed to withstand the impact of a large passenger aircraft. However, the wall thickness at the Chinon B1 NPP is less than 1.0 m. Furthermore, the increasing availability and performance of drones is raising the potential threat to nuclear facilities. A recent assessment of the nuclear security in the France points to shortcomings compared to necessary requirements for nuclear security in regard to "security culture", "cybersecurity" and "protection against insider threats"

- Information on the methods, data and assumptions used for the PSHA performed to determine the SND for Chinon B should be provided, in particular, the types of seismic sources considered (source zones and/or fault sources), time coverage of the earthquake catalogue, minimum and maximum magnitudes, ground motion prediction equations, and site conditions.
- Information on the ground motion value corresponding to the occurrence probability of 10^{-4} per year derived from the PSHA which was performed to determine the SND for the Chinon NPP should be provided.
- A comparison of the ground motion values (PGA, spectral accelerations) of the current deterministically derived design basis earthquake and the corresponding values derived by PSHA should be provided.
- Information on protection requirements of the Chinon B1 NPP with regard to the intentional crash of a commercial aircraft should be provided.
- The PSHA performed for determining the SND should be reviewed by assessing the validity of methods, data and assumptions used in the PSHA and to benchmark the PSHA with regard to WENRA requirements (WENRA 2021) and recommendations (WENRA 2020 a,b).
- Dedicated assessments of near-regional faults for which it cannot be excluded that they are active should be required, in line with WENRA (2020b). The approach may be similar to the one currently applied by EDF to the site of Cruas NPP including field geology, morphostructural and dating studies, and paleoseismology.

- The deterministically derived SMA and the current seismic design basis of Chinon B with the ground motion values derived from probabilistic seismic hazard assessment for a DBE with the occurrence probability of 10^{-4} per year should be compared.
- Additional safety demonstrations to ensure that all SSCs relevant to safety can cope with a probabilistically derived new DBE in case the probabilistically derived DBE exceeds the ground motion parameters of the current seismic design basis of the plant should be required
- The methods, data and assumptions used to derive hazard values for all external hazards considered in the EIA should be reviewed in line with WENRA requirements and guidance (WENRA 2020a-d; 2021).
- Design basis events and design basis parameters should be defined for external hazards conform with WENRA (2021) requirements.
- It should be ensured that the use of the Noyau Dur's DEC equipment is not required to protect the facility against design events, i.e., events with recurrence intervals of 10,000 years or less (e.g., earthquakes). This is to ensure the independence of Defence-in-Depth (DiD) levels 3 and 4.
- It should be evaluated if the long timeframe for implementing the Noyau Dur at the Chinon reactors is in line with the requirement of the *“timely implementation of the reasonably practicable safety improvements identified”* (WENRA 2021, Issue A, Reference Level A2.3). Background: the timeframe for implementing the Noyau Dur at the Chinon reactor 1 extends up to 2029 (for alle reactors up to 2036), i.e., 24 years after ASNR’s initial decision to implement Hardened Safety Cores at the French NPP fleet.
- In this context the following questions should be addressed:
  - Is it correct that strong earthquakes with recurrence periods longer than 150,000 years were not considered in the seismic PSA for the Chinon NPP which, according to the EIA documents, revealed a contribution to the CDF of approximately 10^{-6} per year? If yes: What would be the CDF if earthquakes with longer recurrence intervals were taken into account as well?
  - Have design basis events with exceedance frequencies not higher than 10^{-4} per annum and corresponding design basis loads been defined for all natural hazards considered in the EIA documents (extreme temperatures, river floods, high wind, tornado etc.)?
  - What are the main reasons for the excessively long timeframe (up to 2036) for implementing the Noyau Dur at the Chinon reactors?
  - Have any studies been or will be carried out on the threat posed by newer technologies, in particular potential attacks using civilian or military drones?
  - How is the result of the Nuclear Security Index 2023 for France assessed? Are improvements planned with regard to “security culture”, “cybersecurity” and “protection against insider threats”?

5 SAFETY ASPECT OF ACCIDENT WITHOUT CORE MELT AND SPENT FUEL POOL

5.1 Treatment in the EIA documents

As established in the Chapter on Procedure, the Periodic Safety Review (PSR) framework in France is structured into two distinct phases: a generic assessment and a plant-specific assessment. Each phase addresses two core objectives:

- Safety Requirements Compliance: A thorough assessment of the plant's adherence to the defined and evolving Design Basis safety requirements.
- State-of-the-Art Upgrades: Identification and specification of measures required to align the plant with the Current State of the Art in nuclear technology. The Flamanville 3 EPR (European Pressurized Reactor) serves as the reference standard for the Current State of the Art in this review.

Scope of Measures and Review Focus: This chapter details the modifications and upgrades specified in EIA-REPORT P.1 – P.5 (2025), focusing on two critical safety topics:

- Accidents Without Core Melt: This category encompasses operational transients, Design Basis Accidents (DBA) of varying likelihood, and Design Extension Conditions (DEC) involving multiple system failures that are prevented from progressing to core melt or significant fuel damage.
- Spent Fuel Pool (SFP) Integrity and Cooling.

Key Measures for Accidents Without Core Melt (EIA-REPORT P.1 2025)

EIA-REPORT P.1 (2025) provides the executive summary and outlines the highest-priority measures identified for implementation regarding Accidents Without Core Melt.

Measures Already Implemented:

Accidents-1, Augmented Ultimate Heat Sink Connection for Steam Generators (SGs):

Modification: Establishment of diversified interconnection points linking the Steam Generator Auxiliary Feedwater System (ASG) to the Fire Fighting Water Reservoir.

Rationale: To mitigate certain accident sequences involving the complete loss of both main and emergency feedwater systems. This connection provides a crucial alternate, unconventional heat removal source by ensuring a robust water supply to the Steam Generators, thereby maintaining the primary system's heat sink capability.

Accidents- 2, Increased Relief Capacity of Steam Line Valves (GCTa Modification):

Modification: Uprating of the mass flow capacity through the Main Steam Line Safety and Relief Valves.

Rationale: The enhanced steam relief rate permits a significantly faster depressurization and cooldown of the Reactor Coolant System (RCS) during specific design basis or design extension conditions. This capability accelerates the transition to a safe shutdown state and reduces thermal-hydraulic stress on the system components.

Accidents-3, The allowable amount of Iodine in the primary system coolant was decreased:

While this measure is undoubtable beneficial, the report does not indicate which operative measures were taken to achieve it. Iodine concentration in the primary coolant results from a balance of release of iodine from the fuel due to micro-failures in the fuel rods, and the operation of make-up and let-down system, removing fission products from the primary system coolant. Was this system modified? Or will it be operated for longer time periods? If so, how will this affect its reliability? And how are the phenomena of iodine spiking considered?

Key Measures for Spent Fuel Pool Integrity and Cooling.

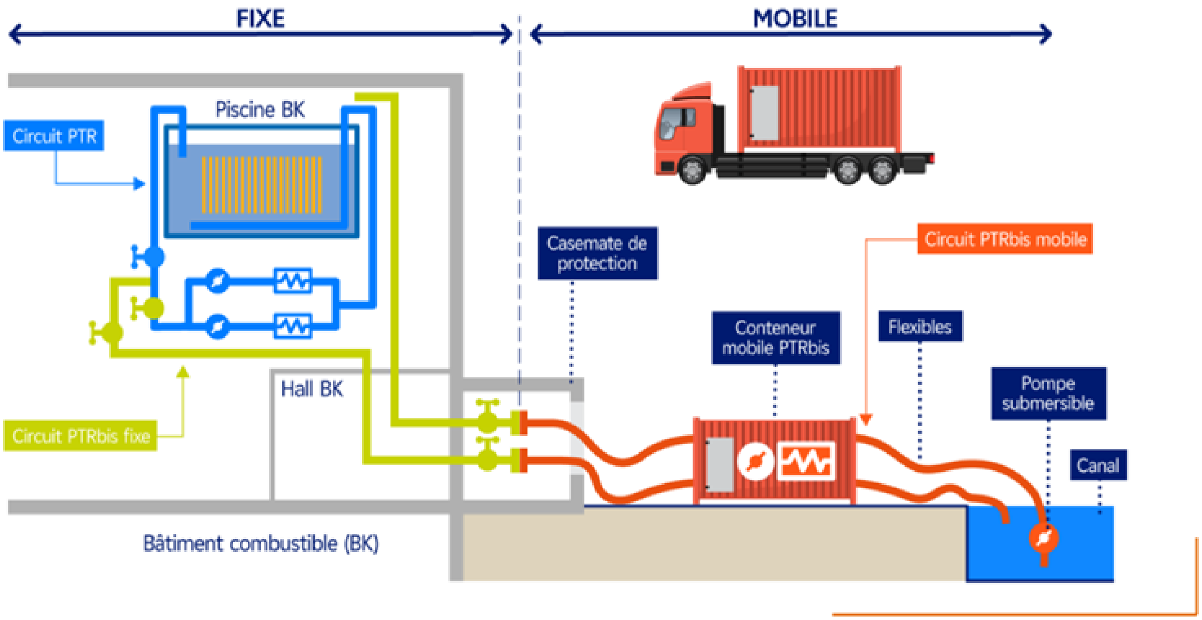
Regarding Spent Fuel Pool the EIA-REPORT P.1 (2025) lists the following items:

Pool-1: Fire: In the event of a fire, to prevent the loss of both cooling paths, EDF has planned the addition of a flame arrestor device to eliminate the risk of a fire spreading from one pump in the cooling circuit to the other.

Pool-2: Additional pool cooling “PTR bis”: As part of the post-Fukushima measures, the diversified water source (SEG) allows for the replenishment of water in the fuel building pool. During 4th PSR, a new mobile cooling system (PTR bis) for the pool allows for diversification of the cold source and, in the event of a loss of the cooling circuit during normal operation, ensures a return to a cooling state for the fuel pool without boiling. This type of arrangement brings the design of 900 MWe reactors closer to that of EPR FLA3 type reactors.

Figure 3: Schematic diagram of the mobile cooling circuit of the fuel element pool (PTR bis) (EIA-REPORT P.2 2025)

Schematic diagram of the mobile cooling circuit of the fuel element pool



Source: Environment Agency Austria

While the mobile cooling system is already implemented, the fire prevention system is still in the planning phase.

The EIA-REPORT P.2 (2025) represents the most extensive of the five reports submitted for the Lifetime Extension (LTE) review. Its section on risks is logically segmented into two main components:

- Conformity Evaluation to Applied Safety Standards: An assessment against the existing licensing basis.
- Re-evaluation (SOTA Comparison): Derivation of necessary measures by comparing the safety profile of the Chinon B1 NPP against the Current State of the Art (SOTA), as defined by the FLA 3 EPR design.

The "Conformity" section is deemed outside the scope of this discussion as it does not relate to Accidents Without Core Melt or the Spent Fuel Pool (SFP). The following focuses on the considerations within the Re-evaluation chapter.

Re-evaluation of Accidents Without Core Melt

EDF's approach to the "Accidents Without Core Melt" scenario involved a comprehensive safety re-evaluation of operational transients, Design Basis Accidents (DBA), and Design Extension Conditions (DEC) Category A.

This re-evaluation utilized both deterministic safety analysis (DSA) and probabilistic safety analysis (PSA) methodologies. A primary goal of this exercise was the reduction of potential radiological consequences associated with these events, aligning the older units with the risk profile of the EPR.

The generic Periodic Safety Review (PSR) specifically mandated the investigation of the following categories of initiating events and accidents:

Reactivity Initiating Accidents (RIA)

- Uncontrolled withdrawal of control rod banks during startup.
- Uncontrolled withdrawal of control rod banks at power.
- Control rod cluster misalignment, drop of a control rod cluster, or drop of a control rod bank (group of clusters).
- Uncontrolled boron dilution.
- Withdrawal of a single Power Control Rod Cluster.
- Control rod ejection accident.

Thermal-Hydraulic and Heat Removal Transients

- Partial loss of primary coolant flow or Forced reduction of primary coolant flow.
- Total loss of load and/or turbine trip.
- Loss of normal feedwater to the Steam Generators (SGs).
- Malfunction of normal feedwater.
- Excessive load increase.
- Inadvertent opening of a secondary relief valve.
- Small break on secondary piping.
- Major Steam Line Break, Category 4.
- Major feedwater line break.
- Momentary depressurization of the primary circuit.
- Loss-of-Coolant Accidents (LOCA) and System Integrity Events
- Loss-of-Coolant Accident (LOCA) due to a small break with a diameter ≤2.5 cm.
- Intermediate Break LOCA, Category 4.
- Inadvertent actuation (startup) of the safety injection system.
- Inadvertent opening of a pressurizer safety valve.
- Steam Generator Tube Rupture (SGTR), Category 3.
- Category 4 SGTR (combined with a stuck-open secondary relief valve).

Equipment and Operational Failures

- Total loss of off-site power (or Loss of external electrical power supplies).
- Seizure/Locked rotor of a Reactor Coolant Pump (RCP).
- Fuel and Core Design Events
- Class 2 Power Capability (a capacity limit check for verifying the sizing of the Reactor Protection System).
- Fuel assembly misalignment in the core.

- Fuel handling accident (in-reactor).
- Irradiated fuel container handling accident.

Chinon B: Plant-Specific PSR Modification Status

During the plant-specific phase of the Periodic Safety Review (PSR) directed at the Chinon B Nuclear Power Plant, EDF categorized safety enhancements into three groups based on their implementation status: fully completed, currently deploying (Phase A), and scheduled for later deployment (Phase B).

Fully Implemented Modifications (Unit 1)

The following modifications have been fully completed on Chinon B1, and all associated documentation impacts have been integrated:

- PNPP1595: Replacement of SEBIM valve heads across various systems.
- PNRL1817: Installation of the Filter – SIS C.
- PNRL1829: Increase in the required REA boron volume and the free volume of the Spent Fuel Pool. (REA: Boron and Water Storage Tank).
- PNPP1864: Establishment of refill capability for the ASG tank via the fire protection fire water system.
- Dilution at power alarm logic update.
- Generalization of Hafnium control rods across the 4th PSR baseline.

Modifications Currently Being Deployed (Phase A)

The following modifications are currently being deployed on Chinon B1, with remaining integration activities scheduled for completion within Phase A of the 4th PSR modifications:

- PNPE1141: Increase in the flow rate of the GCTa regulating valves (Main Steam Line Relief).
- PNPP1838: Renovation of the RPN CPY to VD4 standard. (RPN: Reactor Protection System).
- PNPP1873: SIP-Protection System Evolution.

Modifications Scheduled for Phase B

The following modifications are planned for deployment on Chinon B1during the subsequent Phase B of the 4th PSR modifications:

- PNPE1359: Increase in the pressure of the RIS accumulators. (RIS: Safety Injection System/High Head Injection).
- PNRL1957: Modification of the right blocking plate for Rod bank R or other (PMOX water rod).

Regarding the spent fuel pool, the analysis of EDF came to two main measures that were described in EIA-REPORT P.2 (2025):

First measure, the final connection of the water supply to the spent fuel pool has been strengthened to confirm with "hardened core" requirements. The second measure was already described in EIA-REPORT P.1 (2025) and is portrayed earlier in this chapter.

The document EIA-REPORT P.3 (2025) provides an easy-to-use list of measures but no new information in respect to EIA-REPORT P.1 (2025) and EIA-REPORT P.2 (2025).

5.2 Discussion

Accidents-1: Augmented Ultimate Heat Sink Connection (SG Feedwater)

The installation of a diversified connection to the Fire Fighting Water Reservoir for the Steam Generator Auxiliary Feedwater System (ASG) is a recognized and valuable enhancement. This measure aligns with post-Fukushima accident safety upgrades implemented across numerous Nuclear Power Plants (NPPs) globally to secure the Ultimate Heat Sink (UHS) function.

The historical operation of the Narora NPP Unit 1 (India), which utilized the fire brigade system to sustain cooling during a prolonged Station Blackout (SBO) exceeding 18 hours following a catastrophic cable fire, provides a practical precedent for the long-term effectiveness of this approach. Providing a dedicated connection ensures that mobile fire pump assets can effectively facilitate long-duration residual heat removal from the primary system.

Accident-2. Uprated Steam Line Safety and Relief Valve Capacity (GCTa)

While the increased mass flow capacity of the Main Steam Line Safety and Relief Valves is clearly beneficial for accelerating reactor cooldown during various transients, the assessment report is deficient in providing key quantitative data.

Information Gaps: the report omits the initial and final mass flow rates (e.g., in kg/s) achieved by the upgrade. Crucially, a comparison is missing between the new maximum discharge capacity and the steam flow per steam line during normal operation to contextualize the magnitude of the capacity increase.

Potential Adverse Effects: Increasing valve capacity could potentially introduce adverse effects in specific high-pressure scenarios, such as a Steam Generator Tube Rupture (SGTR) accident. An SGTR constitutes a containment bypass scenario which typically leads to a transient increase in SG pressure. While the valve opening is intended to relieve pressure, an excessively large discharge capacity could intensify the uncontrolled release of primary coolant (contaminated with radioactive material) to the atmosphere, thus challenging the integrity of the release mitigation strategy.

<u>Accidents-3, Reduced Primary System I-131 Limit</u>

The measure to enforce a lower permissible concentration of Iodine-131 (I-131) in the Reactor Coolant System (RCS) water is undeniably beneficial for reducing the potential radiological source term during accidents.

Implementation Gaps: The report lacks crucial details on the methodology for implementing and enforcing this reduced limit.

The assessment does not specify whether the effects of iodine spiking—a rapid, transient increase in iodine concentration during depressurization events—have been adequately considered in the design basis or operational procedures related to this new limit.

<u>Pool-1: Installation of Flame Traps in the SFP Building</u>

The planned installation of flame traps within the Spent Fuel Pool (SFP) building ventilation system represents a highly commendable and undoubtedly beneficial safety enhancement, particularly against hydrogen combustion or other potential ignition sources.

Implementation Status Gap: The benefit of this measure is currently mitigated by the fact that it is not yet fully implemented, and the report fails to provide a firm, committed timeline for its completion.

<u>Pool 2: Mobile Cooling Capabilities:</u>

The establishment of infrastructure and procedures to enable SFP cooling via mobile, diverse sources is a critical defense-in-depth measure. This measure is directly aligned with the lessons learned and subsequent industry requirements arising from the Fukushima Daiichi accident. This enhancement ensures the long-term cooling and inventory control of the SFP under Design Ex-tension Conditions (DEC) and has been successfully implemented.

The re-evaluation during the generic phase has resulted in a large number of safety improvements, many of which are already implemented. However, the status of two crucial measures mandated by the ASNR following the conclusions of the 4th PSR remains to be clarified. EDF is currently carrying out supplementary studies on these two fuel-related topics:

<u>1. Critical Heat Flux (CHF) Correlation Validity (Requirement [Study-B])</u>

Requirement: By December 31, 2024, EDF must evaluate, using an experimental approach, the validity of the Critical Heat Flux (CHF) correlation applied to the periphery of deformed fuel assemblies. Concurrently, EDF must define the work program and schedule to integrate the lessons learned.

Action & Status Question: EDF submitted a detailed test configuration program to the ASNR in June 2021. The text provides no information on whether the CHF experimental program has been completed or what its current status is.

2. Fuel Assembly Grid Buckling Limit (Requirement [Study-D])

Requirement: EDF performed tests to characterize the buckling limit of fuel assembly grids under a more realistic configuration than historical test rigs.

Finding: The test results were used to evaluate fuel assembly mechanical behaviour during a Category 4 Loss-of-Coolant Accident (LOCA) concurrent with a contemporary seismic event. This evaluation confirmed that neither core cooling capability nor the control of reactivity via control rod drop were com-promised.

Implementation: EDF must update the relevant safety analysis reports and integrate the findings into the Target Technical Specifications (TTS) by the deadline of the 5th PSR of the 900 MWe series. This timeline is standard for integrating complex, regulator-approved technical specifications that affect operational procedures.

For the site-specific measure for Chinon B1, the question remains open as to whether there is a specific date by which these measures will be fully implemented.

5.3 Conclusions

While the generic and plant-specific phases have resulted in numerous beneficial safety improvements, several key issues require immediate resolution. Firstly, the reports suffer from a lack of quantitative data necessary to fully assess the benefit and potential adverse effects (e.g., during an SGTR) of the GCT-a valve uprate. Secondly, the implementation status of some critical measures, such as the SFP Flame Trap Installation, is currently unconfirmed with a firm timeline, creating an unquantified safety risk. Finally, there are conflicting implementation statuses reported for certain measures (e.g., PNPE1141) and a lack of justification for deferring beneficial State of the Art upgrades like the RIS Accumulator Pressure Increase (PNPE1359). Transparency in reporting, commitment to firm deadlines, and clarification of technical justifications are necessary to fully validate the safety improvements derived from the PSR.

Enhance Transparency and Provide Clarity on Key Quantitative Data

- Quantitative Data: The reports should provide the initial and final mass flow rates for the GCT-a Valve Uprate (PNPE1141), along with a comparison to the nominal operational flow. This is necessary to quantify the safety benefit.
- Adverse Effects Analysis: The analysis of the uprated GCT-a capacity should be expanded to quantify the risk of increased radioactive release

during a Containment Bypass scenario like a Steam Generator Tube Rupture (SGTR). This ensures that the modification does not introduce new, unacceptable risks.

- Radiological Implementation: Detailed methodology on how the Reduced Primary System I-131 Limit will be implemented and monitored should be provided, explicitly addressing how iodine spiking will be accounted for in operational procedures and design basis analyses.

Establish Firm and Accountable Timelines

- Missing Deadlines: EDF and the ASNR should establish a firm, committed timeline for the completion of the SFP Flame Trap Installation (Pool-1). The absence of a fixed date creates an unquantified safety risk.
- Study Status and Next Steps: For the Critical Heat Flux (CHF) experimental program (Requirement [Study-B]), EDF should immediately provide an updated status on its completion and publicly commit to the defined work program and schedule for incorporating the findings, as the reporting deadline was December 31, 2024.

Clarify Status Reporting and Implementation Rationale

- Resolve Discrepancies: The conflicting status of PNPE1141 (GCT-a flow rate) between EIA-REPORT P.1 (Implemented) and EIA-REPORT P.2 (Deploying) should be clarified. Future reporting should clearly define the criteria for "implemented" (design complete vs. installation complete) to prevent ambiguity.
- Justify Deferral: A comprehensive safety justification for deferring beneficial SOTA measures like the RIS Accumulator Pressure Increase (PNPE1359) to Phase B of the implementation cycle should be provided. This justification should explicitly weigh the cost/complexity against the temporary safety margin reduction.

6 SAFETY ASPECTS OF CORE MELT ACCIDENTS

6.1 Treatment in the EIA documents

As part of 4th PSR, EDF's goal is to significantly reduce the risk of early and significant releases in the event of core-melt accidents in order to avoid lasting effects on the environment. Two projects are planned to achieve this goal:

- Stabilization of the corium on the reactor building basement by distributing and cooling it. The aim is to prevent the basement from breaking through in order to retain the contaminated water resulting from the accident in the reactor building, treat it to remove the radionuclides it contains, and thus prevent the spread of liquid radioactive substances outside the site (“waterway”).
- the removal of residual heat from the core without opening the containment pressure relief and filtration system (U5-System), in order to prevent the release of radioactive substances into the air (“air route”).

Stabilization and Cooling of the Corium

The corium spreads after breaking through the reactor pressure vessel in the vessel well and in the room of the reactor core instrumentation (RIC room). To limit the risk of losing the containment integrity in the event of a core-melt accident due to erosion of the basement, a device is used that is based on stabilizing the corium underwater after it has spread in the dry (PNPP1976). According to EDF, this solution is similar in principle to that used in EPR (core catcher). This arrangement complies with regulation [AG-A-I].

In application of regulation [AG-A-II], EDF has submitted

- a detailed preliminary draft for the reinforcement of the containment basement, whose concrete has a high silica content,
- submitted the conclusions of its test-based investigation program on the behavior of basement in the event of core-melt accidents.

EDF has identified the sites where the basements need to be reinforced. The thickening of the basement will be carried out specifically at the sites concerned.

In accordance with ASNR regulation [AG-A-II] the thickening of the basement with lime-silica concrete in the containment room and in the adjacent RIC room has been performed at Chinon B1.

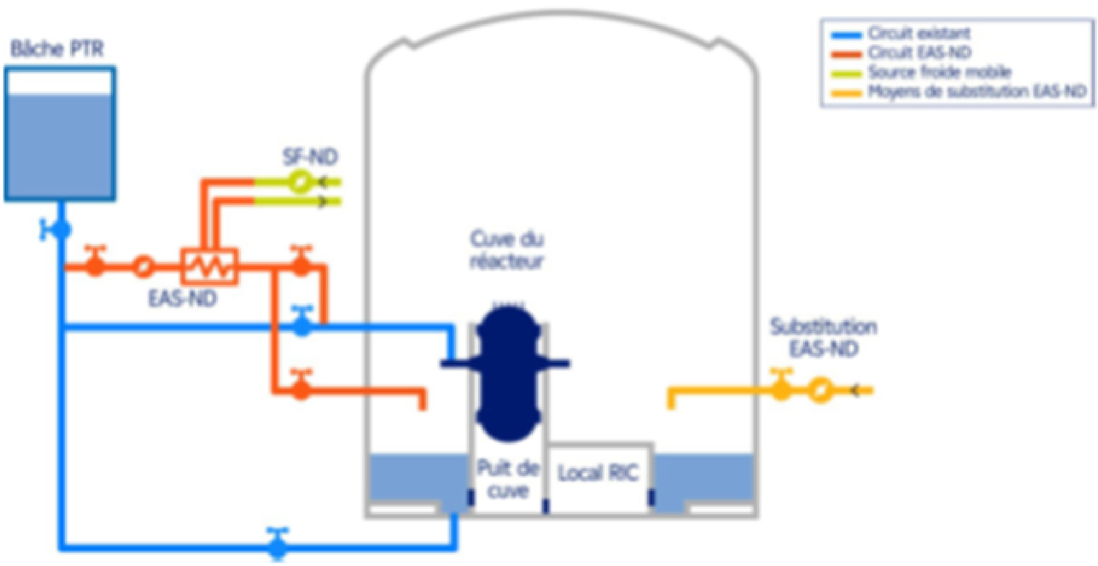
In addition, and in accordance with regulation [AG-A-III], EDF will reinforce the walls between the RIC room and the area of the water collection basins at the bottom of the reactor building in order to avoid any risk of corium penetration (PNPE1460).

The dry distribution of the corium is ensured by the prior sealing of the containment room and the adjacent RIC room. The corium is then drowned by gravity with the water present in the sumps at the bottom of the reactor building filled by the safety injection systems (SIS), the sprinkler system (EAS) or the "Hard Core" sprinkler system (EAS-ND). Gravity refilling of the corium is ensured by redundant holes in the walls of the vessel and RIC rooms, which are closed by passive valves (or flaps) that ensure tightness between the water accumulated at the bottom of the building and the spreading area. This guarantees dry spreading of the corium. The removal of the sealing device is triggered after the corium has spread by the tearing of fusible plugs.

The measurement for detecting a vessel penetration (PNXX1746) makes it possible to ensure water injection onto the corium at the most effective time. The cooling of the corium and the long-term removal of residual power are ensured by the EAS-ND and hard-core cooling source (SF-ND) measures.

Figure 4: Cooling in the event of core meltdown (EIA-REPORT P.1 2025)

Schematic graphic of cooling in the event of core meltdown



Source: Environment Agency Austria
umweltbundesamt

EDF will implement an additional measure that, in the event of a medium- to long-term failure of the EAS-ND, allows water to be replenished using mobile means for a sufficient period of time to limit erosion of the basement (PNPE1362). This measure complies with regulation [AG-B-III]. This replenishment is controlled by measuring the water level at the bottom of the reactor building (PNPE1386).

In addition, following the investigation by the Permanent Group of Experts on Reactors (GPR), special instrumentation to detect the spread of corium over the entire area of the RIC room (PNPE1387) will be implemented.

According to the EIA-REPORT P.2 (2025), the annual frequency of breakthroughs in the basement was estimated at around 10^{-6} / year at the end of the 3rd PSR.

Due to the planned measures, the probability of a breakthrough of the basement is reduced to approximately 10^{-7} / year, which is in line with the goal of avoiding effects on the environment.

Removal of residual heat without filtered venting

The evaporation of water on the corium and the formation of non-condensable gases during the interaction between corium and concrete lead to a slow increase in pressure in the containment. The pressure can reach the design pressure of the containment and necessitate the opening of the pressure relief and filter device (U5-System), resulting in radioactive releases into the environment.

The implementation of the EAS-ND provision (PNPP1811)[10] as part of the 4th PSR also enables the residual heat to be dissipated from the containment. The EAS-ND arrangement is dimensioned in such a way that situations involving core meltdown, which would lead to the opening of the containment filter device, are avoided.

The "EAS-ND" arrangement comprises:

- A pump that can be operated either with direct injection from the PTR tank into the primary circuit or with recirculation from the collection tanks of the reactor building,
- A heat exchanger that transfers the heat from the primary circuit pumped by the pump (EAS-ND) to the hard-core cooling source (SF-ND),
- The SF-ND consists of a mobile pumping device that is transported and deployed by the FARN. It is connected to the cooling circuit via flexible pipes connected to connections at the edge of the reactor building.

Certain valves or valve seals on auxiliary lines of the EAS-ND device will be replaced as part of measure (PNPE1471[11]) to ensure their resistance under accident conditions involving a core-melt accident.

In order to further limit the risk of a pressure increase in the containment building, EDF has defined measures in accordance with regulation [AG-B-II-1], that, in addition to the water contained in the tank of the water treatment and cooling system of the pools (PTR), will allow a further quantity of boron-containing water to be fed into the reactor building in the short term in order to remove residual heat from the containment in the event of a core-melt accident.

The long-term management of core-melt accidents is based on the circulation operation of the EAS-ND system to keep the corium submerged and remove residual power from the reactor. EDF is setting up a system to manage any leaks

[10] PNPP1811: "Installation of an EAS-ND system for feeding water into the primary circuit and for dissipating residual power" is currently being implemented, with integration still pending as part of phase A of the changes to 4th PSR 900.

[11] PNPE1471: "Replacement of valves or valve seals on the EAS ND" will be carried out in Phase B at the latest.

that may occur in the EAS-ND circuit (PNPP1541)[12] outside the containment building. In addition, EDF is installing a device to return the wastewater present in the collection tanks of the spent fuel building to the reactor building (PNPE1362)[13]. These devices for collecting and recirculating comply with the regulations with regulations [AG-B-IV] and [AG-D-I].

To reduce the potential radiological consequences, the modification "Installation of sodium tetraborate baskets in the sump basins of the reactor building" (PNPE1410) will be implemented in Unit 1 of the Chinon nuclear power plant in accordance with [CR-B] by April 24, 2029. The proposed arrangement consists of installing fixed devices in the floor of the reactor building that contain an alkali salt that dissolves in water and retains the iodine in the water, thus limiting its transition to the gas phase. The devices are passive and consist of baskets filled with disodium tetraborate decahydrate.

Reinforcement of the U5-System

Based on the lessons learned from the Fukushima accident, the pressure relief and filter system of the containment (U5-System) was initially reinforced to ensure its resistance to an SMHV earthquake. In accordance with regulation [AG-C-II], the U5-System will be further reinforced to ensure its resistance to earthquakes of magnitude SMS (PNPE1377)[14].

Management of contaminated water

As part of crisis management, short- and long-term compliance with drinking water quality guidelines following a core-melt accident must be ensured as follows:

- In accordance with regulation [AG-D-II], EDF has the necessary means to reduce water contamination in the reactor building following a core-melt accident and ensures that these means are operational on site (PNPE1362[15] and PNPE1449[16]).
- In accordance with regulation [AG-D-III], EDF has investigated ways of limiting the spread of radioactive substances via the soil and groundwater outside the site in order to limit water contamination in the environment following a core-melt accident. According to EDF, these investigations have not revealed any need for additional measures with regard to safety risks.

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[12] PNPP1541: "Introduction of a system for collecting wastewater in the event of a core-melt accident" has been implemented.

[13] PNPE1362: see above

[14] PNPE1377: Reinforcement of the compression and filter device of the U5 container in the event of an SMS earthquake within the deadline specified in AG-CII (04/24/2029).

[15] PNPE1362: see above

[16] PNPE1449 "Investigation of a mobile water treatment module for treating contaminated water" will be implemented as part of the "Supplementary phase".

6.2 Discussion

Severe accidents (SA) were not taken into account in the design of the French 900 MWe reactors. However, as a result of previous PSRs, equipment and measures for SA management have been implemented. The EU stress tests have nevertheless revealed a number of shortcomings.

According to ASNR, the objective of the 4th PSR for the 900 MWe reactors is to approximate the safety level of the third-generation reactor in Flamanville (EPR). In third-generation reactors, core-melt accidents are already taken into account in the design of the reactors; the measures taken for these reactors cannot be fully transferred to second-generation reactors such as Chinon B1.

It is state of the art to use the WENRA "Safety Goals for New Power Reactors" as a reference for identifying meaningful safety improvements during an LTE project. (WENRA 2013) According to the WENRA safety objectives, core-melt accidents that would lead to early or large releases should be practically excluded. The occurrence of certain severe accidents can be considered to be practically excluded "if it is physically impossible for the conditions to occur, or if it can be assumed with high confidence that the occurrence of these conditions is extremely unlikely". The concept of "extremely unlikely with high confidence" is an essential part of the IAEA's concept of "practical exclusion". Although this concept applies only to new reactors, it should also be applied to the Chinon B1 in order to reduce the existing risks. Especially since the goal of the 4th PSR is to approach the safety level of the new EPR in Flamanville. The EIA documents do not include a systematic comparison between the safety level of the 900 MWe reactors and modern safety standards in order to highlight the remaining gaps.

EDF's modifications focused on heat removal without opening the filtered venting devices and stabilizing and cooling the corium on the basement.

Stabilization and Cooling of the Corium

The strategy envisaged by EDF in the context of the 4th PSR to limit the risk of the basement melting through consists of solidifying the corium after failure of the reactor pressure vessel (RPV) and cooling it over the long term. In order to implement this strategy, adaptation work must be carried out inside the reactor building and new circuits must be installed.

The concrete dissolves under the influence of the heat of the corium, which can cause the basement to melt through. The solidification of the corium and the thickness of the melted concrete depend on the type of concrete used in the basements. For the Chinon B, highly siliceous concrete has been used.

IRSN simulations regarding the eroded thickness of highly siliceous concrete differ significantly from EDF's results. According to IRSN, the corium only solidifies when the melted thickness reaches approximately three meters. The complex physical phenomena involved in the solidification of corium were the subject of extensive research. (UMWELTBUNDESAMT 2021b) Pending the results, ASNR requires EDF to prepare the necessary work to reinforce the basements made of highly siliceous concrete so that these measures can be implemented from 2025 onwards. (see [AG-A-II]). The EIA documents do not explain when the thickening of the basement will be performed, and it is not clear if the necessary thickness considered by IRSN will be achieved.

There is a risk of lateral failure of the walls of the RIC room. ASNR therefore considers the strength of the walls to be insufficient and calls for reinforcement. (see [AG-A III]) The walls to the RIC room have not yet been reinforced, although this is necessary to avoid the risk of the corium breaking through. This will be only implemented as part of the Supplementary Phase (PNPE1460).

Although the “installation of a dry spreading device” will take place in Phase A of the project, effective medium- and long-term cooling can only be guaranteed once all measures have been implemented after Phase B.

It was one of the important lessons learned of the Fukushima accident that is important to have instrumentation that do not lose its function under accident conditions. EDF plans to install temperature measuring devices and instruments for measuring the water level at the bottom of the plant. (PNPE1386) In addition, measuring devices are to be installed to monitor the spread of corium in the RIC room. However, these necessary devices will only be installed in the Supplementary Phase.

Removal of residual heat without filtered venting

The EAS system is designed to dissipate residual heat from the containment in the event of a severe accident. The EAS system is used both to prevent severe accidents and to limit the consequences of severe accidents. A malfunction in one component of the system could therefore disable two safety levels. It does not comply with current IAEA safety requirements for a safety system to be assigned to multiple safety levels.

ASNR requires that the injection of an additional volume of borated water be enabled in order to significantly reduce the risk of a pressure increase. (see [AG-B]) The EAS-ND system for feeding water into the primary circuit and for dissipating residual power (PNPP1811) is currently being implemented.

In ASNR's view, numerous additional components and measures beyond those previously planned by EDF are necessary to ensure that the residual heat removal system functions effectively in the long term. However, these important modifications are only to be carried out in Phase B or Supplementary Phase of the program.

In the event of leaks, contaminated water could run onto the floor of the fuel building, where the components of the EAS system are installed, and impair its availability and reliability. Early reinjection of water from the floor of the fuel building into the reactor building would limit the impact. The measure provided for this purpose will only be implemented during the Supplementary Phase (PNPE1362). The necessary “replacement of valves or valve seals on the EAS ND” will also be carried out only in Phase B. (PNPE1471)

Reinforcement of the U5-System

The U5-System is to be used in the event of a failure of the EAS system to enable filtered venting into the atmosphere during a severe accident in the event of excessive pressure in the containment. ASNR requires that the U5-System remain operational even after a severe earthquake. (see [AG-C])

The backfitting of the U5-System with regard to its lack of resistance against an extreme earthquake has not yet been carried out, although this safety deficit was already identified during the EU stress tests. The backfitting is not scheduled to take place until April 2029.

Management of contaminated water

Following the accident at the Fukushima Daiichi nuclear power plant, ASNR instructed EDF to submit a feasibility study for the installation of a geotechnical barrier to prevent the spread of contaminated water in the event of a serious accident. According to a 2012 EDF study, the benefits of such barriers do not justify the costs.

IRSN assessed the consequences of a meltdown of the basement without a special device to limit contamination. At most river sites, the radionuclide concentration in the respective river could exceed the reference dose values for drinking water (0.1 mSv/year) by a factor of approximately 1,000 several months after the meltdown. In addition, even without penetration of the basement, contaminated water can leak from the reactor building and cause the reference values for drinking water to be exceeded. (UMWELTBUNDESAMT 2021a). EDF has therefore committed to providing measures to reduce the risk of contamination of the surrounding water. (see [AG-D]).

The development and implementation of a sufficiently effective measure to limit the spread of contaminated water into the environment is still ongoing. The measures designated as the second and third lines of defense will only be implemented or investigated during the Supplementary Phase.

A mobile water treatment module for treating contaminated water is envisaged to investigate during the Supplementary Phase. (PNPE1449). Thus, it is not clear if this measure will be implemented at all.

Overall, it cannot be ruled out that contaminated water will be released into the environment following a core-melt accident.

6.3 Conclusions

Severe accidents (SA) involving core meltdown were not taken into account in the design of the French 900 MWe reactors. However, as a result of previous PSRs, facilities and measures for SA management have been implemented. According to the ASNR, the objective of the fourth PSA for the 900 MWe reactors is to bring the safety level of the reactor closer to that of the EPR in Flamanville, a third-generation reactor. In third-generation reactors, features to mitigate the effects of core melt accidents are already implemented in the design; these cannot be fully transferred to second-generation reactors such as Chinon B1. The EIA documents do not contain a systematic comparison between the safety level of the 900 MWe reactors and the safety level of the EPR in order to identify the remaining gaps.

The modifications planned as part of the 4th PSR in the event of a core-melt accident focus on heat removal from the containment without opening the filtered pressure relief system and on stabilizing and cooling the corium on the basement.

Based on current knowledge, a failure of the containment cannot be ruled out after the modification to stabilize and cool the molten core has been implemented. On the one hand, not all important modifications have been implemented yet, and on the other hand, it is not possible to assess whether the modifications (especially the reinforcement of the basement) are sufficient based on the available information.

The planned modifications for heat removal without using the filtered pressure relief system in the event of a core-melt accident have not yet been fully implemented. In addition, the reinforcement of the filtered pressure relief system (U5 system) against severe earthquakes has not yet been carried out. This means that even after completion of all Phase A measures of the 4th PSR, a core-melt accident with a major release of radioactive substances is still possible at Chinon B1. The EIA documents do not provide a complete overview of which of the planned modifications meet the ASNR requirements published at the end of the generic phase of the 4th PSR. Most of the measures are not scheduled to be implemented until the end of phase B and the supplementary phase (2029). The EIA documents do not indicate whether this schedule will be adhered to.

- The EIA documents should include an overview of which of the planned measures are to be used to meet the ASNR requirements published at the end of the generic phase of the 4th PSR and when they are to be implemented.
- Information about the status of the thickening of the containment basement, the envisaged thickness and the studies to justify this should be provided.
- It should be explained which options were examined to limit the spread of radioactive substances via soil and groundwater after a core melt accident in accordance with Regulation [AG-D-III]. How is it justified that there is no need for additional measures with regard to safety risks?
- A systematic comparison between the safety level of the 900 MWe reactors and modern safety standards of the EPR Flamanville 3 should be included in order to identify the gaps.
- Information about the core damage frequency (CDF) and the large (early) release frequency L(E)RF before the 4th PSR, after implementation of all

modification of 4th PSR and after the end of Phase A of the 4th PSR should be provided

- The WENRA Safety Objectives for new NPP should be used to identify reasonably practicable safety improvements for Chinon B1. The concept of practical elimination should be used in this approach. Especially since the goal of the 4th PSR is to move closer to the safety level of the EPR Flamanville 3.
- The authorization for continued operation of Chinon B1 should be issued only after the planned measures to mitigate the release in the event of a core-melt accident have been fully implemented.

7 RADIOLOGICAL IMPACT OF ACCIDENTS / TRANSBOUNDARY EFFECTS

7.1 Treatment in the EIA documents

The EIA-REPORT P.3b (2025) provides an overview of accident categories considered for the Chinon B NPP, beginning with the three types of design-basis accidents historically used in plant planning. At the time Chinon NPP was constructed, only design-basis accidents were analysed; therefore, the fourth periodic safety review expands the scope to include beyond-design-basis accidents, including spent fuel pool and core melt scenarios. The EIA -REPORT P.3b (2025) briefly characterizes each accident category, indicating their expected frequency and describing in general terms which safety features may be compromised. However, it does not include detailed accident progression analyses.

Main measures to mitigate radiological consequences following accidents without core melt, accidents caused by internal (fire, explosion, flood, failure of pressure equipment, collision and fall of loads, electromagnetic interference, release of hazardous substances, malicious acts) and external (natural and man-made) events, accidents involving spent fuel pool and accident with core melt implemented during the plant construction and complemented by additional measures implemented as a result of improvements in plant's safety were described in Chapters 4-6.

The EIA documents present the results of calculations demonstrating the potential impacts on public health in terms of projected doses assuming no protective measures are implemented. For the three categories of design-basis events, only the results for the nearest settlements are reported. For events classified as Category 4 – additional accidents, which in practice correspond to beyond-design-basis accidents, transboundary impacts are also assessed for distances of up to 1000 km, including the territory of Austria.

The EIA documents also refer to results of activity concentrations in food, stating that contamination of food for human consumption at distances greater than 5 km does not exceed marketing limits after 7 days; after one year, this distance is reported to be less than 1 km. However, the EIA documents do not present any additional results of the food contamination assessment, nor do they provide calculated activity concentrations in specific food items to substantiate these statements.

The radiological impact of accidents, whether design-basis or beyond design-basis, on the environment in terms of ground deposition is not provided in the EIA documents.

7.2 Discussion

Generic aspects

For beyond-design-basis events, the EIA examines several scenarios: an accident at a decommissioned reactor, an incident involving the spent fuel pool, a station blackout, and a core melt accident. While the assessment claims to consider parameters that increase radioactive releases to ensure conservative, “worst-case” outcomes, it does not provide the underlying source-term data. No radionuclide inventories, release fractions, or other key parameters are included, and the document does not present sufficient information to reproduce or verify the calculations. Similarly, the EIA documents contain no information on the atmospheric dispersion model used to estimate off-site consequences.

Results for design-basis accidents indicate that projected population exposures at the nearest inhabited areas remain below French regulatory reference levels. The assessment also acknowledges that only core melt scenarios may have transboundary implications. The EIA evaluates the long-range transport of radioactive material within a 1,000-km radius under “worst-case” conditions, a distance that includes Austrian territory. Reported results expressed as effective dose for different age groups suggest that the lifetime dose to the Austrian population would not exceed 1 mSv (0.11–0.13 mSv).

The EIA documents state that long-distance atmospheric dispersion calculations used transfer coefficients derived from five years of meteorological data, accounting for topography, wind conditions, and deposition processes. Although this description appears detailed, the assessment still lacks information on the actual dispersion model or calculation method used. It remains unclear whether simulations were performed continuously using daily meteorological input over five years, or whether only a limited number of calculations using average transport coefficients were conducted.

The EIA documents also claim that in case of a beyond design-basis accident with core melt EU maximum levels of radionuclides in food would not be exceeded, but it does not present calculated values to confirm this claim.

Austria has set level for ground deposition of Cs-137 which is 650 Bq/m^2. Values of ground deposition above this value will trigger the screening of food measure agricultural protective measures according to the catalogue of measures (BMLFUW 2014). The EIA documents do not contain information on levels of ground deposition or contamination. While doses to population might be below reference levels, ground deposition of Cs-137 above 650 Bq/m^2 could have serious non-radiological consequences, such as psychological and economic consequences in the affected areas.

Site-specific aspects

As the EIA documents did not provide sufficient data to reproduce calculations of which results are presented and in order to assess whether, under specific circumstances, the limit value for the protective measures in Austria could be exceeded, the expert team conducted related dispersion modelling for large-scale release following two hypothetical accidents scenarios for Chinon B NPP. The aim of the assessment was to assess whether a severe accident at Chinon B could possibly cause a deposition on Austrian territory above 650 Bq/m², a value that triggers protective actions related to prevention of food contamination. Probability of a large-scale release was not assessed nor considered in this study on atmospheric dispersion following a severe accident.

The source terms, marked as release categories FK1 and FK2, used in the JRODOS dispersion modelling to assess the deposition on Austrian territory are referenced in publication "*Übersicht über Maßnahmen zur Verringerung der Strahlenexposition nach Ereignissen mit nicht unerheblichen radiologischen Auswirkungen (Maßnahmenkatalog)*", 2010, Table 7.2-7 (SSK 2010). The source terms for both release scenarios, expressed as cumulative release fractions, are derived from a reference core inventory representative of a 1000 MWe-class PWR. For application to Chinon B, the reference source term is scaled to reflect the characteristics of the French 900-MWe series reactors. This scaling ensures that the assumed radionuclide inventory is consistent with the actual core power and isotopic inventory of the Chinon B.

The release category FK1 considers an accident at PWR resulting in core-melt with steam explosion. Release happens one hour after the reactor shut-down and lasts for 1 hour. The release category FK2 considers an accident at PWR resulting in core-melt with large containment release. Release happens one hour after the reactor shutdown and lasts for 3 hours. Activities expressed as fractions of the core inventory for both release categories are shown in Table 3.

Table 3: Cumulative release rates, based on the core inventory according to the German Risk Study Phase A (adapted from SSK 2010))

		Release category	
		FK1	**FK2**
Start (h)		1	1
Duration (h)		1	3
Release height (m)		30	10
Thermal energy (GJ/h)		540	15
Released fraction of the core inventory	Kr-Xe	1,0	1,0
	I(org)	$7{,}0 \cdot 10^{-3}$	$7{,}0 \cdot 10^{-3}$
	I2-Br	$7{,}9 \cdot 10^{-1}$	$4{,}0 \cdot 10^{-1}$
	Cs-Rb	$5{,}0 \cdot 10^{-1}$	$2{,}9 \cdot 10^{-1}$
	Te-Sb	$3{,}5 \cdot 10^{-1}$	$1{,}9 \cdot 10^{-1}$
	Ba-Sr	$6{,}7 \cdot 10^{-2}$	$3{,}2 \cdot 10^{-2}$
	Ru[1)]	$3{,}8 \cdot 10^{-1}$	$1{,}7 \cdot 10^{-2}$
	La[2)]	$2{,}6 \cdot 10^{-3}$	$2{,}6 \cdot 10^{-3}$

[1)] "Ru" also applies to Rh, Co, Mo, Tc

[2)] "La" also applies to Y, Zr, Nb, Ce, Pr, Nd, Np, Pu, Am, Cm

Ideally, atmospheric dispersion modelling for a specific type of accident with a release would be done with daily meteorological data for at least one year to understand transport and deposition of a radioactive plume in all meteorological conditions. As the goal of modelling in this study was only to confirm whether a deposition of Cs-137 above 650 Bq/m^2 from an accident in Chinon B would be possible, a historical weather data that could support dispersion of the radioactive plume to Austria was used for the analysis.

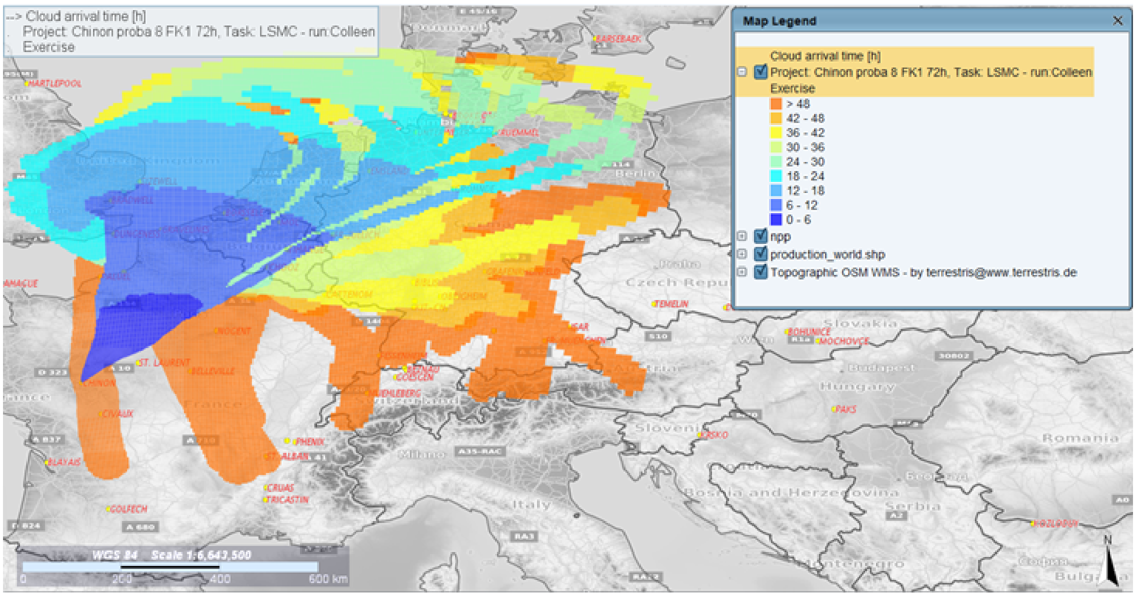
Presented here are the results of one of the calculations which confirmed possibility of ground contamination in Austria from a release in Chinon B. For both release scenarios it was assumed that they started at the same time.

Location:	Chinon B, France
Release start:	4 January 2024, 06:00 UTC
Prognosis duration:	72 hours

Information on cloud arrival time (Figure 5 and Figure 6) tells when the cloud is expected to arrive in the affected country. In both scenarios, it takes around 60 hours for the cloud to reach Austrian territory. As it heavily depends on the weather, cloud arrival time may be significantly different for different meteorological conditions.

Figure 5: Cloud arrival time for the release category FK1

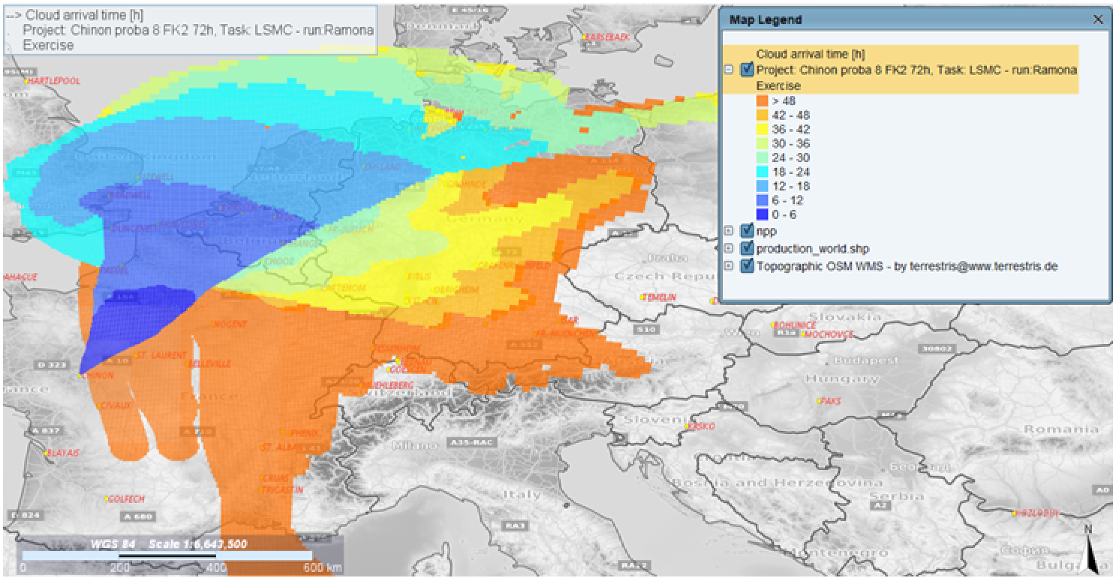
Cloud arrival time for FK1



Source: Environment Agency Austria

Figure 6: Cloud arrival time for the release category FK2

Cloud arrival time for FK2

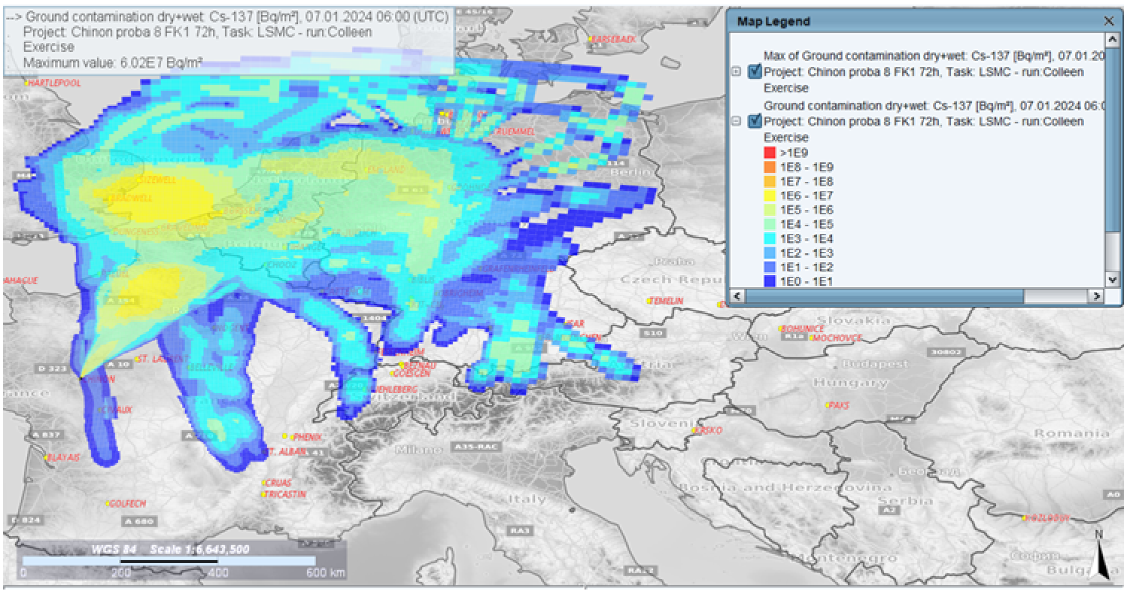


Source: Environment Agency Austria **umwelt**bundesamt

Deposition of the radioactive material released in an accident depends on a number of factors: characteristics of a release, meteorological conditions, deposition surface and others. For this task, meteorological conditions for the period 4 – 7 January 2024, which led to transport of a radioactive plume over Austrian territory, were chosen. Based on the reference core inventory, scaled down to reflect characteristics of Chinon B NPP, estimated released activity of Cs-137 in release category FK1 was 1.3×10^{17} Bq and 8.1×10^{16} in release category FK2.

Figure 7: Ground contamination with Cs-137 for the release category FK1

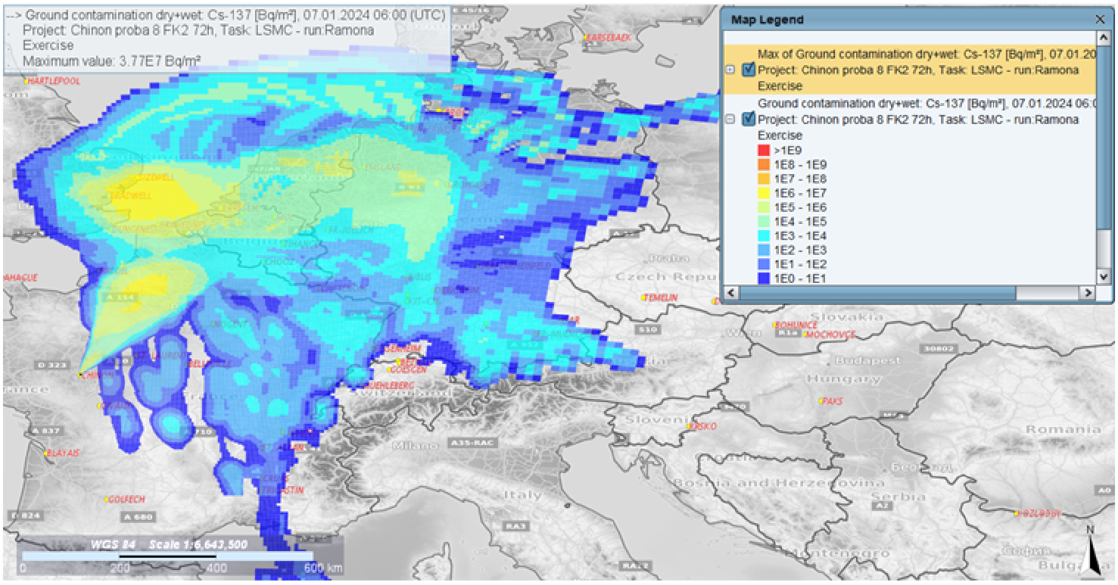
Ground contamination with Cs-137 for FK1



Source: Environment Agency Austria **umwelt**bundesamt

Figure 8: Ground contamination with Cs-137 for the release category FK2

Ground contamination with Cs-137 for FK2



Source: Environment Agency Austria

umweltbundesamt

Results of the JRODOS calculation for both release categories, FK1 and FK2 presented in Figure 7 and Figure 8, show that there is a possibility of contamination in Austria above 650 Bq/m2 with the maximum calculated value exceeding 1×10^4 Bq/m^2. The probability of such contamination was not assessed in this study.

7.3 Conclusions

The EIA documentation considers events and accident sequences corresponding to three categories of design-basis events and an additional category representing beyond-design-basis accidents, including core-melt and spent fuel pool scenarios.

The analysis of radiological consequences presented in the document lacks technical information. Key elements required for independent verification, such as radionuclide inventories, source-term assumptions, release fractions, and detailed dispersion modelling methodology, are not provided. As a result, the transparency of the radiological impact assessment is limited as well as reproducibility of the assessment results.

For design-basis accidents, the EIA concludes that consequences remain below national reference levels and do not pose transboundary risks. For beyond-design-basis accidents, including core melt scenarios, the EIA does acknowledge potential long-range impacts, but again without providing sufficient technical data to allow validation of these results. Quantitative assessments to confirm statements regarding food contamination remaining below EU limits at a distance of more than 5 km after 7 days and less than 1 km after 1 year are not provided. The EIA also omits any information on ground deposition, despite its relevance for long-term consequences and food-chain contamination.

Modelling of atmospheric dispersion and deposition conducted by the expert team demonstrates that, under certain meteorological conditions, a severe accident at Chinon B could lead to ground deposition of Cs-137 in Austria above the national screening threshold of 650 Bq/m². Although the study does not assess the probability of such conditions, the results indicate that transboundary impacts greater than those implied in the EIA cannot be excluded.

Overall, the EIA provides an assessment of radiological consequences without providing complete information on assessment methodology and underlying data to support the claims, particularly for severe accidents with potential transboundary effects. More detailed source-term information, dispersion modelling inputs, and food-chain contamination assessments would be needed to fully evaluate the potential impact on Austria and to support the claims made in the EIA documents.

- Information on the release parameters is needed for the reconstruction of the results of the assessment provided in the EIA. Where detailed information on core inventory and source terms cannot be disclosed, minimum required information to be requested is on released activities of Cs-137 and iodine for beyond design-basis accidents
- A presentation of the modelling results supporting statements of lifetime dose for transboundary impact (Austria) should be provided
- A presentation of atmospheric dispersion and ground deposition calculations for key radionuclides, including spatial distribution maps, modelling assumptions, and uncertainty evaluation should be provided
- Information of the calculations supporting statements on food contamination should be provided.

8 ASSESSMENT OF THE TIME FRAME

8.1 Treatment in the EIA documents

The EIA documents emphasize the goals of the investigation undertaken, covering three areas:

- "risks", where the plant is assessed against the requirements set by current standards and regulations, but also for opportunities to increase safety levels to those comparable to Generation III reactors, with Flamanville 3 EPR as a reference reactor. The latter includes four distinctive areas: accidents without core damage, accidents with core damage, external impacts, and spent fuel pool issues.
- "disadvantages", where issues that lead to release that could affect people and the environment are assessed, and
- "Aging management", where processes to prevent degradation due to aging are assessed, especially for the period beyond 40 years of operation.

The aim of the 4th PSR was to assess the status in relation to these goals, with the objective of identifying specific measures, either technical or administrative (analyses), that would lead to enhanced safety, to comply with the goals set.

According to a decision by the French regulator ASNR, each plant has a period of 6 years following the release of the PSR report, to implement all safety measures identified.

EDF organizes this 6-year period in different phases. The Phase A measures are those that could be implemented during operations or within an outage related to the 4th PSR. Those measures have already been implemented at the time of the release of the EIA document. Next, the measures that will not be implemented in Phase A are scheduled for implementation within Phase B, which is planned to be completed by April 2029. Measures that are not completed within Phase B (or its extension, which is also planned to be completed by April 2029) are then to be completed within further phases, to be finalized by April 2030. This coincides with the "6 years after the release of the PSR report", as required by the Regulators ASNR

8.2 Discussion

Many countries typically require the completion date of all measures within a period of 5 years after the approval of the PSR report by the regulator (this might be the same as the "release" in the case of the Chinon NPP). Whether the deadline is 5 or 6 years does not make a significant difference. Nevertheless, as the period following the 4th PSR coincides with the entry into Long-Term Operation (LTO), it is expected that some of the specific measures related to the ageing management would either need to be implemented now or require special attention for implementation (if they were implemented earlier).

It is important that the agreed implementation period (6 years) is not extended. Some of the information circulating around seems to suggest uncertainties related to the financial resources needed for the implementation of the safety modification, including the ageing management. Lack of financial resources could cause delays. Another issue is the availability of the supply chain, including human resources, which are known to be in short supply and may impact implementation.

Another possible challenge appears to be the uncertainty regarding the completion of all the measures that have been proposed and agreed upon in the Post-Fukushima Action Plan. While some important safety modifications, including the EAS-ND cooling systems as well as "Corium stabilization" are presented as a part of the post 4th PSR modification, some elements of those might still be parts of the post-Fukushima safety upgrades. It remains unclear whether these would be fully addressed only as part of the ongoing efforts. The EIA report has yet to provide full clarity on this issue. (see also chapter 4, 5 and 6)

8.3 Conclusions

The timeframe for completing all measures under the 4th PSR (6 years after the release of the PSR report = 2029/2030) is not uncommon. However, as the period following the 4th PSR corresponds with the start of long-term operation (LTO), some of the specific measures require special attention. It is important that the agreed implementation period is not extended. A lack of financial resources or the known problems with supply chain availability, including human resources, could affect the implementation period. It is particularly noteworthy that important safety modifications listed as part of the 4th PSR were already considered necessary as part of the EU stress test (2012), and their implementation had been agreed upon.

- Maintaining agreed schedule, or when possible, accelerating the safety improvements and LTO measures to be completed, where possible, even before 6 years deadline is strongly recommended.
- EDF should put the priority on the funding for the safety upgrade measures required in the 4th PSR and those related to the LTO, rather than on construction of a series of new EPR-2.
- Additional clarity of how the post Fukushima measures are being integrated with the measures that were decided on the basis of 4th PSR would be appreciated.

9 LIST OF CONCLUSIONS

9.1 Long-Term operation and Operational experience

- The justification that no checks are to be carried out for Chinon B1 as part of the Program for Complementary Investigations (PIC) should be provided
- In-depth investigations on components relevant for preventing external events to affect the nuclear safety of the plant should be carried out, in particular concerning those components of the original systems that connect the newly installed "hardened safety core" and systems for mitigating the effects of core-melt accidents.
- A complete analysis of the causes of the cracks in the auxiliary line due to stress corrosion cracking should be carried out and taken into account in order to take preventive protective measures against such damage and its effects already within the framework of the 4th PSR.
- The modification of the ageing management for the secondary and primary circuit components to detect unexpected degradation should be considered. A systematic ageing control of the components safety relevant concerning the resistance with regard to earthquakes should be considered.

9.2 External hazards

- Information on the methods, data and assumptions used for the PSHA performed to determine the SND for Chinon B should be provided, in particular, the types of seismic sources considered (source zones and/or fault sources), time coverage of the earthquake catalogue, minimum and maximum magnitudes, ground motion prediction equations, and site conditions.
- Information on the ground motion value corresponding to the occurrence probability of 10^{-4} per year derived from the PSHA which was performed to determine the SND for the Chinon NPP should be provided.
- A comparison of the ground motion values (PGA, spectral accelerations) of the current deterministically derived design basis earthquake and the corresponding values derived by PSHA should be provided.
- Information on protection requirements of the Chinon B1 NPP with regard to the intentional crash of a commercial aircraft should be provided.
- The PSHA performed for determining the SND should be reviewed by assessing the validity of methods, data and assumptions used in the PSHA and to benchmark the PSHA with regard to WENRA requirements (WENRA 2021) and recommendations (WENRA 2020 a,b).

- Dedicated assessments of near-regional faults for which it cannot be excluded that they are active should be required, in line with WENRA (2020b). The approach may be similar to the one currently applied by EDF to the site of Cruas NPP including field geology, morphostructural and dating studies, and paleoseismology.
- The deterministically derived SMA and the current seismic design basis of Chinon B with the ground motion values derived from probabilistic seismic hazard assessment for a DBE with the occurrence probability of 10^{-4} per year should be compared.
- Additional safety demonstrations to ensure that all SSCs relevant to safety can cope with a probabilistically derived new DBE in case the probabilistically derived DBE exceeds the ground motion parameters of the current seismic design basis of the plant should be required
- The methods, data and assumptions used to derive hazard values for all external hazards considered in the EIA should be reviewed in line with WENRA requirements and guidance (WENRA 2020a-d; 2021).
- Design basis events and design basis parameters should be defined for external hazards conform with WENRA (2021) requirements.
- It should be ensured that the use of the Noyau Dur's DEC equipment is not required to protect the facility against design events, i.e., events with recurrence intervals of 10,000 years or less (e.g., earthquakes). This is to ensure the independence of Defence-in-Depth (DiD) levels 3 and 4.
- It should be evaluated if the long timeframe for implementing the Noyau Dur at the Chinon reactors is in line with the requirement of the *"timely implementation of the reasonably practicable safety improvements identified"* (WENRA 2021, Issue A, Reference Level A2.3). Background: the timeframe for implementing the Noyau Dur at the Chinon reactor 1 extends up to 2029 (for alle reactors up to 2036), i.e., 24 years after ASNR's initial decision to implement Hardened Safety Cores at the French NPP fleet.
- In this context the following questions should be addressed:
  - Is it correct that strong earthquakes with recurrence periods longer than 150,000 years were not considered in the seismic PSA for the Chinon NPP which, according to the EIA documents, revealed a contribution to the CDF of approximately 10^{-6} per year? If yes: What would be the CDF if earthquakes with longer recurrence intervals were taken into account as well?
  - Have design basis events with exceedance frequencies not higher than 10^{-4} per annum and corresponding design basis loads been defined for all natural hazards considered in the EIA documents (extreme temperatures, river floods, high wind, tornado etc.)?
  - What are the main reasons for the excessively long timeframe (up to 2036) for implementing the Noyau Dur at the Chinon reactors?
  - Have any studies been or will be carried out on the threat posed by newer technologies, in particular potential attacks using civilian or military drones?

- How is the result of the Nuclear Security Index 2023 for France assessed? Are improvements planned with regard to "security culture", "cybersecurity" and "protection against insider threats"?

9.3 Safety aspects of accidents without core melt and spent fuel pool

Enhance Transparency and Provide Clarity on Key Quantitative Data

- Quantitative Data: The reports should provide the initial and final mass flow rates for the GCT-a Valve Uprate (PNPE1141), along with a comparison to the nominal operational flow. This is necessary to quantify the safety benefit.
- Adverse Effects Analysis: The analysis of the uprated GCT-a capacity should be expanded to quantify the risk of increased radioactive release during a Containment Bypass scenario like a Steam Generator Tube Rupture (SGTR). This ensures that the modification does not introduce new, unacceptable risks.
- Radiological Implementation: Detailed methodology on how the Reduced Primary System I-131 Limit will be implemented and monitored should be provided, explicitly addressing how iodine spiking will be accounted for in operational procedures and design basis analyses.

Establish Firm and Accountable Timelines

- Missing Deadlines: EDF and the ASNR should establish a firm, committed timeline for the completion of the SFP Flame Trap Installation (Pool-1). The absence of a fixed date creates an unquantified safety risk.
- Study Status and Next Steps: For the Critical Heat Flux (CHF) experimental program (Requirement [Study-B]), EDF should immediately provide an updated status on its completion and publicly commit to the defined work program and schedule for incorporating the findings, as the reporting deadline was December 31, 2024.

Clarify Status Reporting and Implementation Rationale

- Resolve Discrepancies: The conflicting status of PNPE1141 (GCT-a flow rate) between EIA-REPORT P.1 (Implemented) and EIA-REPORT P.2 (Deploying) should be clarified. Future reporting should clearly define the criteria for "implemented" (design complete vs. installation complete) to prevent ambiguity.
- Justify Deferral: A comprehensive safety justification for deferring beneficial SOTA measures like the RIS Accumulator Pressure Increase (PNPE1359) to Phase B of the implementation cycle should be provided. This justification should explicitly weigh the cost/complexity against the temporary safety margin reduction.

9.4 Safety aspects of core melt accidents

- The EIA documents should include an overview of which of the planned measures are to be used to meet the ASNR requirements published at the end of the generic phase of the 4th PSR and when they are to be implemented.
- Information about the status of the thickening of the containment basement, the envisaged thickness and the studies to justify this should be provided.
- It should be explained which options were examined to limit the spread of radioactive substances via soil and groundwater after a core melt accident in accordance with Regulation [AG-D-III]. How is it justified that there is no need for additional measures with regard to safety risks?
- A systematic comparison between the safety level of the 900 MWe reactors and modern safety standards of the EPR Flamanville 3 should be included in order to identify the gaps.
- Information about the core damage frequency (CDF) and the large (early) release frequency L(E)RF before the 4th PSR, after implementation of all modification of 4th PSR and after the end of Phase A of the 4th PSR should be provided
- The WENRA Safety Objectives for new NPP should be used to identify reasonably practicable safety improvements for Chinon B1. The concept of practical elimination should be used in this approach. Especially since the goal of the 4th PSR is to move closer to the safety level of the EPR Flamanville 3.
- The authorization for continued operation of Chinon B1 should be issued only after the planned measures to mitigate the release in the event of a core-melt accident have been fully implemented.

9.5 Radiological impact of accidents / Transboundary effects

- Information on the release parameters is needed for the reconstruction of the results of the assessment provided in the EIA. Where detailed information on core inventory and source terms cannot be dis-closed, minimum required information to be requested is on released activities of Cs-137 and iodine for beyond design-basis accidents
- A presentation of the modelling results supporting statements of lifetime dose for transboundary impact (Austria) should be provided

- A presentation of atmospheric dispersion and ground deposition calculations for key radionuclides, including spatial distribution maps, modelling assumptions, and uncertainty evaluation should be provided
- Information of the calculations supporting statements on food contamination should be provided.

9.6 Assessment of the time frame

- Maintaining agreed schedule, or when possible, accelerating the safety improvements and LTO measures to be completed, where possible, even before 6 years deadline is strongly recommended.
- EDF should put the priority on the funding for the safety upgrade measures required in the 4th PSR and those related to the LTO, rather than on construction of a series of new EPR-2.
- Additional clarity of how the post Fukushima measures are being integrated with the measures that were decided on the basis of 4th PSR would be appreciated.

10 REFERENCES

ASN (2011a): Complementary Safety Assessment of the French Nuclear Power Plants. Report by the French Nuclear Safety Authority (December 2011). https://www.ensreg.eu/category/countries/france

ASN (2012): Complementary Safety Assessments Follow-up to the French Nuclear Power Plants Stress tests, National Action Plan of the French Nuclear Safety Authority, December 2012

ASN (2021) - Décision n° 2021-DC-0706 de l'Autorité de sûreté nucléaire du 23 février 2021 fixant à la société Électricité de France (EDF) les prescriptions applicables aux réacteurs des centrales nucléaires du Blayais (INB n° 86 et n° 110), du Bugey (INB n° 78 et n° 89), de Chinon (INB n° 107 et n° 132) [etc.] au vu des conclusions de la phase générique de leur quatrième réexamen périodique. Montrouge, le 23 février 2021.

ASN (2022a): National Report of France for the combined 8th and 9th Review meeting in 2023 Convention on Nuclear Safety (CNS); August 2022

BAIZE, S., CUSHING, E. M. ET AL. (2002) - Inventaire des indices de rupture affect-ant le Quaternaire en relation avec les grandes structures connues, en France métropolitaine et dans les régions limitrophes. Mém. Soc. géol. Fr. (1924), 175: 1-141.

BMLFUW – BUNDESMINISTERIUM FÜR LAND- UND FORSTWIRTSCHAFT, UMWELT UND WASSERWIRTSCHAFT (2014): Maßnahmenkatalog für radiologische Notstandssituationen. Arbeitsunterlage für das behördliche Notfallmanagement auf Bundesebene gemäß Interventionsverordnung, Wien, Juli 2014.

EIA-REPORT P.1 (2025) – Enquête publique sur le rapport du 4ème réexamen périodique, du réacteur n° 1 de Chinon B, Pièce 1 - Note de présentation; EDF; 2025.

EIA-REPORT P.2 (2025) – Enquête publique sur le rapport du 4ème réexamen périodique, du réacteur n° 1 de Chinon B; Pièce 2 – Rapport du réexamen périodique de Chinon B1 Objet de l'enquête publique; EDF 2025

EIA-REPORT P.3 (2025) – Enquête publique sur le rapport du 4ème réexamen périodique, du réacteur n° 1 de Chinon B Pièce 3 - Pièce 3 - Description des dispositions proposes par l'exploitant à la suite du réexamen périodique; EDF 2025

EIA-REPORT P.3b (2025): Öffentliches Anhörungsverfahren über den Bericht der 4. periodischen Sicherheitsüberprüfung Reaktor Nr. 1 Kernkraftwerk Chinon B. Dokument 3b; Dokument bezüglich der Auswirkungen auf die Umwelt, die mit dem Betrieb des Reaktors während der nächsten zehn Jahre verbunden ist; EDF 2025

EIA-REPORT P.4 (2025) – Enquête publique sur le rapport du 4ème réexamen périodique, du réacteur n° 1 de Chinon B; Pièce 4 – Bilan des actions de concertation mises en œuvre pour la partie générique du 4e réexamen périodique des réacteurs de 900MWe. EDF; 2025.

ENSREG (2012b): France. Peer review country report. Stress tests performed on European nuclear power plants. http://www.ensreg.eu/document/peer-review-report-eu-stress-tests-france

FRANO (2021): Aircraft Impact Effects on an Aged NPP. Materials 2021, 14, 816. Frano, R.L. 2021.

GP – Greenpeace Deutschland (2014): Gefahr aus der Luft – Drohnenüberflüge bedrohen französische Atomanlagen, Oda Becker im Auftrag von Greenpeace Deutschland e.V.; November 2014

IAEA – International Atomic Energy Agency (2021a): International Physical Protection Advisory Service (IPPAS); http://www-ns.iaea.org/security/ippas.asp

IAEA – International Atomic Energy Agency (2022) - Seismic Hazards in Site Evaluation for Nuclear Installations. Specific Safety Guide No. SSG-9 (Rev. 1), Vienna.

IAEA – International Atomic Energy Agency (2025a): Peer Review and Advisory Services Calendar; https://www.iaea.org/services/review-missions/calenda

JOMARD, H., Cushing, E. M. et al. (2017): Transposing an active fault database in-to a seismic hazard fault model for nuclear facilities - Part 1: Building a database of potentially active faults (BDFA) for metropolitan France. Nat. Hazards Earth Syst. Sci., 17(9): 1573-1584.

NEOPAL (2009): Database of neotectonic and paleoseismic evidences. Online version available at https://data.oreme.org/fact/fact_map/neopal.

RITZ, J.F., Baize, S. et al. (2021): New perspectives in studying active faults in metropolitan France: the “Active faults France” (FACT/ATS) research axis from the Resif-Epos consortium. Comptes Rendus Géoscience - Sciences de la Planète, 353, no S1: 381-412.

SSK – Strahlenschutzkommission (2010): Übersicht über Maßnahmen zur Verringerung der Strahlenexposition nach Ereignissen mit nicht unerheblichen radiologischen Auswirkungen (Maßnahmenkatalog) 2010, Heft 60; CD-ROM.

UMWELTBUNDESAMT (2019a): Becker, O.; Giersch, M.; Meister, F.; Mertins, M.; Weimann, G.: Review of the 900 MWe reactor fleet (VD4-900). Expert Statement on the Generic Phase. By Order of the Federal Ministry for Sustainability and Tourism Directorate I/6 General Coordination of Nuclear Affairs BMNT. REP-0686, Wien.

UMWELTBUNDESAMT (2021a). Becker, O.; Mertins, M.; Mraz, G.: Frankreich: Konsultation zu den Bedingungen für den Weiterbetrieb der 900 MWe-Reaktoren über 40 Jahre hinaus. Fachstellungnahme. Erstellt im Auftrag des BMK, Abt. VI/9 Allgemeine Koordination von Nuklearangelegenheiten, REP-0752, Wien.

UMWELTBUNDESAMT (2021b). Becker, O.; Decker, K.; Mertins, M.; Mraz, G.: Frankreich: Beschluss der ASN zur Festlegung der Anforderungen an die 900 MW Reaktoren. Kurzgutachten. Erstellt im Auftrag des Bundesministeriums für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie, Abteilung VI/9 Allgemeine Koordination von Nuklearangelegenheiten BMK, REP-0764, Wien.

UMWELTBUNDESAMT (2024): Becker, O.; Decker, K.; Frieß, F.; Marignac, Y.; Mertins, M.; Mraz, G; Müllner, N.: Lifetime extension of the French 1300 MWe reactor fleet - generic requirements for the periodic safety review 4. Expert statement – synthesis report. Erstellt im Auftrag des BMK, Abt. VI/9 Allgemeine Koordination von Nuklearangelegenheiten, REP-0915, Wien.

UMWELTBUNDESAMT (2024a): Becker, 0; Decker, K.: Lifetime extension of the French 1300 MWe reactor fleet - generic requirements for the periodic safety review. Task 3: Hazards Report. Erstellt im Auftrag des BMK, Abt. VI/9 Allgemeine Koordination von Nuklearangelegenheiten, REP-0936, Wien.

UMWELTBUNDESAMT (2024b): Becker, 0.; Kühteubl, F.; Meister, F.: Lifetime extension of the French 900 MWe reactor fleet - generic requirements for the periodic safety review 5. Expert Statement. Erstellt im Auftrag des BMK, Abt. VI/9 Allgemeine Koordination von Nuklearangelegenheiten, REP-0938, Wien.

WENRA – Western European Nuclear Regulators' Association (2013): Report Safety of new NPP designs, Study by Reactor Harmonization Working Group RHWG; March 2013.

WENRA – Western European Nuclear Regulators' Association (2014): Report WENRA Safety Reference Levels for Existing Reactors – Update in Relation to Lessons Learned from TEPCO Fukushima Dai-Ichi Accident, WENRA, 24th September 2014. http://www.wenra.org/publications/.

WENRA – Western European Nuclear Regulators Association (2020a): Guidance Document Issue TU: External Hazards. Head Document http://www.wenra.org/publications/.

WENRA – Western European Nuclear Regulators Association (2020b): Guidance Document Issue TU: External Hazards. Guidance on External Flooding. Annex to the Guidance Head Document. http://www.wenra.org/publications/.

WENRA – Western European Nuclear Regulators Association (2020c): Guidance Document Issue TU: External Hazards. Guidance on External Flooding. Annex to the Guidance Head Document. http://www.wenra.org/publications/.

WENRA – Western European Nuclear Regulators Association (2020d): Guidance Document Issue TU: External Hazards. Guidance on Extreme Weather Conditions. Annex to the Guidance Head Document. http://www.wenra.org/publications/.

WENRA – Western European Nuclear Regulators Association (2021): WENRA Safety Reference Levels for Existing Reactors, Update in relation to lessons learned from TEPCO Fukushima Dai-ichi Accident; 17th February 2021. http://www.wenra.org/publications/.

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12 GLOSSARY

ASG .... Steam Generator Auxiliary Feedwater System

ASN .... French Authority for Nuclear Safety

ASNR .... French Authority for Nuclear Safety and Radiation Protection (result of the merger of ASN and IRSN (see below) since 1.1.2025)

BAN .... Buildings for Nuclear Auxiliary Facilities

BK .... Spent Fuel Building

Bq .... Becquerel

CDF .... Core Damage Frequency

CHF .... Critical Heat Flux

Cs-137 .... Caesium-137

DBA .... Design Basis Accidents

DBE .... Design Basis Earthquake

DEG .... System for generating and distributing cold water

DEC .... Design Extension Conditions

DID .... Defence-in-Depth

DVN .... Ventilation and air conditioning system

EAS .... Sprinkler System

EAS-ND .... "Hard Core" Sprinkler System

EDF .... Électricité de France

EDG .... Emergency Diesel Generators

EIA .... Environmental Impact Assessment

EIPS .... Emergency Intervention Systems ()

ENSREG .... European Nuclear Safety Regulators Group

EPR .... European Pressurized Reactors

EU .... European Union

FK .... Release Category

FLA3 .... Flamanville Unit 3

GCTa .... Main turbine bypass system with venting to the atmosphere

GPR .... Permanent Group of Experts on Reactors

GW .... Giga Watt hour

HCTINS .... High Committee for Transparency and Information on Nuclear Safety

I-131 .... Iodine-131

IAEA .... International Atomic Energy Agency

INES .... International Nuclear and Radiological Event Scale

IPCC .... Intergovernmental Panel on Climate Change

IRSN .... Institut de Radioprotection et de Sûreté Nucléaire

LHP/LHQ .... Emergency power supply with 6.6 kV AC

LOCA .... Loss of Coolant Accident

LTO .... Long-Term Operation

mSv .... Millie-Sievert

MWe .... Mega Watt Electric

NPP .... Nuclear Power Plant

PGA .... Peak Ground Acceleration

PSR .... Periodic Safety Review

PSHA .... Probabilistic Safety Hazard Assessment

PSA .... Probabilistic Safety Assessment

PTR .... Tank of Water Treatment and Cooling System of Pools

PTR bis .... Mobile auxiliary cooling system for fuel element pools

PWR .... Pressurized Water Reactor

REA .... Boron and Water Storage Tank

RIA .... Reactivity Initiating Accidents

RIC .... Reactor Core Instrumentation

RCP .... Reactor Coolant Pump

RCS .... Reactor Cooling System

RFS .... Règle Fondamentale de Sûreté

RPN.................................... Reactor Protection System

RPV.................................... Reactor Pressure Vessel

SA .... Severe Accidents

SBO.................................... Station Black Out

SFP..................................... Spent Fuel Pool

SF-ND .... Hard-Core Cooling Source

SG .... Steam Generator

SGTR.................................. Steam generator tube ruptures

SIS .... Safety Injection Systems

SMHV................................. Maximal plausible historical earthquake (Séisme Majoré Historiquement Vraisemblable)

SMS .... Safe Shutdown Earthquake, Maximum safety earthquake, equivalent to design basis earthquake (Séisme Majoré de Sécurité)

SND .... Séisme Noyau Dur – Seismic level for the hardened safety core

SOTA.................................. State of the Art

SSCs................................... Structures, Systems and Components

TBq .... Tera-Becquerel, E12 Bq

TLD .... Température Longue Durée

TE....................................... Température Exceptionnelle

TTS..................................... Target Technical Specifications

UHS .... Ultimate Heat Sink

WENRA............................... Western European Nuclear Regulators´ Association

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