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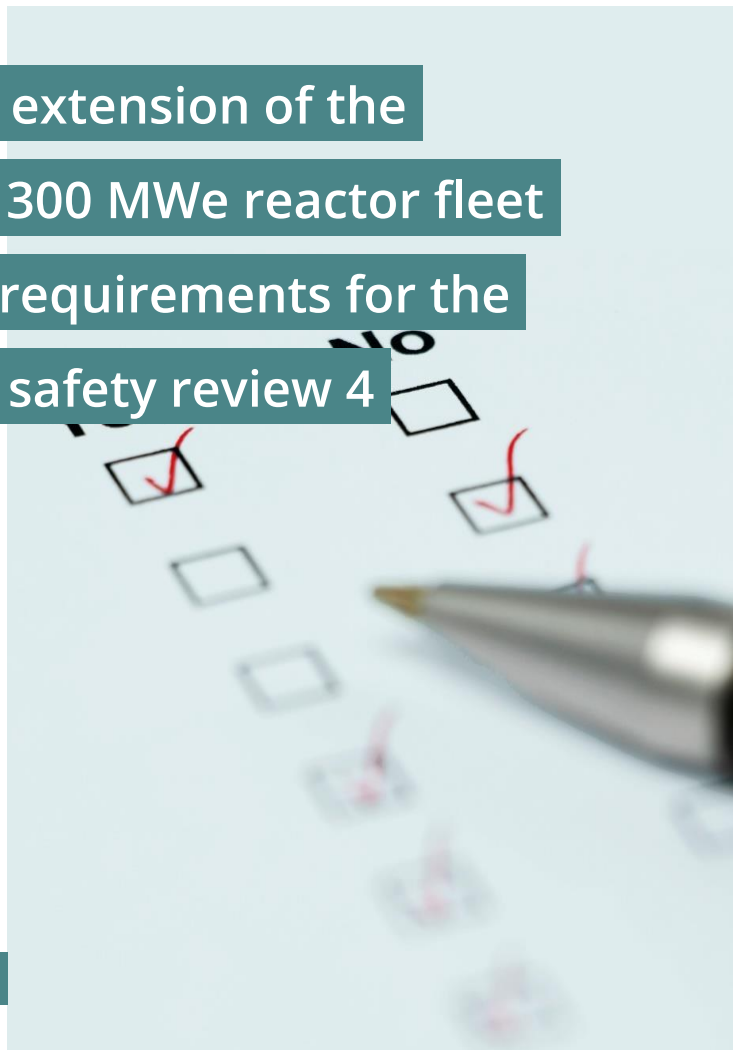
Lifetime extension of the French 1300 MWe reactor fleet

Generic requirements for the periodic safety review 4



Expert Report

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LIFETIME EXTENSION OF THE FRENCH 1300 MWE REACTOR FLEET GENERIC REQUIREMENTS FOR THE PERIODIC SAFETY REVIEW 4

Expert Report

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1 INTRODUCTION

In France, 56 nuclear power plants (NPPs) are in operation, including 20 1300 MWe reactors that will soon reach or have already reached 40 years of operation. A periodic safety review (PSR) must be carried out every ten years to ensure continued operation.

In 2024 the French High Committee for Transparency and Information on Nuclear Safety (HCTISN) organized a voluntary consultation on the generic phase of the PSR4 of the 1300 MWe reactors. In case of a severe accident in a French NPP, significant impacts on Austria cannot be excluded. Therefore, Austria participated in this consultation.

In July 2024, the Federal Environment Agency had coordinated the preparation of an expert statement (UMWELTBUNDESAMT 2024) on behalf of the Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology. The expert statement was submitted to the competent French authorities.

On 7 March 2025, the HCTISN submitted a document (HCTISN 2025) containing the responses of Électricité de France (EDF)) and l'Autorité de sûreté nucléaire et de radioprotection (ASNR) to the recommendations contained in the expert statement.

Additionally, in spring 2025 ASNR published a draft report (ASNR 2025) containing an analysis of the results of the generic phase of the fourth periodic review of EDF's 1300 MWe reactors, with a view to public consultation.

The present expert report lists the recommendations from the expert statement (UMWELTBUNDESAMT 2024) from June 2024 (*Recommendation (2024)*) in relation to the *ASNR draft position* (ASNR 2025) and summarises for each of the recommendations to what extent they are considered in the ASNR draft position paper. Based on this analysis, an evaluation as well as final recommendations are provided by the experts (*Evaluation and final recommendations*).

All final recommendations are summarised in a compact way in the final chapter of this report.

2 GENERAL RECOMMENDATIONS

2.1 Governance of the decision-making process

Recommendations (2024)

The governance of the decision-making process following the PSR4 should ensure that the absence of an alternative does not lead to an extension by fait accompli.
The decision-making process on the possible terms and conditions for extending operation must make it possible to guarantee safety independently of any consideration of EDF's industrial and financial capacity.

ASNR draft position

The draft report describes a two-level licence chain: after the generic phase, each reactor must undergo a site-specific review. Each review process includes a public consultation that may trigger extra regulations.
While ASNR acknowledges the industrial and financial limits of EDF, the process is sequenced into two phases, with high-value safety items having priority and coming first. Additionally, ASNR obliges EDF to publish annual progress reports that disclose both schedule status and industrial capacity, allowing ASNR to impose corrective actions if delays threaten safety.

Evaluation

Recommendations are taken into account.

2.2 Safety system's level P4/P'4 and EPR

Recommendations (2024)

The proposed change in safety requirements for 1300 MWe reactors through the PSR4 is substantial and should therefore be reflected in the regulatory provisions laid down in their authorisation decrees (Design Acceptance Confirmation DAC).
As the means introduced to achieve general objectives as close as possible to those of the EPR rely, by design and nature, on a very different defence in depth strategy, this difference should be explained and its implications elucidated.
In practice, the implementation of the general requirements results in numerous deviations (in design, rules, studies and compliance criteria). All these deviations and their implications should be explained.

ASNR draft position

Annex 2 of the draft report lists binding technical prescriptions that will be attached to the ASNR decision, thereby giving most PSR-4 obligations regulatory force, though they are not reflected in each reactor's original DAC. The report describes in great detail the defence-in-depth strategy and compares it with the EPR, clarifying both the differences and the residual shortfalls. Finally, it sets up a compliance mechanism (consisting of CONF-A, annual progress reports and ASNR inspections) to surface any deviations.

Evaluation

Recommendations are largely taken into account.

2.3 Evaluation and final recommendations of safety margins

Recommendations (2024)

The main safety margins from which reactors benefit in relation to the requirements applicable should be systematically identified, quantified where possible, and their use in the context of the PSR4 should be explained.

The safety margins that 1300 MWe reactors aim to achieve after extension in relation to the previously defined safety requirements should be compared with the margins that a newly built EPR-type reactor achieves in relation to comparable requirements.
When the safety margins relating to important parameters are reduced by identifiable or foreseeable phenomena, temporary or definitive shutdown criteria should be set in relation to a predefined threshold.

ASNR draft position

The draft report quantifies the main probabilistic and deterministic safety margins (for example a core-damage frequency of 2.6×10^{-6} / year and a mandated 5 % spare load on each emergency generator) and it compares these figures against the more demanding benchmarks of the Flamanville EPR, showing that the post-review 1300 MWe units come close to the risk objectives of the EPR standard.
However, pre-determined automatic shutdown criteria are not established, as the regulator has left itself full discretion over the consequences of a persistent margin loss.

Evaluation and final recommendation

Recommendations are partially taken into account. Stricter consequences for non-compliance with a deadline would be advisable.

2.4 Experience feedback

Recommendations (2024)

The extent and variety of the causes of non-compliance call for open and traceable processes to be put in place to monitor all the actions taken to examine compliance.
In view of the shortcomings revealed by the random examination approach, a (much more) exhaustive, controlled verification of all the items important to safety that are accessible to physical inspection should be considered as part of the PSR4.
The risk of non-compliance should be covered more comprehensively in the studies, by examining the consequences of the accumulation of non-compliances observed on the one hand, and by developing a method with regard to the risk of non-compliance on important elements not accessible to physical verification on the other.
Temporary or definitive shutdown criteria should be defined in advance in order to manage the detection of significant non-conformities, in a way that is proportionate to their consequences.

ASNR draft position

The issue of non-compliance is discussed in detail in the draft report. The planned actions by EDF consist of the following measures:

- Unit conformity examination
- Extended in situ verification
- System design reviews
- Additional specific tests

Evaluation and final recommendation

The experts consider the proposed handling of non-compliances as satisfactory. However, no shutdown criteria are defined, and the implementation of the measures can be postponed in case it is not possible to deal with the deviation in time. It would be advisable to implement stricter consequences in order to avoid delays.

2.5 Implementation of Post-Fukushima action plan

Recommendations (2024)

In view of the continuous slippage in the deadlines for carrying out studies and work, it is necessary to provide the review with a more precise and stricter framework of timetable obligations.
To ensure that all stakeholders and the public are properly informed, this framework should be accompanied by the introduction of a public scoreboard of the commitments made by the operator, which should, wherever possible, be the subject of instructions, and by monitoring of their implementation.
In order to avoid fait accompli situations where deadlines are not met, stricter technical criteria for information from the operator and justification of deadlines should be defined.
Temporary or permanent shutdown criteria could then be developed to deal with situations where there is an unjustified slippage in relation to these criteria for assessing the technical difficulties of meeting deadlines.

ASNR draft position

The draft report defines concrete deadlines for the different measures in Annex 2. Any measures related to the HSC should be implemented by the fourth refuelling outage after the fourth ten-yearly overhaul.
EDF is also obliged to submit and publish a detailed progress scoreboard every 30 June, to make the progress visible to the public.
Any found deviation must be fixed by EDF by the next ten-yearly outage or a dossier must be filed to justify any postponement. The deviations from the original timeline must also be reported in the annual report
However, no automatic temporary or permanent shutdown criteria are defined if deadlines are missed, leaving ultimate enforcement to the regulator's discretion.

Evaluation and final recommendation

Recommendations are partially taken into account. Stricter consequences for non-compliance with a deadline would be advisable.

2.6 Prestress losses in 1300 MWe containments

Recommendation (2024) To operate the 1300 MWe reactors beyond 40 years it is recommended to require an assessment of existing containment prestress levels.

ASNR draft position EDF has demonstrated the suitability of the containments for continued operation until the fifth ten-yearly inspection. This is based on both monitoring actions implemented in normal operation, in shutdown or during the ten-yearly test as well as on a reassessment of the mechanical behaviour of the containments in normal or accident situations, including data from experience feedback. In addition, monitoring linked to extensometric displacement measurements is used to monitor concrete creep phenomena.

Evaluation Recommendation is taken into account.

3 OPERATIONAL EXPERIENCE OF THE 1300 MWE REACTORS

3.1 Implement Hardened Safety Core and safety upgrades before start of lifetime extension (LTE)

Recommendation (2024) ASN should take measures to ensure that the necessary upgrades to improve the safety of the 1300 MWe reactors are carried out before the start of LTE. In particular, the "Hardened Safety Core" should be fully realised.

ASNR draft position The draft report defines that 'the operator shall implement all the other provisions of the hard core no later than the fourth scheduled maintenance and fuel renewal outage following the fourth ten-yearly outage inspection.'

Evaluation Recommendation is taken into account.

3.2 Reduce number of reportable incidents related to "safety culture"

Recommendation (2024) ASN should ensure that EDF acts in compliance with the "culture for safety" in order to reduce the number of such incidents in French NPPs.

ASNR draft position The draft report describes that ASNR has rejected EDF's initial goals regarding organisational and human factors (OHF) and demanded EDF to conduct a study programme to evaluate how the staff of the nuclear facilities copes with real-life operating situations.
However, ASNR will address the analyses conducted by EDF regarding OHF in a separate ASNR draft position that is unconnected to PSR4.

Evaluation and final recommendation Recommendation is partially taken into account. While the experts welcome the thorough studies conducted by EDF to identify and solve possible risk control issues, it is surprising that the issue is dealt with completely separated to the PSR4. As the establishment of a safety culture is an important aspect for a safe operation of a nuclear reactor, it would be advisable to also analyse this topic already as part of the requirements for the lifetime extension.

3.3 Perform root cause analysis for feed-in system damage events before LTE

Recommendation (2024) The root cause of safety-related damage in the safety feed-in system of French NPPs would have to be conclusively clarified before an LTE could be initiated.

ASNR draft position The draft report recognises that stress-corrosion cracking (SCC) in the safety-injection (RIS) piping is the proven damage mechanism. EDF has updated its ageing-analysis sheets accordingly and launched a multi-year programme of inspections, pipe replacements and further research. ASNR accepts the general strategy and has converted key actions into enforceable prescriptions such as [CONF-E], yet they also flag a number of open points. The full test-and-demonstration campaign that underpins long-term recirculation reliability will only be reviewed after 2025, with most work stretching out to 2026–2035.

Evaluation and final recommendation Recommendation is partially taken into account. The report identifies the root cause and puts corrective actions in motion, but the root-cause investigation should be completed before LTE decisions are taken.

3.4 Avoid corrosive environment for steam generator u-tubes

Recommendation (2024) The operation mode of 1300 MWe reactors should ensure that failure of more than one steam generator u-tube can be excluded.

ASNR draft position While EDF and ASNR have updated studies, operating procedures and hardware to keep margins for a single-tube rupture, the draft report never demonstrates (deterministically or probabilistically) that multiple u-tube failures can be excluded. Integrity improvements reduce the likelihood of defects, yet no explicit criterion is defined that would exclude a dual-tube (or worse) rupture scenario.

Evaluation Recommendation is not taken into account.

4 HAZARD ASSESSMENTS

4.1 Application of the requirements of the WENRA Safety Reference Levels in the PSR4

Recommendation (2024)

It is recommended to strictly apply the contents and requirements of WENRA Safety Reference Levels relevant to external hazards and the protection against such hazards in the PSR4, in particular Issues E, F and TU. Where there is room for interpretation of the rules, ASN should give preference to interpretations that result in higher levels of safety.

ASNR draft position

The draft report confirms that the hazard assessments now follow the 2014 / 2021 WENRA safety-reference levels, taking an exceedance probability of 10^{-4} per year as the design target
For each natural hazard, EDF has defined a "WENRA 2014" hazard and positioned it in relation to hazard levels adopted for the fourth review of the 1300 MWe reactors. Where these hazard levels are lower than the "WENRA 2014" hazard, EDF has studied the ability of the facilities to withstand significantly higher levels of stress. These studies sometimes conclude that modifications to the facilities are necessary.

Evaluation

Recommendation is largely taken into account. While the WENRA levels are not strictly applied, EDF links the internal hazard levels to the corresponding WENRA level and confirms the compliance accordingly.

4.2 Update the Guide for protection against external flooding

Recommendations (2024)

The ASN guide No. 13 for the protection against external flooding should be updated. The relevant WENRA documents developed after the Fukushima accident should be systematically taken into account (WENRA 2021; 2020c). Where possible, the determination of the phenomena should be based on scientific analysis rather than expert judgment. For relevant flooding events, exceedance probabilities of 10^{-4} should be assumed. In addition, extreme weather phenomena due to climate change should be adequately taken into account. These are, in particular, local heavy rainfall events.

ASNR draft position

As previously described, EDF considers now the 2014 / 2021 WENRA safety-reference levels, also for external floodings. To address issues related to climate change, a five-yearly “climate watch” was proposed. ASNR reinforces the scientific basis by asking for richer datasets and tighter statistical treatment of rainfall and other site-specific parameters.
However, two important gaps remain: ASN guide No. 13 itself has not been up-

dated and ASNR describes "difficulties in quantifying a ten-year exceedance frequency hazard for certain hazards, in particular those relating to high temperatures".

Recommendations are partially taken into account.

4.3 Development of a Guide on the protection against extreme weather events

Recommendations (2024) It is recommended to develop a guide on the protection of nuclear installations against extreme weather events that reflects the current scientific status and that must be applied within the framework of the PSR4 of the 1300 MWe NPPs. Climate change phenomena should be adequately addressed.

ASNR draft position EDF introduces a "climate watch", a five-yearly reassessment, together with a continuous monitoring of "major climatic events" (MCE) to address phenomena related to climate change such as extreme weather events.
However, the development of a dedicated guide on this topic is not foreseen.

Evaluation Recommendations are not taken into account.

4.4 Hazard screening including hazard combinations

Recommendation (2024) It is recommended to require for the PSR4 a demonstration that all hazards and combinations of hazard that apply to the individual 1300 MWe sites have been identified by comprehensive site-specific hazard screening. WENRA (2020a) provides a non-exhaustive, yet extensive, list of natural and human-made hazards to be used as a starting point for screening. DECKER & BRINKMAN (2017) provide detailed information on hazard combinations.

ASNR draft position The draft report confirms that EDF has re-screened every 1300 MWe site against the extended WENRA hazard list and updated each stress study accordingly. Site-specific hazards (such as Belleville's soft-soil seismic amplification or Cattenom's frazil risk) trigger tailored reinforcements or further studies.
Regarding hazard combinations, the report only mentions certain coupled scenarios (notably earthquake-induced flooding), yet the probabilistic and deterministic analyses still handle most threats individually.

Evaluation The requirement for exhaustive site-specific hazard screening is substantially taken into account, but the systematic demonstration that all significant combinations have been identified and assessed remains incomplete.

4.5 Definition of design basis events and protection against design basis events

Recommendations (2024)

It is recommended to require for the PSR4 (1) the definition of design basis events with occurrence probability of 10^{-4} per year in accordance with WENRA (2014; 2021) and (2) a demonstration that the fundamental safety functions of the reactors are conservatively ensured for the effects of these design basis event. The requirement should apply to all natural hazards for which the required probability can be calculated with sufficient accuracy, in particular to earthquake and external flooding.

ASNR draft position

PSR4 embeds the WENRA benchmark of a $\leq 10^{-4}\,yr^{-1}$ exceedance frequency into its hazard policy and obliges EDF to justify any shortfall.
Nonetheless, ASN concedes that a precise exceedance frequency quantification remains elusive for certain of hazards, where the hazard assessment relies on deterministic Evaluation and final recommendations instead.

Evaluation

Recommendations are taken into account.

4.6 Analysis and protection against external flooding

Recommendations (2024)

As part of the PSR4, studies to evaluate the hazard of external flooding should be updated for all sites. This is particularly important as the ASN Guideline No. 13 does not represent the state of the art.
Comprehensive inspection and maintenance of the Volumetric Protection (VP) should be carried out as part of the PSR4. Building's leak tightness should be inspected and maintained for walls, floors, joints, conduits, sumps and drainages related to potential flooding issues. Maintenance, with adequate frequency, planning, training and review, is important for flooding protection. At the very least, the monitoring and maintenance of the VP to ensure flood protection should be comprehensively regulated as part of the PSR4.

ASNR draft position

EDF has already re-assessed the external flooding studies for Paluel, Cattenom and Saint-Alban and will do the same “for the other sites [...] according to a timetable consistent with the first fourth ten-yearly inspection of each site”. However, the report sets no fleet-wide maintenance programme or periodic inspection rules for VP barriers; obligations are limited to isolated site-specific hardware upgrades. The outdated ASN Guideline No. 13 still remains the baseline for protection against external flooding and is not properly updated.

Evaluation and final recommendation

Recommendations are partially taken into account. Updating Guide No. 13 is strongly recommended to fully reflect the 2021 WENRA guidance and modern hydrological science.

4.7 Earthquake-induced flooding and seismic resistance of Volumetric Protection against external flooding

Recommendations (2024)

Earthquake induced flooding scenarios, which have an impact on safety should be thoroughly studied and relevant protection measures should be implemented as part of the PSR4.
In addition, other elements of the VP should be comprehensively checked. Since protection against extreme external flooding is essentially based on VP and, on the other hand, there have so far been considerable deficiencies in the implementation and analysis of the VP, extensive investigations and conformity tests should be required.

ASNR draft position

In the draft report, a dedicated subsection "Seismo-induced flooding" describes that EDF has re-evaluated the watertightness of inter-building joints under the differential displacements expected during the design-basis earthquake. The resulting studies "are currently being analysed by the ASNR." The generic hazard chapter confirms that this coupled (earthquake + flood) scenario was added to the list of external events to be reassessed during PSR4.
However, ASNR has not yet issued its conclusions and no fleet-wide hardware prescriptions are established. The report sets no fleet-wide maintenance programme or periodic inspection rules for VP barriers; obligations are limited to isolated site-specific hardware upgrades.

Evaluation and final recommendation

Recommendations are mainly taken into account – analysis is ongoing. It is recommended that the analysis by ASNR is completed before PSR4 to include the findings in the hazard assessment.

4.8 Protection against effects of extreme weather

Recommendation (2024)

It is recommended to require for the PSR4 that the selection of design basis events for extreme weather conditions complies with WENRA (2014; 2021) by (1) demonstrating that the selected event leads to a level of safety equivalent to WENRA target (occurrence probability of 10^{-4} per year) and (2) the design basis parameters are developed on a conservative basis.

ASNR draft position

The WENRA target of an occurrence probability of 10^{-4} per year is recognised by ASNR, and EDF is instructed to benchmark each selected hazard level against that target or, if the frequency cannot be calculated, to justify the plant's robustness to a more severe event.
In practice, certain hazards are still defined through deterministic estimations or 100-year return period data, because a statistical analysis does not lead to a reliable value.
The design basis parameters are chosen by deliberately adding numerical or analytical margins (wind-speed uplift, temperature headroom, aggravating factors).

Evaluation

Recommendation is taken into account.

4.9 Scope and timetable for re-assessing man-made hazards

Recommendations (2024)

The reassessment of man-made hazards as part of the PSR4 should be appropriate in scope and timeframe to the possible consequences. Inspections and resulting retrofits should be carried out during VD4. In addition, updated PSAs should also be carried out to determine the possible risks.

ASNR draft position

Section 5.2.7 of the draft report confirms that all air-crash and industrial-environment threats have been re-evaluated with updated traffic and accident data for every 1300 MWe site. ASNR has accepted EDF's upgraded methods, but notes that the detailed, site-specific studies will only be produced when each reactor enters its own VD4 process.
Hardware and organisational countermeasures are legally tied to VD4 through a two-phase schedule, with the fixes with the highest benefit scheduled for during the outage itself. Nonetheless, ASN flags that several retrofit designs are still incomplete, so some details (and therefore some deadlines) remain at risk.

Evaluation

As the detailed studies for man-made hazards are only produced as part of the site-specific phase of VD4, the topic cannot be evaluated in detail during the current generic phase. The recommendations are substantially addressed.

4.10 Update of Design Basis Earthquakes and seismic design basis parameters

Recommendations (2024)

It is recommended to define design basis earthquakes with exceedance frequencies not higher than 10^{-4} per year based on site-specific hazard assessments and an up-to-date PSHA methodology. Hazard curves should be calculated down to exceedance probabilities of 10^{-6} or beyond for DEC considerations and adequate considerations of seismic hazards in PSA. If the reassessments result in higher values for the design basis earthquakes, adequate retrofitting of SSCs important to safety would be required.

ASNR draft position

The report states that EDF and ASNR agree to keep the deterministic "SMS" spectrum from the 3rd review for calculating the seismic design basis parameter. While the WENRA reference level and the PSHA methodology are acknowledged, the design-basis spectrum itself is still deterministic and may fall above or below 10^{-4} depending on the site. The hazard curves are calculated based on a 20,000 year return period, which does not comply with exceedance probabilities down to 10^{-6}.
A binding timetable exists for retrofitting where higher hazards are found, as all hard-core seismic reinforcements need to be finished by the 4th post-VD4 outage.

Evaluation and final recommendation

Recommendations are not taken into account. It is strongly recommended to use the up-to-date PSHA methodology to evaluate seismic risks.

4.11 Use of active fault data and paleoseismological data in PSHA

Recommendations (2024) PSHA updates should meet the requirements and specifications of the WENRA Reference Levels (2021, Issue TU) and the WENRA guidelines relevant to earthquakes (WENRA 2020a; WENRA 2020b, p. 11-13, guidance on Issue TU3.3). For the PSR4 it should be generally required that site-specific PSHA be carried out taking into account data on active faults (fault location, fault kinematics, fault dimension, slip rate etc.) and using methods that capable of using fault models. It is recommended to define an obligatory and standardized workflow to assess faults located near the sites of the 1300 MWe reactors to reduce uncertainties. Particular attention should be paid to Pliocene and post-Pliocene faults listed in the French active fault database (BDFA). Investigations should focus on fault location (distance from site), fault dimension and segmentation (for estimating maximum magnitude), fault kinematics, fault slip rates (to constrain PSHA fault models), and paleoseismological trenching (timing and magnitude of prehistorical earthquakes).

ASNR draft position Based on the draft report, PSR4 keeps the historical deterministic SMS as the design-basis spectrum; probabilistic work is confined to an HCE anchored at a 20 000-year return period. A modern, fault-based PSHA down to the 10^{-6} / yr range envisaged by WENRA-TU3.3 is not foreseen, and the draft never refers to the French Active Fault Database or to paleoseismological trenching.

Evaluation Recommendations are not taken into account.

4.12 Protection against earthquake

Recommendations (2024) In addition to the inadequate earthquake analyses, the design of the 1300 Mwe reactors showed a number of weaknesses with regard to protection against a design basis earthquake (DBE) (e.g., the piping of the fire extinguishing system). Furthermore, significant deficits to the earthquake protection has already been identified during targeted investigations in some safety relevant components. (e.g., emergency diesel generator) It cannot be excluded that further deficits exist in other components or systems.
In order to prevent similar defects concerning the seismic protection, a comprehensive inspection of the entire safety systems would have to be carried out.

ASNR draft position The draft report sets up two complementary inspection programmes: the statutory unit compliance review (ECOT), which now includes seismic-protection items, and an “extended in-situ verification” that visually checks piping, anchors, supports and emergency-diesel auxiliaries across the key safety systems.
Known critical areas such as fixed fire-extinguishing piping are being re-qualified to the full design-basis earthquake. Any found weaknesses must be corrected under prescription [AGR-C].

Evaluation Recommendations are taken into account.

4.13 Design extension conditions

Recommendations (2024)

It is recommended to investigate whether the safety margins resulting from the design of the Hardened Safety Core for earthquakes with a return period of 20,000 years are sufficient and in line with the requirements of the WENRA Reference Levels for Design Extension Conditions (WENRA 2021, Issues F and TU). Depending on the results further reasonably practicable provisions could be identified and implemented.

ASNR draft position

As previously mentioned, the PSR4 uses an explicit "hard-core earthquake" spectrum. ASNR accepts this basis for most sites, but flags Belleville and Saint-Alban as possibly under-estimated; the regulator therefore requires EDF to analyse higher loads and reinforce if needed.
The draft report also provides mandatory prescriptions that make reinforcements compulsory for every reactor by the fourth refuelling outage after the VD4 inspection, with an earlier study milestone (end-2027) for the two sensitive sites.
However, it is not demonstrated that, after applying the HCE, the residual cliff-edge frequency fulfils WENRA-2021 Design-Extension objectives.

Evaluation and final recommendation

Recommendations are partially taken into account. It is recommended to use the WENRA directives as baseline for a probabilistic earthquake hazard analysis.

4.14 Update of the seismic ground motion values to be taken into account for the Hardened Safety Core (HSC)

Recommendation (2024)

It is recommended to base the probabilistic ground motion values taken into account for the design of the HSC on updated site-specific PSHAs.

ASNR draft position

The HSC spectrum is derived from probabilistic curves calculated individually for every reactor site. ASNR provisionally accepts this methodology, expect for two sites (Belleville, Saint-Alban), where it considers the hazard as potentially under-estimated, ordering supplementary studies and possible reinforcements.
The draft report provides no evidence that the underlying PSHAs incorporate the most recent active-fault data or new methodologies; for most sites the deterministic SMS from the previous review is simply "renewed" because "no significant change" was detected.

Evaluation and final recommendation

Recommendation is largely taken into account. The consideration of most recent PSHAs is recommended.

4.15 Robustness of existing SSCs of the HSC with respect to *earthquake*

Recommendations (2024) It is recommended to require demonstrating that the existing SSCs associated with the HSC are sufficiently qualified to resist the SND. Resistance should be demonstrated using standard design methods. Depending on the results measures should be identified to ensure the functionality of the SSCs during and after an SND.

ASNR draft position The draft report contains formal methodological guides that EDF must use to show every Hardened-Safety-Core structure, system and component can survive the design-basis earthquake (SND) and keep its safety function. ASNR accepts the overall method but requires periodic in-situ checks of supports and anchors to prove ongoing compliance.
If any shortfalls are found, prescription [AGR-C] obliges EDF to reinforce it no later than the fourth refuelling outage after the VD4 inspection.

Evaluation Recommendations are taken into account.

4.16 Mechanical design requirements for new SSCs of the HSC

Recommendations (2024) For all new HSC equipment, systematic checks of welds should be carried out in order to ensure that this equipment is highly robust to hazards. In addition, a test of all of the welds of the existing components belonging to the HSC should be carried out.

ASNR draft position The draft report does not mention a dedicated weld-inspection routine for the Hardened Safety Core. For new HSC equipment, ASNR states that the mechanical design rules are still under review, with no mention of systematic weld quality controls. For existing HSC equipment, ASNR requires a broad robustness verification, but does not explicitly mention weld examinations as a mandatory task.

Evaluation Recommendations are not taken into account.

4.17 Probabilistic analysis for external flooding

Recommendation A comprehensive PSA for external flooding should be conducted in accordance with WENRA (2014; 2021) and WENRA (2020c). Scenarios should not be excluded due to the lack of information. It is important to define appropriate requirements in the generic PSR4 in order to be able to adequately assess the site hazard in the context of the site-specific PSR.

ASNR draft position ASNR has embedded WENRA 2014/2021 principles in its generic hazard assessment request. The report states that "EDF decided to carry out probabilistic studies for certain sites on the risks associated with [...] external flooding", based on where the external hazard was considered to be plausible. A dedicated "no-exclusion" rule for data-poor scenarios is not explicitly mentioned.

Evaluation and final recommendation Recommendations are partially taken into account. A fleet-wide PSA for external flooding is advisable to take into account any site-specific effects.

4.18 Protection of the HSC against external flooding

Recommendations (2024) EDF should follow the recommendation by IRSN (2012) concerning the protection of the HSC against external flooding. In particular EDF should reassess the above mentioned issues. Most important, EDF should consider extending the safety margins for the protections of the HSC against external flooding.
As the availability of HSC installations is crucial for the management of an external flooding situation, the relevant installations should be reviewed as part of the PSR4 and training should take place. In addition, a regular review of the HSC should be established.

ASNR draft position The draft report states that the protection level for HSC equipment is raised to cover external floods that "exceed the previous baseline". Operator training is being conducted through a "core-operability" programme and the binding FOH-A milestones. A long-term review routine is not foreseen.

Evaluation Recommendations are largely taken into account.

4.19 Indirect effects of extreme weather events

Recommendations (2024) As part of the PSR4, biological hazards threatening cooling water inlets should be considered and assessed. The possible entry of neobiota should be investigated and, if necessary, measures for protection should be implemented.

ASNR draft position The fourth periodic review does recognise biological clogging of cooling-water intakes as a safety-relevant external hazard, considering it as "massive influx of clogging agents (AMC) which may come from fauna, flora, minerals or human sources". However, a possible entry of neobiota and the definition of standard are not included in the draft report.

Evaluation and final recommendation Recommendations are partially taken into account. An extension of the scope on neobiota is advisable.

4.20 Extreme external man-made hazards

Recommendations (2024)

The residual heat removal from the reactor core and the spent fuel pool should also be ensured in the event of a crash of a commercial airplane. All practical improvements for appropriate protection should be taken. The new need for protection resulting from the war situation in Ukraine in terms of weapons used and attack scenarios should also be considered.

ASNR draft position

The draft report mentions that the probability of a commercial aircraft crash was calculated. However, only the consequences of a crash of a general type aircraft (small civil aircraft weighing less than 5.7 tons) were explicitly examined. Consequently, no proof is offered that the core- or pool-cooling trains would withstand the higher loads of a jet-liner impact.
The report adds that ASNR "will take a position… on the acceptability of the risks associated with the fall of an aircraft" only during the site-specific phase of PSR4.
Additionally, the report does not mention any considerations of contemporary warfare threats (missiles, drones, and other weapons that are used in the war in Ukraine). For this extended range of man-made hazards, no broadened hazard spectra or design-extension analyses are presented.

Evaluation and final recommendation

Recommendations are not taken into account. The accident analysis of an aircraft crash should not be limited to a small civil aircraft.

5 RETROFIT TO STATE-OF-THE-ART

5.1 Planned provisions to terminate accidents with core melt at P4/P'4 reactors

Recommendation (2024)

The EPR has a system for the stabilization of the core melt (corium) to prevent failure of the containment in case of severe accidents. Retrofitting of an EPR type core catcher to the P4/P'4 reactors is not possible due to space limitations below the reactor pressure vessel. EDF is planning to retrofit other measures to stop accident progression in case of core melt accidents instead and claims that those provisions are similarly effective. However, they rely on a number of assumptions, including that the corium would spread on a large area and that the corium, once spread on the containment floor, could be effectively cooled by flooding with water from above. The OECD/NEA Project "Reduction of Severe Accident Uncertainties" ROSAU plays a crucial role in the demonstration of the effectiveness of the corium retention system for the 1300 MWe reactor fleet, but those R&D efforts (LICHT 2023) are still on-going and have not shown convincing results yet.
It is recommended to require full experimental proof and the demonstration of applicability before approving LTE.

ASNR draft position

The draft report recognises that the 1300 MWe fleet cannot be retrofitted with an EPR-type core-catcher and instead relies on a "spread-flood-cool" strategy using new EAS-ND circuits and engineered spreading surfaces.
ASNR concedes that the key cooling phenomena remain poorly characterised experimentally, especially for siliceous concretes, and that IRSN's latest calculations exceed EDF's erosion targets.
According to Annex 2 of the report, a general "specific test programme" must be defined by 31 Dec 2025 and all physical core tests have to be completed by 31 Dec 2026. All technical provisions must be installed by the fourth ten-yearly outage.

Evaluation and final recommendation

Recommendation is not taken into account. The experimental proof of concept and applicability remain open issues. The LTE should be permitted under the condition, that these issues are resolved in theory and after practical implementation, if possible.

5.2 Qualification of emergency diesel generators

Recommendation (2024)

For the 1300 MWe reactors only two EDGs fulfil the more rigorous requirements for level 3 safety systems, there is only a single redundancy, while this holds true for four EDGs of the EPR. While the EPR emergency diesel generators follow a n+3 redundancy concept, the P4/P'4 reactors follow a n+1 approach. It is recommended to try to elevate the safety level of the 1300 MWe fleet to the EPR

also at the level of design basis safety systems, or, in case this is not possible, clearly state the deltas and evaluate the resulting additional risk.

ASNR draft position The draft report retains the original two emergency diesel generators. While a last-resort diesel and hard-core electrical distribution improve resilience to beyond-design-basis events, they do not upgrade the design-basis redundancy to the four-diesel (n + 3) concept of the EPR.
The report recognises the ambition to come closer to EPR-level objectives, and the probabilistic studies quantify that overall core-melt risk is in the range of a few 10^{-6} per year, with electrical-source losses still dominant. However, it never spells out the exact shortfall compared to the EPR nor evaluates the risk reduction if EPR-level redundancy were adopted.

Evaluation Recommendation is not taken into account.

5.3 Design basis accidents – redundancy of safety systems

Recommendation (2024) It is recommended to retrofit additional safety systems and qualify them as design basis safety systems to elevate the P4/P'4 design closer to the EPR.

ASNR draft position The draft report makes it clear that 1300 MWe units still rely on two 100 % trains for design-basis accidents (e.g., only two EDGs). While the report mentions Hardened Safety Core and mobile (FARN) resources, these are explicitly classified outside the design-basis envelope. ASNR requires EDF to publish a dedicated report on the remaining safety differences with the EPR, including the "number of safety systems". EDF states that closing this gap "would make the installation much more complex and could lead to technical infeasibilities."
The report does not propose the addition of permanently installed, seismically qualified trains that would bring redundancy up to the level of the EPR, and no design-basis retrofits are mandated.

Evaluation Recommendation is not taken into account.

5.4 Consideration of FARN in the safety Evaluation and final recommendations of P4/P'4 reactors

Recommendation (2024) Non-permanent measures such as the implementation of FARN are covered in IAEA Safety Standard SSG-88. One aspect is that mobile equipment should not be relevant in the short-term phase of design basis and design extension conditions. It is therefore recommended to not credit FARN equipment when comparing the safety level of 1300MWe reactors with state of the art (EPR).

ASNR draft position The draft report repeatedly integrates FARN mobile equipment into the safety demonstration and into the comparison with the EPR. ASNR explicitly states that "the implementation of an ultimate provision for the evacuation of residual power outside [...] relies in part on mobile resources provided by the FARN".

Evaluation Recommendation is not taken into account.

5.5 State of the art consideration of aircraft crash

Recommendations (2024) It is recommended to elevate the P4/P'4 level of protection against aircraft crash to the EPR level, which would include the same assumption on load cases and require the same method of analysis. In case this is considered to be not feasible, it is recommended to point out this gap in the safety level to the EPR and evaluate the resulting risks in a risk report.

ASNR draft position The draft report shows that air-crash protection for the 1300 MWe fleet is evaluated using a probabilistic approach, the only deterministic analysis concerns a general-aviation aircraft hitting the fuel-building pool. Neither the commercial-aircraft load cases analysed for EPR nor the associated finite-element impact analyses are applied. The report does quantify the resulting shortfall in barrier strength relative to the EPR, nor does it offer an assessment of the additional core-damage frequency or containment-failure risk.

Evaluation Recommendations are not taken into account.

5.6 Design basis protection and giving credit for HSC/FARN

Recommendations (2024) It is recommended to address deficits in dealing with the design-based earthquake for the 1300 MWe reactor fleet by retrofitting and to also seismically harden the LLS and the TAC. It is recommended to enhance the safety level of the P4/P'4 fleet beyond providing HSC systems and FARN.

ASNR draft position The draft report shows that EDF and ASNR have reassessed seismic hazard and renewed the design-basis spectra. It states that, if necessary, "certain SND equipment will be reinforced during phase B of the modifications" and that additional measures are needed at Belleville and Saint-Alban, where hazard underestimation is suspected.
Beyond this generic commitment, the text contains no trace of the specific systems to be seismically upgraded. The report also presents the HSC and the FARN mobile force as the main – and arguably sufficient – solutions for design-extension earthquakes, without proposing additional fixed or redundant systems to enhance safety.

Evaluation Recommendation are not taken into account.

5.7 Spent fuel pool cooling/emergency cooling systems

Recommendation (2024)

It is recommended to retrofit spent fuel pool cooling systems/emergency cooling systems to match the degree of redundancy and diversity of the EPR spent fuel pool cooling systems and strengthen the structures which are housing the spent fuel pool to the level of the EPR containment.

ASNR draft position

The draft report introduces two different cooling systems. SEG-ND is entirely fixed, but PTRbis depends on FARN mobile equipment, which makes it not redundant by design. Prescription [PISC-A/B/C] forces these systems to be installed and operable by the fourth post-VD4 outage.
Regarding the housing of the spent fuel pool, the report sets no requirement to thicken or reinforce the entire building to the level of an EPR containment standard.

Evaluation

Recommendation is not taken into account. The proposed diversification of the cooling system is an improvement, yet still below the safety level of EPR.

6 FINAL RECOMMENDATIONS

6.1 General Recommendations

- **Evaluation and final recommendations of safety margins:**
  It is recommended to set temporary or definitive shutdown criteria in relation to a predefined threshold when the safety margins relating to important parameters are reduced.
- **Experience feedback:**
  It is recommended to define in advance temporary or definitive shutdown criteria in order to manage the detection of significant non-conformities, in a way that is proportionate to their consequences. It would be advisable to implement stricter consequences in order to avoid delays.
- **Implementation of Post-Fukushima action plan:**
  It is recommended to develop temporary or permanent shutdown criteria to deal with situations where there is an unjustified slippage in relation to the criteria for assessing the technical difficulties of meeting deadlines.

6.2 Operational Experience of the 1300 MWe Reactors

- **Reduce number of reportable incidents related to “safety culture”:**
  ASNR should ensure that EDF acts in compliance with the "culture for safety" in order to reduce the number of such incidents in French NPPs. It is recommended that the issues are analysed as part of the requirements for the lifetime extension, as the establishment of a safety culture is an important aspect for a safe operation of a nuclear reactor.
- **Perform root cause analysis for feed-in system damage events before LTE:**
  It is recommended that the root cause analysis of safety-related damage in the safety feed-in system of French NPPs (stress-corrosion cracking (SCC) in the safety-injection (RIS) piping) is completed before LTE decisions are taken.
- **Avoid corrosive environment for steam generator u-tubes:**
  The operation mode of 1300 MWe reactors should ensure that failure of more than one steam generator u-tube can be excluded.

6.3 Hazard assessments

- **Update the Guide for protection against external flooding:**
  It is recommended to update the ASN guide No. 13 for the protection against external flooding to fully reflect the 2021 WENRA guidance and modern hydrological science.
- **Development of a Guide on the protection against extreme weather events:**
  It is recommended to develop a guide on the protection of nuclear installations against extreme weather events that reflects the current scientific status and that must be applied within the framework of the PSR4 of the

1300 MWe NPPs. Climate change phenomena should be adequately addressed.

- **Hazard screening including hazard combinations:**
  It is recommended to demonstrate that all significant hazard combinations have been identified and assessed properly.
- **Earthquake-induced flooding and seismic resistance of Volumetric Protection against external flooding:**
  It is recommended that the analysis by ASNR of the studies regarding seismo-induced floodings is completed before PSR4 to include the findings in the hazard assessment.
- **Update of Design Basis Earthquakes and seismic design basis parameters:**
  It is recommended to define design basis earthquakes with exceedance frequencies not higher than 10^{-4} per year based on site-specific hazard assessments and an up-to-date PSHA methodology. Hazard curves should be calculated down to exceedance probabilities of 10-6 or beyond for DEC considerations and adequate considerations of seismic hazards in PSA.
- **Use of active fault data and paleoseismological data in PSHA:**
  PSHA updates should meet the requirements and specifications of the WENRA Reference Levels (2021, Issue TU) and the WENRA guidelines relevant to earthquakes (WENRA 2020a; WENRA 2020b, p. 11-13, guidance on Issue TU3.3). For the PSR4 it should be generally required that site-specific PSHA be carried out taking into account data on active faults (fault location, fault kinematics, fault dimension, slip rate etc.) and using methods that capable of using fault models. It is recommended to define an obligatory and standardized workflow to assess faults located near the sites of the 1300 MWe reactors to reduce uncertainties. Particular attention should be paid to Pliocene and post-Pliocene faults listed in the French active fault database (BDFA). Investigations should focus on fault location (distance from site), fault dimension and segmentation (for estimating maximum magnitude), fault kinematics, fault slip rates (to constrain PSHA fault models), and paleoseismological trenching (timing and magnitude of prehistorical earthquakes).
- **Design extension conditions:**
  It is recommended to use the WENRA directives as baseline for a probabilistic earthquake hazard analysis.
- **Mechanical design requirements for new SSCs of the HSC:**
- For all new HSC equipment, systematic checks of welds should be carried out in order to ensure that this equipment is highly robust to hazards. In addition, a test of all of the welds of the existing components belonging to the HSC should be carried out.
- **Probabilistic analysis for external flooding:**
  A fleet-wide comprehensive PSA for external flooding should be conducted in accordance with WENRA (2014; 2021) and WENRA (2020c) to take into account any site-specific effects. Scenarios should not be excluded due to the lack of information.

- **Indirect effects of extreme weather events:**
  As part of the PSR4, the possible entry of neobiota into cooling water inlets should be assessed and, if necessary, measures for protection should be implemented.
- **Extreme external man-made hazards:**
  The residual heat removal from the reactor core and the spent fuel pool should also be ensured in the event of a crash of a commercial airplane. All practical improvements for appropriate protection should be taken. The new need for protection resulting from the war situation in Ukraine in terms of weapons used and attack scenarios should also be considered.

6.4 Retrofit to the State-of-the-Art

- **Planned provisions to terminate accidents with core melt at P4/P'4 reactors:**
  The EPR has a system for the stabilization of the core melt (corium) to prevent failure of the containment in case of severe accidents. EDF is planning to retrofit other measures to stop accident progression in case of core melt accidents instead and claims that those provisions are similarly effective. However, they rely on a number of assumptions, including that the corium would spread on a large area and that the corium, once spread on the containment floor, could be effectively cooled by flooding with water from above.
  It is recommended to require full experimental proof and the demonstration of applicability before approving LTE.
- **Qualification of emergency diesel generators:**
  For the 1300 MWe reactors only two EDGs fulfil the more rigorous requirements for level 3 safety systems, there is only a single redundancy, while this holds true for four EDGs of the EPR. While the EPR emergency diesel generators follow a n+3 redundancy concept, the P4/P'4 reactors follow a n+1 approach. It is recommended to try to elevate the safety level of the 1300 MWe fleet to the EPR also at the level of design basis safety systems, or, in case this is not possible, clearly state the deltas and evaluate the resulting additional risk.
- **Design basis accidents – redundancy of safety systems:**
  It is recommended to retrofit additional safety systems and qualify them as design basis safety systems to elevate the P4/P'4 design closer to the EPR.
- **Consideration of FARN in the safety Evaluation and final recommendations of P4/P'4 reactors:**
  Non-permanent measures such as the implementation of FARN are covered in IAEA Safety Standard SSG-88. One aspect is that mobile equipment should not be relevant in the short-term phase of design basis and design extension conditions. It is therefore recommended to not credit FARN equipment when comparing the safety level of 1300MWe reactors with state of the art (EPR).
- **State of the art consideration of aircraft crash:**
  It is recommended to elevate the P4/P'4 level of protection against aircraft

crash to the EPR level, which would include the same assumption on load cases and require the same method of analysis. In case this is considered to be not feasible, it is recommended to point out this gap in the safety level to the EPR and evaluate the resulting risks in a risk report.

- **Design basis protection and giving credit for HSC/FARN:**
  It is recommended to address deficits in dealing with the design-based earthquake for the 1300 MWe reactor fleet by retrofitting and to also seismically harden the LLS and the TAC. It is recommended to enhance the safety level of the P4/P'4 fleet beyond providing HSC systems and FARN.
- **Spent fuel pool cooling/emergency cooling systems:**
  It is recommended to retrofit spent fuel pool cooling systems/emergency cooling systems to match the degree of redundancy and diversity of the EPR spent fuel pool cooling systems and strengthen the structures which are housing the spent fuel pool to the level of the EPR containment.

7 REFERENCES

ASN (2012a): ASN 2012: Complementary Safety Assessments Follow-up of the French Nuclear Power Plants Stresstests, National Action Plan of the French Nuclear Safety Authority, December 2012.

ASN (2013a): ASN 2013a: Lettre ASN CODEP-DCN-2013-013464 du 28 juin 2013 relative au programme générique proposé par EDF pour la poursuite de fonctionnement des réacteurs en exploitation au-delà de leur quatrième réexamen de sûreté

ASN (2013g): Protection of Basic Nuclear Installations Against External Flooding - GUIDE N° 13; Version of 08/01/2013

ASN (2014): TECHNICAL GUIDELINES FOR THE DESIGN AND CONSTRUCTION OF THE NEXT GENERATION OF NUCLEAR POWER PLANTS WITH PRESSURIZED WATER REACTORS. Published on 28/02/2014.

ASN (2016): CODEP-DCN-2016-016677. Réacteurs électronucléaires – EDF Agressions externes extrêmes à prendre en compte pour la mise en place du «noyau dur». Montrouge, le 19 juillet 2016

ASN (2018): CODEP-DCN-2018-002381. Centrales nucléaires de Saint-Alban, Tricastin et Fessenheim. Séisme extrême à prendre en compte pour la mise en place du «noyau dur». 8 février 2018.

ASN (2019a): Orientations de la phase générique du quatrième réexamen périodique des réacteurs de 1300 MWe d'EDF (RP4-1300). Letter from ASN to EDF from 11 Dec 2019. Réf.: CODEP-DCN-2019-009228.

ASN (2019b): RAPPORT DE L'ASN sur l'état de la sûreté nucléaire et de la radioprotection en France en 2019.

ASN (2020): LES APPRÉCIATIONS DE L'ASN PAR EXPLOITANT, Les centrales nucléaires en fonctionnement, Rapport de l'ASN sur l'état de la sûreté nucléaire et de la radioprotection en France en 2020.

ASN (2020a) Flamanville, Paluel, Belleville, Nogent and Penly nuclear power plants: ASN rates a significant safety event affecting the emergency diesel generator sets at level 2 on the INES scale, Information notice 13/02/2020; https://www.french-nuclear-safety.fr/asn-informs/news-releases/significant-safety-event-affecting-the-emergency-diesel-generator-sets-at-level-2-on-the-ines-scale

ASN (2022b): Contrôle des installations nucléaires de base (INB); Lettre de suite de l'inspection du 26 octobre 2022 sur le thème des améliorations de sûreté post-Fukushima; N° dossier : Inspection n° INSSN-LYO-2022-0524; Référence courrier : CODEP-LYO-2022-060936; Lyon, le 13 décembre 2022

ASN (2022c): Contrôle des installations nucléaires de base, CNPE de Flamanville, INB 108 et 109; Inspection n° INSSN-CAE-2022-0150 du 13 juillet 2022 sur le thème des améliorations de sûreté Post-Fukushima; N° dossier : Inspection n° INSSN-CAE-2022-0150 À Caen, le 9 aout 2022

ASN (2024a): RÉACTEURS NUCLÉAIRES DE 1300 MWE. Fonctionnement au-delà de 40 ans : les enjeux du 4e réexamen périodique. Les cahiers de l'ASN #4, Janvier 2024.

ASNR (2025): 4e RÉEXAMEN PÉRIODIQUE DES RÉACTEURS DE 1300 MWe D'EDF. Bilan de la phase générique. Rapport CODEP-DCN-2025-022156. https://www.asnr.fr/actualites/consultation-du-public-sur-le-projet-de-decision-de-lasnr-relative-la-poursuite-de

BAIZE, S., CUSHING, E. M. ET AL. (2002): Inventaire des indices de rupture affectant 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.

BECKER et al. (2020): The impacts of climate change on nuclear risk and supply security. Working Paper; Oda Becker, Eszter Matyas, Patricia Lorenz. 26 June 2020

CHARTIER, T., SCOTTI, O., CLÉMENT, C., JOMARD, H. & BAIZE, S. (2017): Trans-posing an active fault database into a fault-based seismic hazard assessment for nuclear facilities - Part 2: Impact of fault parameter uncertainties on a site-specific PSHA exercise in the Upper Rhine Graben, eastern France. Nat. Hazards Earth Syst. Sci., 17: 1585-1593.

CLÉMENT C., BONILLA L.F., SCOTTI O. & BAIZE S. (2004a): Site-specific probabilistic seismic hazard study for the Tricastin nuclear power plant, France. In: Proc. XXXIX General Assembly ESC, Potsdam, Germany, pp. 186.

CLÉMENT C., SCOTTI O., BONILLA L.F., BAIZE S. & BEAUVAL C. (2004b): Zoning versus faulting models in PSHA for moderate seismicity regions: preliminary results for the Tricastin nuclear site, France. Bollettino di Geofisica Teorica ed Applicata, 45: 187-204.

DECKER, K. & BRINKMAN, H. (2017): List of external hazards to be considered in ASAMPSA_E. Technical report ASAMPSA_E / WP21 / D21.2 / 2017-41, 51 pp.

DUROUCHOUX, C., LABBE, P. & TRAVERSA, P. (2014). I-5/1 Post-Fukushima French Seismic Hazard Assessment. 9th Nuclear Plant Current Issues Symposium, Charlotte, North Carolina, USA.

EDF (2017): Dossier d'Orientation du Réexamen Périodique VD4 1300. Document issu de la GED DPI Nucléaire le 12/07/2017. https://www.asn.fr/content/download/167479/file/dossier%2520EDF%2520orientations%2520g%25C3%25A9n%25C3%25A9riques%2520RP%25204%25201%2520300%2520MWe.pdf&ved=2ahUKEwjOqumk1MGGAxXaQvEDHY2mCYYQFnoECBQQAQ&usg=AOvVaw2q7zAN6P8GAiabGBH8gUw-.

EDF (2023a): Note de Réponse aux Objectifs du 4ème Réexamen Périodique du Palier 1300 MWe. https://concertation.suretenucleaire.fr/media/default/0001/01/abcb9641947b78e6ad2c1100f554d7eaab3e5c3e.pdf.

EDF (2023b): 4th Periodic Safety Review of the 1300 MWe Reactor Fllet. Summarised version of the Fulfilment Report. https://concertation.suretenucleaire.fr/media/default/0001/01/aa96ecad52f0dfc96f66debe95f9936c7ab9a893.pdf.

EDF (2023c): 4e Réexamen Périodique des Centrales 1300 MWe. Synthèse de la note de réponse aux objectifs. https://concertation.suretenucleaire.fr/media/default/0001/01/6d2c36bb296d68e1d5e0438bc3fe0ccac7975dbb.pdf.

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

EUR (1996): C.J. Ablott, S. Bouabdallah and S. Simm: The key issues in transient analysis calculations which affect the radiological consequences following design-basis steam generator tube rupture accidents. European Commission, nuclear science and technology: Office for Official Publications of the European Communities.

HCTISN (2025): Document de réponse. https://www.umweltbundesamt.at/fileadmin/site/themen/energie/kernenergie/verfahren/frankreich/1300mw_vd4/hctisn_document_de_reponses_ministere_autrichien.pdf

IRSN (2012): Definition of a post-Fukushima hard core for EDF's REPs: objectives, content and associated requirements. (Définition d'un noyau dur post-Fukushima pour les REP d'EDF : objectifs, contenu et exigences associées RAPPORT IRSN N°2012-009I) Réunion des Groupes permanents d'experts pour les réacteurs nucléaires du 13 décembre 2012 IRSN Report N°2012-009; 2012.

IRSN (2022a) : Avis IRSN n°2022-00035. EDF - Réacteur de 1300 MWe - Référentiel «Accidents graves» applicable au quatrième réexamen périodique. Objectifs généraux - Fonctions nécessaires en accident grave et exigences associées aux équipements assurant ces fonctions. To Monsieur le Président de l'ASN, 18 février 2022.

IRSN (2023c) : Avis IRSN n°2023-00066. Réacteurs électronucléaires d'EDF de 1300 MWe – RP4 1300 – Instruction anticipée portant sur le noyau dur post-Fukushima. To Monsieur le Président de l'ASN, 12 mai 2023.

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

LICHT, Jeremy (2023): NEA NUCLEAR SAFETY RESEARCH JOINT PROJECTS WEEK: Success Stories and Opportunities for Future Developments, Seassion 4, Joint Projects for Safety in Accidental Situations, Learnings and Perspectives, ROSAU, 9- 13 January 2023.

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

PISTNER et al. (2018): Sicherheitsdefizite des AKW Cattenom. Pistner, C., Sailer, M., Mohr, S., Küppers, C. Im Auftrag der Bundesländer Rheinland-Pfalz und Saarland, Öko-Institut Darmstadt

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.

SCOTTI, O., CLEMENT, C & BAUMONT, D. (2014): Seismic hazard for design and verification of nuclear installations in France: regulatory context, debated issues and ongoing developments. Bollettino di Geofisica Teorica ed Applicata, 55/1: 135-148.

STANDING GROUP OF EXPERTS (2019): Guidance for the generic phase of the fourth periodic reviews of nuclear reactors 1300 MWe from EDF. CODEP-DCN-2019-017737, Session of May 22, 2019.

UMWELTBUNDESAMT (2019a): Becker, O.; Giersch, M.; Meister, F.; Mertins, M.; Weimann, G.: Review of the 900 MWe reactor fleet (VD4-900). Expert ASNR draft position 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 BMK, Abt. VI/9 Allgemeine Koordination von Nuklearangelegenheiten, REP-0764, Wien.

UMWELTBUNDESAMT (2024). Becker, O.; Decker, K.; Drapalik, M.; 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.

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 Seismic Events. 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/.

8 GLOSSARY

ASG	Steam Generator Emergency Feedwater System
ASN	French Nuclear Safety Authority
BDFA	French active fault database
CAV	Cumulative Average Velocity
DAC	Design Acceptance Confirmation
DBE	Design Basis Earthquakes
DBF	Design Basis Flood
DEC	Design Extension Conditions
DUS	Ultimate Backup Diesel Generators
EDF	Electricité de France
ENSREG	European Nuclear Safety Regulators Group
EPR	European Pressurised Reactors
EUR	European Utility Requirements
FARN	Nuclear rapid intervention force
G	Ground acceleration expressed as a fraction of the acceleration of gravity of 9.81 m/s²
GPE	Advisory Board of Experts for ANS
HCTISN	High Committee for Transparency and Information on Nuclear Safety
HSC	Hardened Safety Core, in French: Noyau Dur
IAEA	International Atomic Energy Agency
INES	International Nuclear Event Scale
IRSN	Institute for Radiation Protection and Nuclear Safety
LLS	Emergency electricity system
LTE	Lifetime extension
LTO	Long Term Operation
MWe	MegaWatt electric
ND	Noyau Dur, in English: Hardened Safety Core
NPP	Nuclear Power Plant

NRO	Note de réponse aux objectifs”
PSA	Probabilistic safety analyses
PSHA	Probabilistic Seismic Hazard Assessment
PSR	Periodic Safety Review
ROSAU	Reduction of Severe Accident Uncertainties
SEG	Ultimate Heat Sink
SIS	Safety Injection System
SND	Séisme Noyau Dur, design basis earthquake for the HSC
SRL	Safety Reference Level
SSC	Structures, systems and components
TAC	Emergency electricity system on level 4
VD4	Visites décennales, ten-year-visits, no 4
VP	Volumetric protection
WENRA	Western European Nuclear Regulators´ Association

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