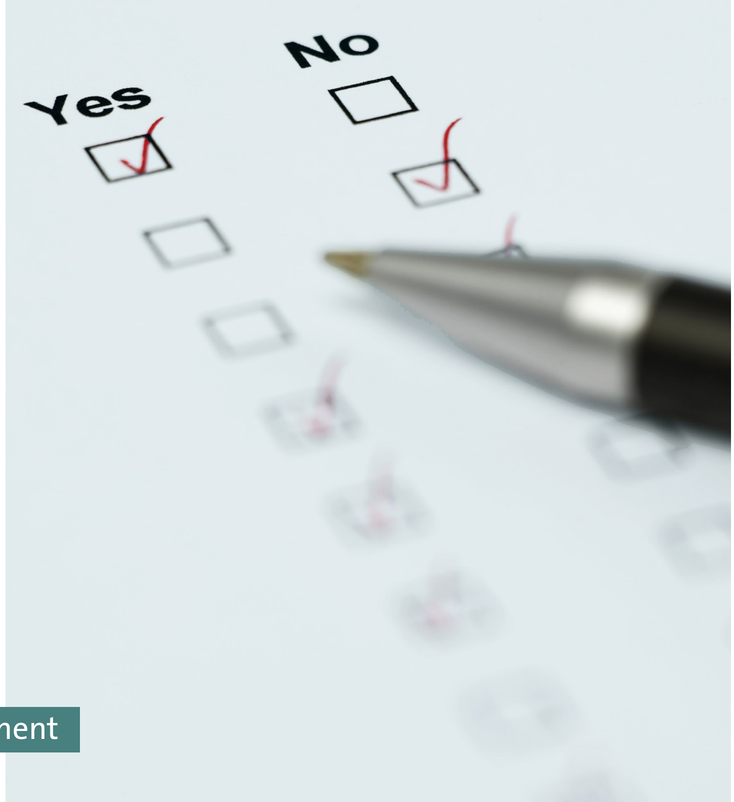
PERSPEKTIVEN FÜR UMWELT & GESELLSCHAFT umweltbundesamt

Rivne 1&2 Lifetime Extension

Environmental Impact Assessment



Expert Statement

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pulswerk
Das Beratungsunternehmen des
Österreichischen Ökologie-Instituts

ENVIRONMENT AGENCY AUSTRIA umweltbundesamt

RIVNE 1&2 LIFETIME EXTENSION ENVIRONMENTAL IMPACT ASSESSMENT

Expert Statement

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Commissioned by
Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology,
Directorate VI/9 General Coordination of Nuclear Affairs
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Federal Ministry
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SUMMARY

Ukraine is conducting an Environmental Impact Assessment (EIA) for the lifetime extension of the reactors Rivne 1&2 under the Espoo Convention. The nuclear power plant Rivne is located near the town of Varash in the Rivne Oblast. At the Rivne site, four reactors are in operation. Rivne 1&2 are the oldest of these reactors, they were connected to the grid in 1980 and 1981, respectively.

Austria has been notified by Ukraine and decided to participate in the EIA. The Austrian Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology commissioned the Environment Agency Austria to provide the expert statement at hand which assesses the submitted EIA Document. The objective of the Austrian participation in the EIA procedure is to minimise or even eliminate possible significant adverse impacts on Austria which might result from this project.

Overall and procedural aspects of the Environmental Impact Assessment

The original license has been issued for 30 years and was prolonged in 2010 until December 2030. The project of the lifetime extension of Rivne 1&2 is violating the Espoo Convention because the Environmental Impact Assessment has not been conducted in 2010. The “EIA/IC/CI/4 Ukraine” case under the Espoo Convention started in 2011 and is still open. Ukraine was asked to conduct an EIA before 2020. In December 2020, the Meeting of the Parties to the Espoo Convention asked Ukraine to revise its final decision on the lifetime extension of Rivne 1&2, taking due account of the outcomes of the now ongoing EIA procedure. This ongoing case under the Espoo procedure shows that it is not clear if and how the results of the ongoing EIA procedure will be taken into account by the Ukrainian side. Furthermore, the next steps of the licensing procedure are not clear.

According to the Espoo Convention a description and an assessment of reasonable alternatives and also the no-action alternative have to be included in the Environmental Impact Assessment Documentation. In this regard the EIA Documentation is not sufficient.

On 16 December 2020, the State Nuclear Regulatory Inspectorate of Ukraine SNRIU already decided upon amendment of the EO 000943 series license for Rivne 1 until 22 December 2030. But the Espoo Implementation Committee had recommended to conduct and finalise the EIA before the next Periodic Safety Review (PSR) in 2020 was finished, that would have been before the license was prolonged.

Spent fuel and radioactive waste

The EIA Document lacks important information on the management of the spent fuel and radioactive waste from Rivne 1&2. The expected inventory of spent fuel and radioactive waste resulting from the lifetime extension is not given.

Information on the status of the central interim storage where the spent fuel from Rivne 1&2 shall be stored (CSFSF) was not provided. The final repository of spent fuel and high level waste, where also the vitrified HLW from reprocessing in Mayak/Russian Federation will be stored, remains unclear.

Spent fuel and radioactive waste can cause adverse environmental impacts and therefore it will be welcomed if the Ukrainian side provides more information on its national nuclear waste management plan.

Long-term operation of reactor type VVER 440

Although ageing of the 40 years old structures, buildings and equipment is a safety issue for Rivne 1&2, it is not addressed in the EIA Document. It only refers to "Structures, systems and components aging" being a safety factor (SF) within the periodic safety review (PSR). The adverse effect of ageing depends also on the inspection, restoration and protection measures taken. A comprehensive ageing management program (AMP) is necessary to limit ageing-related failures at least to a certain degree. However, information of an ageing management programme (AMP) is also not provided in the EIA Document.

Ukraine participated in the Topical Peer Review (TPR) “Ageing Management” in the framework of the implementation of the Nuclear Safety Directive 2014/87/EURATOM, carried out in 2017/18. Several “areas for improvement” were identified, i.e. deviation of the TPR expected level of performance for ageing management that should be reached to ensure consistent and acceptable management of ageing throughout Europe. The results of the TPR and the activities to remedy the weaknesses should be presented in the EIA Document, in particular the very important safety issue of the RPV embrittlement should be discussed.

Although conceptual ageing is also an issue for the Rivne 1&2, the EIA Document does not deal with any of the known safety issues of the VVER-440/V213 reactors. VVER 440/V213 units have several design weaknesses: the reactor building and the spent fuel pool building are relatively vulnerable against external events. VVER-440 reactors are designed as twin units, sharing many operating systems and safety systems. The sharing of safety systems increases the risk of common-cause failures affecting the safety of both reactors at the same time.

This NPP design developed in the 1980s, only partly meets modern design principles such as redundancy, diversity and physical separation of redundant subsystems or the preference for passive safety systems. The EIA Document neither provides a description of the safety-relevant systems, nor information about the capacities, redundancies and physical separation.

In December 2010, although safety relevant issues are not completely solved, the State Nuclear Regulatory Inspectorate of Ukraine (SNRIU) granted 20-year lifetime extensions for Rivne 1&2. The stress tests revealed 2011 that Ukrainian NPPs are compliant only with 172 of the 194 requirements according to the IAEA Design Safety Standards published in 2000[1]. Implementation of necessary improvements is on-going under the Upgrade Package. This includes the Comprehensive (Integrated) Safety Improvement Program (C(I)SIP). The completion of

[1] Under the framework of joint IAEA-EC-Ukraine projects a design evaluation was carried out to conduct an overall evaluation of the compliance of the Ukrainian NPPs design with the IAEA Safety Standards “Safety of Nuclear Power Plants: Design” (NS-R-1) published in 2000.Meanwhile, even this IAEA document is outdated; in January 2012 new safety requirements were published by IAEA (2012).

the program was postponed several times. Completion is now scheduled for 2023.

SNRIU participates in the Western European Nuclear Regulators Association (WENRA) activities as an observer since 2009. In 2014, WENRA published a revised version of the Safety Reference Levels (RLs) for existing reactors developed by the Reactor Harmonisation Working Group (RHWG). The objective of the revision was to take into account lessons learned of the TEPCO Fukushima Daiichi accident. A major update of the RLs was the revision of Issue F "Design Extension of Existing Reactors" introducing the concept of Design Extension Conditions (DEC). However, it has to be noted that Ukraine has not implemented 88 RL of the 342 as of 1 January 2019. (WENRA RHWG 2020a)

Accident Analyses

Maintaining containment integrity under severe accident conditions is an important issue for accident management. The Rivne 1&2 severe accident management (SAM) strategy will rely on retaining corium inside the pressure vessel (in-vessel retention - IVR). However, these measures are not implemented yet. Furthermore, if this feature could be realized it would only reduce the risk of radioactive release in most but not in all severe accident scenarios.

A systematic analysis of beyond design basis accidents (BDBA) is not presented in the EIA Document. To calculate the possible (trans-boundary) consequences, it was assumed that the containment integrity will be kept up. This assumption is not justified. The used source term of a beyond design basis accident (BDBA) was chosen on the basis of safety requirements of the European operators for the design of a light water reactors (LWR). However, this limited source term can only be assumed if the plant has been designed or retrofitted accordingly. This is not the case for Rivne 1&2.

The accident analyses in the EIA Document should use a possible source term derived from the calculation of the current PSA 2. Even though the probability of severe accidents with an early and/or large release for existing plants is estimated to be very small, the consequences caused by these accidents are serious.

In any case, the EIA Document should contain a comprehensive justification for the source term used. In principle, possible Beyond Design Basis Accidents should be part of the EIA, irrespective of their probability of occurrence.

In order to assess the consequences of BDBAs, it is necessary to analyse a range of severe accidents, including those with containment failure and containment bypass. These kinds of severe accidents are possible for the VVER 440/V213 reactor type.

The results of the EU stress tests have revealed a lot of shortcomings of the severe accident management (SAM) (i.e. the prevention of severe accidents and the mitigation of its consequences) at the Ukrainian NPPs. Comprehensive improvements are required by the regulator; however, further improvements are recommended by the ENSREG peer review team. This is one example for the gap between the Ukraine and the EU safety standards and requirements.

The stress tests showed that after decades of safety programs, Ukrainian reactors remain to be plants posing exceptionally high risk. The continuous upgrading programs did not deliver the promised results. The ENSREG peer review team pointed to one of the main problems, which are characteristic of nuclear safety in the Ukraine: the constant severe delay of the implementation of upgrading measures.

The WENRA "Safety Objectives for New Power Reactors" should be used as a reference for identifying reasonably practicable safety improvements for Rivne 1&2. However, the EIA Document does not mention these WENRA safety objectives. The most ambitious WENRA safety objective intends to reduce potential radioactive releases to the environment from accidents with core melt. Accidents with core melt which would lead to early or large releases would have to be practically eliminated. Practical elimination of an accident sequence cannot be claimed solely based on compliance with a general cut-off probabilistic value. Even if the probability of an accident sequence is very low, any additional reasonably practicable design feature, operational measures or accident management procedures to further lower the risk should be implemented. The concept of "practical elimination" of early or large releases is not mentioned for Rivne NPP in the EIA Document.

Accidents initiated by natural events and site assessment

The plant safety assessment takes into account the following natural hazards: river flood, extreme precipitation, abnormally low water level (lack of cooling water), tornado, earthquake, high wind, fog, thunderstorm, snowstorm (snow load) and extreme temperature. In addition, karst and suffusion (including human-induced karstification and suffusion) are discussed.

The assessment of natural phenomena that may have adverse effects on the safety of the NPP is restricted to a small number of hazard types. The EIA Document fails to demonstrate that the site assessment identified all natural hazards that apply to the site. A thorough assessment including the steps

- hazard screening and identification of hazard combinations
- hazard assessment
- definition of design basis events
- development of a protection concept
- analysis of design extension conditions

as required by WENRA (2014a, Issue T) has not been performed.

Hazard screening and the identification of hazard combinations should start from an exhaustive list of natural hazards (e.g., WENRA 2015; DECKER & BRINKMAN 2017) to demonstrate that all relevant hazards and hazard combinations are addressed.

Hazard severities for occurrence probabilities of 10^{-4} per year as required by WENRA (2014) have been determined by hazard assessments for several, but not all hazards considered in the EIA Document. The results, however, are not followed up to define design basis events and develop adequate protection concepts in a way that complies with the WENRA Safety Reference Levels for Existing Reactors (2014). This is particularly the case for external flooding by extreme precipitation, low water level (lack of cooling water), high wind, tornado, snow load/snow storm and extreme temperatures. Adequate protection against several hazards is therefore currently not in place. This is most important for:

- Flooding by extreme precipitation for which the current design only protects against events with occurrence probabilities of 10E-1 per year. Events exceeding the current design value are expected to lead to severe impacts on the on-site power system. This occurrence probability exceeds the exceedance frequency of design basis events required by WENRA by a factor of 10E3.
- High wind for which the EIA Document shows that storms with occurrence probabilities of 1.40E-3 can lead to failure of the essential service water system.
- Drought and lack of riverine cooling water.

We have to assume that the low robustness of the cooling system against wind loads and other meteorological hazards are important reasons for the high conditional probability of core damage due to failure of the essential service water system. This probability is stated with 6,93E-03. Such a high Core Damage Frequency (CDF) value is unacceptable when compared to regulations and safety expectations for existing NPPs that are in place in most of the European countries[2].

Karstification and suffusion pose significant threats to the safety of the NPP Rivne by the possible destabilization of the foundation soil of the reactor buildings and containments, buildings that house safety-relevant structures, systems and components (SSC), safety-relevant underground piping and the cooling towers. Information provided by the EIA Document proves that the operation of the NPP leads to the lasting seepage of large amounts of technical water that has the potential to increase karstification and suffusion, and to destabilize foundation soils. Since human-made karstification and suffusion are self-enhancing mechanisms it may be expected that their safety relevance increases during the future operation of the NPP.

The available EIA Document provides only insufficient information on the safety margins of the reactors with respect to the different natural hazard types. Design Extension Conditions (DEC) are not analysed. This is contrary to the WENRA requirement that DEC analysis shall be undertaken with the purpose of further improving the safety of existing nuclear power plants and enhancing their capability to withstand more challenging events or conditions than those considered in the design basis. Related requirements and procedures are provided by WENRA (2014a) and WENRA (2014b). The Austrian expert team recommended to extend the efforts with respect to natural hazard analysis and develop adequate protection concepts for natural hazards in line with the WENRA approach for DEC.

[2] In the majority of member countries of WENRA (Western European Nuclear Regulators Association) and in the Ukraine the Core Damage Frequency (CDF) shall not exceed the value of 10^{-4} per year. Some WENRA countries require CDF≤10^{-5} per year.

Accidents with involvement of third parties and man-made impacts

Terrorist attacks and acts of sabotage can have significant impacts on nuclear facilities and cause severe accidents – also on the Rivne NPP. Nevertheless, they are not mentioned in the EIA Document. In comparable EIA documents such events were addressed to some extent.

Although precautions against sabotage and terror attacks cannot be publicly discussed in detail in the EIA procedure for reasons of confidentiality, the necessary legal requirements should be set out in the EIA Document.

Information regarding the issue of terror attacks would be of great interest, considering the large consequences of potential attacks. In particular, the EIA Document should include detailed information on the requirements for the design against the targeted crash of a commercial aircraft. This topic is of particular importance, because the reactor building of Rivne 1&2 is vulnerable against terror attacks (including airplane crash).

A recent assessment of the nuclear security in Ukraine points to shortcomings compared to necessary requirements: The 2020 NTI Index assesses nuclear security conditions related to the protection of the nuclear facilities. With a total score of 65 out of 100 points, Ukraine ranked only 29 out of 47 countries, which indicates a low protection level. It has to be pointed out that the low scores for "Insider Threat Prevention" and "Cybersecurity" indicate deficiencies in these issues. It is recommended to invite this International Physical Protection Advisory Service (IPPAS) of the IAEA that assisted states, in strengthening their national nuclear security regimes, systems and measures.

Trans-boundary impacts

The used source term for Cs-137 (30 TBq) of a beyond design basis accident (BDBA) was determined on the basis of the limited value of the release according to the safety requirements of the European operators. The assumption of this relatively moderate source term is not justified. This limited source term can only be used if the plant has been designed or retrofitted accordingly. This is not the case for the Rivne 1&2 NPP. The project flexRISK made an assessment of source terms and identified for Rivne 1&2 a possible source term for Cs-137 (76,500 TBq). This source term is related to the behaviour of the plant in case of a severe accident and the possible release.

Severe accidents with releases considerably higher than assumed in the EIA Document cannot be excluded for Rivne 1&2. Such worst case accidents should be included in the assessment since their effects can be widespread and long-lasting and even countries not directly bordering Ukraine, like Austria, can be affected.

Because of the analysis of the worst case scenarios was not performed the conclusion of the EIA Document concerning trans-boundary effects is not sufficiently proven.

The results of the flexRISK project indicated that after a severe accident, the average Cs-137 ground depositions at most areas of the Austrian territory could be higher than the threshold for agricultural intervention measures (e.g. earlier harvesting, closing of greenhouses). Therefore, Austria could be significantly affected by a severe accident at Rivne 1&2.

ZUSAMMENFASSUNG

Die Ukraine führt eine Umweltverträglichkeitsprüfung (UVP) für die Lebensdauerverlängerung der Reaktoren Rivne 1&2 gemäß der Espoo-Konvention durch. Das Kernkraftwerk Rivne liegt in der Nähe der Stadt Varash in der Region Rivne. Am Standort Rivne sind vier Reaktoren in Betrieb, wobei die Blöcke Rivne 1&2 die ältesten Reaktoren sind und in den Jahren 1980 bzw. 1981 in Betrieb genommen wurden.

Nachdem die Republik Österreich von der Ukraine notifiziert wurde, beschloss Österreich sich an der UVP zu beteiligen. Das österreichische Bundesministerium für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie (BMK) beauftragte das Umweltbundesamt mit der Erstellung des vorliegenden ExpertInnengutachtens, in welchem die übermittelten UVP-Dokumente bewerten werden. Das Ziel der österreichischen Beteiligung an dem UVP-Verfahren ist die Minimierung oder Beseitigung möglicher signifikant negativer Auswirkungen auf Österreich, die von diesem Projekt ausgehen könnten.

Allgemeine Aspekte und Verfahrensaspekte der Umweltverträglichkeitsprüfung

Die ursprüngliche Genehmigung wurde für eine Geltungsdauer von 30 Jahren erteilt und im Jahre 2010 bis Dezember 2030 verlängert. Das Projekt der Lebensdauerverlängerung des KKW Rivne 1&2 steht im Widerspruch zur Espoo-Konvention, da im Jahre 2010 keine Umweltverträglichkeitsprüfung durchgeführt wurde. Die Beschwerde "EIA/IC/CI/4 Ukraine" wurde im Rahmen der Espoo-Konvention im Jahre 2011 eröffnet und ist noch nicht abgeschlossen. Die Ukraine wurde aufgefordert eine UVP vor dem Jahr 2020 durchzuführen. Im Dezember 2020 forderte die Vertragsstaatenkonferenz (MOP) der Espoo-Konvention die Ukraine auf, die finale Genehmigung für die Lebensdauerverlängerung von Rivne 1&2 zu revidieren und die Ergebnisse des jetzt laufenden UVP-Verfahrens zu berücksichtigen. Die noch offene Beschwerde im Rahmen der Espoo-Konvention zeigt, dass noch ungeregelt ist, ob und auf welche Weise die Resultate des laufenden UVP-Verfahrens von der ukrainischen Seite berücksichtigt werden.

Gemäß der Espoo-Konvention hat die Dokumentation für die Umweltverträglichkeitsprüfung eine Beschreibung und eine Prüfung von vernünftigen Alternativen wie auch der Null-Variante zu beinhalten. In dieser Hinsicht ist die vorgelegte UVP-Dokumentation unvollständig.

Am 16. Dezember 2020 hat die Staatliche Atomaufsichtsbehörde der Ukraine, SNRIU, bereits die Verlängerung der Genehmigung EO 000943 für Rivne 1 bis 22. Dezember 2030 beschlossen. Das Espoo-Implementierungskommittee hatte allerdings die Empfehlung ausgesprochen, die UVP vor Abschluss der nächsten Periodischen Sicherheitsüberprüfung (PSÜ) 2020 durchzuführen und abzuschließen, d.h. vor Verlängerung der Genehmigung.

Abgebrannter Nuklearbrennstoff und radioaktive Abfälle

In der UVP-Dokumentation fehlen wesentliche Informationen über das Management von abgebrannten Brennstäben und radioaktiven Abfällen aus dem KKW

Rivne 1&2. Das zu erwartende Inventar der abgebrannten Brennstäbe und radioaktive Abfälle, die in Folge der Lebensdauerverlängerung anfallen werden, wurde nicht angeführt.

Ebenso nicht angeführt wurde die Information über den Stand des Zentralen Zwischenlagers, wo die abgebrannten Brennstäbe aus dem KKW Rivne 1&2 gelagert werden sollen (CSFSF). Weiterhin unklar ist das Endlager für abgebrannten Brennstoff und hochaktiven Abfall, wo auch die verglasten hochaktiven Abfälle aus der Wiederaufbereitung in Mayak in der Russischen Föderation gelagert werden sollen.

Abgebrannter Brennstoff und hochaktiver Abfall können negative Umweltauswirkungen haben, daher wäre es zu begrüßen, wenn die ukrainische Seite weitere Informationen über das nationale Entsorgungsprogramm für Atommüll zur Verfügung stellen würde.

Langzeitbetrieb von Reaktoren des Typs WWER-440

Obwohl die Alterung der 40 Jahre alten Strukturen, Gebäude und Anlagen für Rivne 1&2 sicherheitsrelevant ist, wurde dieser Themenkomplex in der UVP-Dokumentation nicht angesprochen. Diese bezieht sich nur auf „Strukturen, Systeme und Komponentenalterung“ als Sicherheitsfaktor im Rahmen der Periodischen Sicherheitsüberprüfung (PSÜ). Die negativen Auswirkungen der Alterung stehen auch in Abhängigkeit zu den durchgeführten Inspektions-, Erneuerungs- und Schutzmaßnahmen. Ein umfassendes Alterungsmanagementprogramm (AMP) ist notwendig um die altersbedingten Versagen zumindest in einem bestimmten Ausmaß zu beschränken. Allerdings fehlt die Information über das Alterungsmanagementprogramm (AMP) in der UVP-Dokumentation.

Die Ukraine beteiligte sich in den Jahren 2017/18 an der Topical Peer Review (TPR) mit dem thematischen Schwerpunkt „Alterungsmanagement“ im Rahmen der Umsetzung der Nuklearsicherheitsrichtlinie 2014/87/EURATOM. Einige „Bereiche mit Verbesserungspotential“ wurden identifiziert, d.h. Abweichungen, vom erwarteten Niveau der TPR für die Durchführung des Alterungsmanagements, welches im Sinne eines konsistenten und akzeptablen Alterungsmanagements in ganz Europe erzielt werden sollte. Die TPR-Resultate und die Aktivitäten zur Behebung von Schwachstellen sollten in der UVP-Dokumentation präsentiert werden. Das gilt insbesondere für die wesentliche Sicherheitsfrage der Versprödung des Reaktordruckbehälters.

Obwohl die konzeptuelle Alterung für Rivne 1&2 ebenso ein Problem darstellt, befasst sich die UVP-Dokumentation mit keinem der bekannten Sicherheitsdefizite der WWER-440/213 Reaktoren: das Reaktorgebäude und auch das Gebäude für das Abklingbecken abgebrannter Brennstäbe sind gegenüber externen Ereignisse relativ verwundbar. Die WWER-440 Reaktoren sind als Zwillingsanlangen konstruiert, die sich mehrere Betriebs- und Sicherheitssysteme teilen. Die gemeinsame Verwendung erhöht das Risiko eines Versagens aus gemeinsamer Ursache, wodurch die Sicherheit beider Reaktoren gleichzeitig betroffen ist.

Dieses KKW-Design wurde in den 1980ern entwickelt und entspricht nur teilweise modernen Auslegungsprinzipien wie Redundanz, Diversität und physische Trennung von redundanten Subsystemen und der bevorzugten Verwendung von passiven Sicherheitssystemen.

Im Dezember 2010 genehmigte die Staatliche Nuklearaufsichtsbehörde (SNRIU) der Ukraine für das KKW Rivne 1&2 eine Lebensdauerverlängerung für 20 Jahre, obwohl die sicherheitsrelevanten Defizite noch nicht vollständig geklärt waren. Der Stresstest kam zu dem Ergebnis, dass die ukrainischen KKW nur 172 von 194 Anforderung der IAEA Design Safety Standards von 2000[3] erfüllten. Die Umsetzung der notwendigen Verbesserungen ist Teil des noch laufenden Nachrüstungspakets. Darunter fällt auch das Comprehensive (Integrated) Safety Improvement Program (C(I)SIP), dessen Fertigstellung einige Male verschoben wurde. Die Fertigstellung ist nun für 2023 vorgesehen.

Die SNRIU beteiligt sich seit 2009 als Beobachterin an den Aktivitäten der WENRA (Western European Nuclear Regulators Association). Im Jahre 2014 veröffentlichte die WENRA eine revidierte Version der Safety Reference Levels (RLs) für bestehende Reaktoren, die die Reactor Harmonisation Working Group (RHWG) ausgearbeitet hat. Das Ziel der Revision war die Berücksichtigung der Erfahrungen, die aus dem Unfall im KKW TEPCO Fukushima Daiichi gewonnen wurden. Eine wesentliches Update war die Revision des Issue F "Design Extension of Existing Reactors" durch die Einführung des Auslegungskonzepts der Design Extension Conditions (DEC), der Erweiterten Auslegungsbedingungen. Es ist allerdings zu betonen, dass die Ukraine 88 der 342 Reference Levels nicht umgesetzt hat. (WENRA RHWG 2020a)

Unfallanalysen

Der Erhalt der Containment-Integrität unter Bedingungen schwerer Unfälle ist ein wichtiges Thema für das Unfallmanagement. Die Strategie für das Management schwerer Unfälle (SAM) wird vor allem auf das Zurückhalten des Kerns innerhalb des Reaktordruckbehälters setzen (In-Vessel Retention – IVR). Doch diese Maßnahmen sind noch nicht umgesetzt. Selbst wenn diese Einrichtung installiert sein wird, kann es nur zur Reduktion des Risikos von radioaktiven Freisetzungen in den meisten, aber nicht in allen Fällen von schweren Unfallszenarien kommen.

In der UVP-Dokumentation fehlt eine systematische Analyse der Auslegungsstörfall-überschreitenden Unfälle (BDBA). Für die Berechnung möglicher (grenzüberschreitender) Folgen wurde angenommen, dass die Containment-Integrität erhalten bleiben wird. Diese Annahme ist nicht gerechtfertigt. Der für einen Auslegungsstörfall-überschreitenden Unfall verwendete Quellterm wurde auf der Grundlage der Sicherheitsanforderungen der europäischen Betreiber von Druckwasserreaktoren ausgewählt. Doch kann dieser Quellterm nur dann als Annahme verwendet werden, wenn das Kraftwerk dementsprechend ausgelegt oder nachgerüstet wurde. Das ist bei Rivne 1&2 nicht der Fall.

Für die Unfallanalyse in der UVP-Dokumentation sollte ein möglicher Quellterm von der Berechnung der aktuellen PSA 2 abgeleitet werden. Auch wenn die

[3] Im Rahmen eines gemeinsamen IAEO-EK-Ukraine Projekts wurde eine Designevaluierung durchgeführt, um umfassend die Übereinstimmung der ukrainischen KKW-Designs mit den IAEO Safety Standards Safety of Nuclear Power Plants: Design (NS-R-1) aus dem Jahre 2000 zu bewerten. Mittlerweile ist auch dieses IAEO-Dokument veraltet, denn im Jänner 2012 wurden die neuen Sicherheitsanforderungen IAEO (2012) publiziert.

Wahrscheinlichkeit für schwere Unfälle mit einer frühen und/oder großen Freisetzung für bestehende KKW als gering angenommen wird, so sind die Folgen dieser Unfälle schwer.

In jedem Fall sollte die UVP-Dokumentation eine nachvollziehbare Begründung für den verwendeten Quellterm haben. Prinzipiell sollten mögliche Auslegungsstörfall-überschreitende Unfälle (BDBA) Teil der UVP sein, ungeachtet ihrer Eintrittswahrscheinlichkeit.

Um die Konsequenzen von BDBAs zu bewerten ist es notwendig, eine Reihe von schweren Unfällen zu analysieren, einschließlich der Unfälle mit Containmentversagen und Containment-Bypass. Dieser Arten von schweren Unfällen sind für den Reaktortyp WWER 440/V213 möglich.

Die Resultate der EU-Stresstests haben eine Reihe von Defiziten beim Management schwerer Unfälle (SAM), d.h. der Verhinderung von schweren Unfällen und der Verhinderung von deren Folgen bei den ukrainischen KKW aufgedeckt. Die Aufsichtsbehörde verlangt einige umfassende Verbesserungen, wobei das ENSREG Peer Review Team weitere Verbesserungsmaßnahmen verlangt. Dabei handelt es sich um ein Beispiel für die Kluft zwischen den Sicherheitsstandards und Sicherheitsanforderungen der Ukraine und der EU.

Die Stresstests zeigten, dass nach jahrzehntelangen Sicherheitsprogrammen die KKW auch weiterhin ein ungewöhnlich hohes Risiko darstellen. Die kontinuierlichen Nachrüstprogramme haben nicht die versprochenen Resultate gebracht. Das ENSREG Peer Review Team verwies auf eines der Hauptprobleme, die für die nukleare Sicherheit in der Ukraine charakteristisch sind: die permanente Verschiebung der Umsetzung der Nachrüstmaßnahmen.

Die WENRA "Safety Objectives for New Power Reactors" sollten als Referenzdokument für die Identifikation der vernünftig umsetzbaren Sicherheitsverbesserungen für Rivne 1&2 dienen. Die UVP-Dokumentation nennt diese WENRA Sicherheitsziele allerdings nicht. Das ehrgeizigste WENRA-Sicherheitsziel beabsichtigt die Reduktion potentieller radioaktiver Freisetzungen in die Umwelt bei Kernschmelzunfällen. Kernschmelzunfälle mit frühen oder großen Freisetzungen wären dann praktisch ausgeschlossen. Der praktische Ausschluss von Unfallabfolgen kann nicht nur mit einem allgemeinen probabilistischen Grenzwert bestimmt werden. Selbst wenn die Wahrscheinlichkeit für eine bestimmte Unfallabfolge sehr gering ist, so ist ein zusätzliches vernünftig umsetzbares Designelement, eine betriebliche Maßnahme oder Unfallmanagementverfahren einzuführen, um das Risiko weiter zu reduzieren. Das Konzept des „praktischen Ausschlusses" von frühen oder großen Freisetzungen wird für das KKW Rivne in der UVP-Dokumentation nicht genannt.

Unfälle, die durch natürliche Ereignisse initiiert werden, Standortbewertung

Die Sicherheitsbewertung für das KKW betrachtet folgende Naturgefahren: Überschwemmung durch Flusswasser, extremer Niederschlag, außergewöhnlich niedriger Wasserpegel (Mangel an Kühlwasser), Tornado, Erdbeben, Starkwinde, Nebel, Gewitter, Schneesturm (Schneelast) und extreme Temperaturen. Zusätzlich betrachtet wurden Karst und Suffusion (einschließlich menschgemachter Karstifizierung und Suffusion).

Die Prüfung von natürlichen Phänomenen, die negative Auswirkungen auf die Sicherheit des KKW haben können, wurde auf eine geringe Anzahl von Gefährdungstypen beschränkt. Die UVP-Dokumentation weist nicht nach, dass die Standortbewertung alle natürlichen Gefährdungen identifiziert hat, die für diesen Standort möglich sind. Eine gründliche Bewertung mit den folgenden Schritten, wie von WENRA (2014a, Issue T) vorgesehen, wurde nicht durchgeführt:

- Gefährdungsscreening und Identifikation von Gefährdungskombinationen
- Gefährdungsbewertung
- Identifikation von Auslegungsstörfällen
- Entwicklung eines Schutzkonzepts
- Analyse von erweiterten Auslegungsbedingungen

Das Gefährdungsscreening und die Identifizierung von Gefährdungskombinationen sollte mit einer vollständigen Liste der natürlichen Gefährdungen begonnen werden (z.B. WENRA 2015; DECKER & BRINKMAN 2017) um nachzuweisen, dass alle relevanten Gefährdungen und Gefährdungskombinationen berücksichtigt wurden.

Die Gefährdungen mit Eintrittswahrscheinlichkeiten von 10^{-4} pro Jahr, wie von WENRA (2014) vorgesehen, wurden mit einer Gefährdungsprüfung einiger, aber nicht aller Gefährdungen in der UVP-Dokumentation durchgeführt. Die Ergebnisse wurden allerdings nicht dafür verwendet um Auslegungsstörfälle zu definieren und adäquate Schutzkonzepte zu entwickeln, die den WENRA Safety Reference Levels für bestehende Reaktoren (2014) entsprechen. Das gilt insbesondere für die externe Flutung durch extreme Niederschläge, niedrigen Wasserstand (Mangel an Kühlwasser), Starkwinde, Tornados, Schneelast/Schneesturm und extreme Temperaturen. Ein adäquater Schutz liegt somit zurzeit für einige Gefährdungen nicht vor. Das gilt insbesondere für:

- Überflutung durch extreme Niederschläge, für die die aktuelle Auslegung nur gegen Ereignisse mit einer Eintrittshäufigkeit von 10E-1 pro Jahr ausreicht. Diese probabilistische Eintrittshäufigkeit überschreitet die Häufigkeit für Auslegungsstörfälle, wie sie von WENRA gefordert wird, um einen Faktor von 10E3.
- Starkwind, der laut UVP-Dokumentation mit Stürmen mit einer Eintrittswahrscheinlichkeit von 1,40E-3 zum Versagen des wichtigen Speisewassersystems führen kann.
- Trockenheit und Mangel an Flusswasser zur Kühlung.

Es davon auszugehen, dass die geringe Widerstandsfähigkeit des Kühlsystems gegen Windlasten und andere meteorologische Gefährdungen wesentliche Gründe für die hohe Eintrittswahrscheinlichkeit für Kernschmelzen in Folge eines Verlusts der essentiellen Speisewassersystems darstellt. Die Wahrscheinlichkeit wird mit 6,93E-03 angeführt. Ein so hoher Wert für die Kernschmelzhäufigkeit (CDF) ist nicht akzeptabel, wie der Vergleich mit den Regeln und Sicherheitsanforderungen an bestehende KKW zeigt, die im Großteil der Länder Europas[4] herrschen.

[4] Im Großteil der Mitgliedsstaaten der WENRA (Western European Nuclear Regulators Association) und der Ukraine sollte die Kernschmelzhäufigkeit (CDF) den Wert 10^{-4} pro Jahr nicht überschreiten. Einige WENRA-Länder verlangen $CDF \leq 10^{-5}$ pro Jahr.

Die Verkarstung und Suffusion stellen bedeutende Gefährdungen der Sicherheit des KKW Rivne durch die mögliche Destabilisierung des Fundamentbodens unter dem Reaktorgebäude, dem Containment und den Gebäuden dar, die die sicherheitsrelevanten Strukturen, Systeme und Komponenten (SSC) beherbergen, wie auch die sicherheitsrelevanten unterirdischen Rohrleitungen und die Kühltürme. Die Information in der UVP-Dokumentation zeigt, dass der Betrieb des KKW zu einer anhaltenden Versickerung von großen Mengen an technischem Wasser führt, welches das Potential für eine Verstärkung der Verkarstung und Suffusion hat und zu einer Destabilisierung der Fundamentböden führen kann. Da die menschgemachte Verkarstung und Suffusion selbstverstärkende Mechanismen sind, ist davon auszugehen, dass deren Sicherheitsrelevanz im künftigen KKW-Betrieb ansteigen wird.

Die vorliegende UVP-Dokumentation bietet nur unzureichende Informationen über die Sicherheitsreserven der Reaktoren für die verschiedenen natürlichen Gefährdungsarten. Die erweiterten Auslegungsbedingungen (DEC) werden nicht analysiert. Das widerspricht den WENRA-Anforderungen wonach die DEC-Analyse zur weiteren Verbesserung der Sicherheit bestehender KKW und der Erhöhung deren Fähigkeit dient, Ereignisse oder Bedingungen zu bewältigen, die massiver sind als in der Auslegung vorgesehen. Die Dokumente WENRA (2014a) und WENRA (2014b) stellen die damit zusammenhängenden Anforderungen und Vorgangsweisen dar. Das österreichische ExpertInnenteam empfiehlt die Anstrengungen im Bereich der Analyse der natürlichen Gefährdungen auszuweiten und entsprechende Schutzkonzepte für die natürlichen Gefährdungen entsprechend den WENRA-Vorschriften für DEC zu entwickeln.

Unfälle mit Beteiligung Dritter und durch Aktivitäten des Menschen verursachte Auswirkungen

Terrorangriffe und Sabotageakte können schwere Auswirkungen auf Nuklearanlagen haben und zu schweren Unfällen führen – auch beim KKW Rivne. Dennoch werden diese in der UVP-Dokumentation nicht erwähnt. In vergleichbaren UVP-Dokumentationen wurden diese Ereignisse bis zu einem gewissen Umfang angesprochen.

Wenn auch vorbeugende Maßnahmen gegen Sabotage und Terrorangriffe nicht öffentlich im Detail im UVP-Verfahren aufgrund der Vertraulichkeit diskutiert werden können, so wären doch die gesetzlichen Anforderungen in der UVP-Dokumentation zu benennen.

Aufgrund der gravierenden Folgen möglicher Angriffe ist die Information zur Problematik von Terrorangriffen sehr wichtig. Die UVP-Dokumentation sollte detaillierte Informationen über die Auslegungsanforderungen für den gezielten Absturz von Verkehrsflugzeugen anführen. Dieses Thema ist besonders wichtig, da das Reaktorgebäude des KKW Rivne 1&2 gegen Terrorangriffe (einschließlich Flugzeugabstürzen) verwundbar ist.

Die aktuelle Bewertung der nuklearen Sicherung in der Ukraine zeigt Defizite auf: Der NTI Index 2020 bewertet die Bedingungen der nuklearen Sicherung im Zusammenhang mit dem zum Schutz der nuklearen Anlagen. Mit einer Gesamtbewertung von 65 von 100 Punkten wurde die Ukraine nur auf Platz 29 von 47 Ländern eingereiht, was auf ein sehr geringes Schutzausmaß deutet. Die niedrige

Bewertung für "Insider Threat Prevention" und "Cybersecurity" zeigt die Missstände in diesen Bereichen auf. Es wird empfohlen, den International Physical Protection Advisory Service (IPPAS) der IAEO einzuladen, der die Staaten bei der Stärkung von deren nationalen Regelungen, Systemen und Maßnahmen zur Sicherung von Nuklearmaterial unterstützt.

Grenzüberschreitende Folgen

Der verwendete Quellterm für Cäsium 137 (30 TBq) für einen Auslegungsstörfall-überschreitenden Unfall (BDBA) wurde auf der Grundlage des beschränkten Werts festgelegt, der für die Sicherheitsanforderungen der europäischen Betreiber gilt. Diesen relativ moderaten Quellterm heranzuziehen ist nicht gerechtfertigt. Dieser beschränkte Wert kann nur verwendet werden, wenn das KKW entsprechend ausgelegt oder nachgerüstet wurde. Das ist für das KKW Rivne 1&2 nicht der Fall. Das Projekt flexRISK führte eine Bewertung der Quellterme durch und bestimmte für Rivne 1&2 einen möglichen Quellterm für Cs-137 (76 500 TBq). Dieser Quellterm steht in Bezug zum Verhalten des KKW im Fall eines schweren Unfalls und möglicher Freisetzungen.

Schwere Unfälle mit Freisetzungen, die deutlich über den in der UVP-Dokumentation abgeschätzten liegen, können für Rivne 1&2 nicht ausgeschlossen werden. Solche Worst-Case Unfälle sind in der Prüfung zu inkludieren, da deren Auswirkungen weitreichend und langdauernd sein können und auch Länder betreffen können, die nicht direkt an die Ukraine angrenzen, wie etwa Österreich.

Die Schlussfolgerungen der UVP-Dokumentation zu den grenzüberschreitenden Auswirkungen sind nicht ausreichend nachgewiesen, da die Analyse der Worst-Case Szenarien nicht durchgeführt wurde.

Die Resultate des flexRISK Projekts zeigen, dass nach einem schweren Unfall die durchschnittlichen Bodendepositionen von Cs-137 in den meisten Regionen Österreich den Schwellenwert für landwirtschaftliche Interventionsmaßnahmen (z.B. vorgezogene Ernte, Schließen von Glashäusern) überschreiten könnten. Daher könnte Österreich von einem schweren Unfall im KKW Rivne 1&2 signifikant betroffen sein.

РЕЗЮМЕ

Україна проводить Оцінку впливу на довкілля (ОВД) для продовження строку експлуатації енергоблоків № 1 та № 2 Рівненської АЕС згідно з Конвенцією Еспо. Рівненська АЕС знаходиться поблизу міста Вараш Рівненської області. Тут працює чотири енергоблоки. № 1 та № 2 — найстаріші. Вони були підключені до електромережі відповідно у 1980 та 1981 роках.

Україна повідомила Австрію про проведення ОВД, й Австрія вирішила взяти участь у процесі. Австрійське федеральне міністерство з питань кліматичних дій, довкілля, енергетики, мобільності, інновацій та технологій доручило Австрійському агентству з питань довкілля надати відповідну експертну заяву з оцінкою поданого Документа по ОВД. Метою участі Австрії в процедурі ОВД є мінімізація або навіть усунення можливих значних негативних впливів на Австрію, які можуть виникнути в результаті цього проєкту.

Загальні та процедурні аспекти Оцінки впливу на довкілля

Первісна ліцензія була видана на 30 років і у 2010 році була продовжена до грудня 2030 року. Проєкт продовження строку експлуатації енергоблоків № 1 та № 2 на Рівненській АЕС порушує Конвенцію Еспо, оскільки у 2010 році не проводилась Оцінка впливу на довкілля. У 2011 році було розпочато справу за номером EIA/IC/CI/4 про порушення Україною положень Конвенції Еспо, яка й досі лишається відкритою. Україні було запропоновано провести ОВД до 2020 року. У грудні 2020 року зустріч сторін Конвенції Еспо попросила Україну переглянути своє остаточне рішення щодо продовження строку експлуатації енергоблоків № 1 та № 2 Рівненської АЕС, належним чином врахувавши результати поточної процедури ОВД. Ця порушена за процедурою Еспо справа, рішення за якою й досі не прийняте, свідчить, що незрозуміло, чи і як будуть враховані результати поточної процедури ОВД українською стороною. Крім того, подальші кроки процедури ліцензування не зрозумілі.

Згідно з Конвенцією Еспо, в документацію по оцінці впливу на навколишнє середовище мають бути включені опис та оцінка доцільних альтернативних дій, а також альтернатива бездіяльності. У зв’язку з цим Документація по ОВД є недостатньою.

16 грудня 2020 року Державна інспекція ядерного регулювання України (Держатомрегулювання) вже прийняла рішення про внесення змін до ліцензії серії ЕО 000943 для енергоблока № 1 Рівненської АЕС до 22 грудня 2030 року. Але Комітет з імплементації Конвенції Еспо рекомендував провести та доопрацювати ОВД до закінчення чергового періодичного огляду безпеки (ПОБ), що мало б статися до того, як ліцензію було подовжено.

Відпрацьоване ядерне паливо та радіоактивні відходи

У Документі ОВД відсутня важлива інформація щодо поводження з відпрацьованим ядерним паливом і радіоактивними відходами з енергоблоків № 1 та № 2 Рівненської АЕС. Не подається інформація про очікувану інвентаризацію відпрацьованого палива та радіоактивних відходів, що виникають внаслідок продовження строку експлуатації.

Інформація про стан центрального проміжного сховища, де зберігатиметься відпрацьоване ядерне паливо з енергоблоків № 1 та № 2 Рівненської АЕС (ЦСВЯП), також не надавалася. Незрозумілим залишається й місце остаточного сховища відпрацьованого палива та високорадіоактивних відходів, де також зберігатимуться РАВ у склоподібному стані після переробки на ФДУП «ВО «Маяк» в Російській Федерації.

Відпрацьоване паливо та радіоактивні відходи можуть спричинити негативні наслідки для довкілля, тож надання українською стороною більше інформації про національний план поводження з ядерними відходами буде схвально сприйняте.

Тривала експлуатація реакторів типу ВВЕР-440

Хоча старіння 40-річних конструкцій, будівель та обладнання є питанням безпеки для енергоблоків № 1 та № 2 Рівненської АЕС, це питання не розглядається у Документі по ОВД. В документі йдеться лише про «старіння конструкцій, систем та компонентів», що є фактором безпеки (ФБ) в рамках періодичного огляду безпеки (ПОБ). Негативний вплив старіння також залежить від вжитих заходів щодо огляду, відновлення та захисту. Потрібна комплексна програма управління старінням (ПУС), щоб хоча б певною мірою обмежити проблеми, пов’язані зі старінням. Однак інформація про програму управління старінням (ПУС) також не надається у Документі по ОВД.

Україна взяла участь у Тематичному експертному огляді (ТЕО) «Управління старінням» в рамках імплементації Директиви 2014/87/Євроатом з питань ядерної безпеки, що був проведений у 2017-2018 рр. Було визначено декілька «напрямків для вдосконалення», тобто відхилень від очікуваного рівня ТЕО щодо управління старінням, якого слід досягти для забезпечення послідовного та прийнятного управління старінням у всій Європі. Результати ТЕО та заходи щодо усунення прогалин повинні бути представлені у Документі по ОВД, зокрема має бути обговорено дуже важливе питання безпеки через крихкість корпусу реактора.

Хоча концептуальне старіння також є проблемою для енергоблоків № 1 і № 2 Рівненської АЕС, Документ по ОВД не стосується жодної з відомих проблем безпеки реакторів ВВЕР-440/В-213. Блоки ВВЕР-440/В-213 мають кілька конструктивних недоліків: корпус реактора та будівля басейну з відпрацьованим паливом відносно вразливі до зовнішнього впливу. Реактори ВВЕР-440 спроєктовані як спарені блоки, що мають багато спільних операційних систем і систем безпеки. Спільне використання систем безпеки підвищує ризик відмов через загальні причини, що впливають на безпеку обох реакторів одночасно.

Цей проєкт АЕС, розроблений у 1980-х роках, лише частково відповідає таким сучасним принципам проєктування, як фізичне резервування, різнохарактерність і фізичне відокремлення надлишкових підсистем або перевагу систем пасивної безпеки. Документи по ОВД не містять ні опису систем, що стосуються безпеки, ні інформації про потужності, фізичне резервування та фізичне відокремлення.

У грудні 2010 року, хоча питання, що стосуються безпеки, ще не вирішені цілком, Державна інспекція ядерного регулювання України (Держатомрегулювання) надала 20-річне продовження строку експлуатації для енергоблоків № 1 та № 2 Рівненської АЕС. У 2011 році стрес-тести показали, що українські АЕС відповідають лише 172 зі 194 вимог відповідно до стандартів безпеки МАГАТЕ, опублікованих у 2000 році . Запровадження необхідних удосконалень триває згідно з пакетом оновлення, який охоплює Комплексну (зведену) програму підвищення безпеки (К(З)ППБ). Завершення програми кілька разів відкладалося. Зараз завершення планується на 2023 рік.

Держатомрегулювання бере участь у заходах Західноєвропейської асоціації ядерних регуляторів (WENRA) як спостерігач з 2009 року. У 2014 році асоціація опублікувала переглянуту версію Довідкових рівнів безпеки (ДРБ) для існуючих реакторів, що була розроблена Робочою групою з гармонізації реакторів (РГГР). Метою перегляду було врахування висновків, отриманих в результаті аварії на Першій фукусімській АЕС. Основним оновленням ДРБ став перегляд положення F «Запроєктний режим роботи існуючих реакторів», що, власне, вводить поняття запроєктного режиму роботи існуючих реакторів (ЗРРІР). Однак, слід зазначити, що станом на 1 січня 2019 року в Україні не було впроваджено ДРБ 88 з 342 (WENRA RHWG 2020a).

Аналіз аварій

У процесі управління аваріями важливим питанням є підтримання цілісності захисної оболонки в умовах серйозних аварій. Стратегія управління серйозними аваріями (УСА) енергоблоків № 1 та № 2 Рівненської АЕС ґрунтуватиметься на утриманні розплаву ядерного палива всередині корпуса під тиском (утримання в корпусі — УВК). Однак ці заходи ще не виконуються. Ба більше, якби цю функцію вдалося реалізувати, така реалізація лише зменшила б ризик викиду радіоактивних речовин у більшості, але не у всіх сценаріях серйозних аварій.

У Документі по ОВД не представлений систематичний аналіз позапроєктних аварій (ППА). Передбачалося, що для розрахунку можливих (транскордонних) наслідків, буде збережена цілісність захисної оболонки. Це припущення не є виправданим. Використовуване джерело радіоактивності для позапроєктних аварій було обране на основі вимог безпеки європейських операторів для проєктування легководних реакторів (ЛВР). Однак таке обмежене джерело радіоактивності можна використовувати лише у тому випадку, якщо електростанція була спроєктована чи модернізована відповідним чином. У випадку з енергоблоками № 1 та № 2 Рівненської АЕС про таке проєктування чи модернізацію не йдеться.

В аналізі аварій у Документі по ОВД необхідно використовувати можливе джерело радіоактивності, отримане із розрахунку поточного Аналізу безпеки проєкту 2. Попри те, що ймовірність серйозних аварій з дочасним та/або великим викидом для існуючих електростанцій оцінюється як дуже мала, наслідки, спричинені цими аваріями, — дуже серйозні.

У будь-якому випадку, Документ по ОВД повинен містити вичерпне обґрунтування використовуваного джерела радіоактивності. В принципі, позапроєктні аварії повинні бути частиною ОВД, незалежно від їх вірогідності.

Щоб оцінити наслідки позапроєктних аварій, необхідно проаналізувати цілий ряд серйозних аварій, включаючи ті, що містять відмову та байпас захисної оболонки. Такі серйозні аварії цілком можливі для реакторів типу ВВЕР-440/В-213.

В результаті стрес-тестів ЄС на українських АЕС було виявлено багато недоліків управління серйозними аваріями, тобто запобігання серйозним аваріям і пом’якшення їх наслідків. Регулятор вимагає всебічних удосконалень. Подальші вдосконалення також рекомендовані групою експертного аналізу Об’єднання європейських атомних регуляторів ENSREG. Це один із прикладів розриву між стандартами та вимогами безпеки України та ЄС.

Стрес-тести показали, що після десятиліть програм безпеки українські реактори продовжують становити винятково високий ризик. Програми постійного оновлення не дали обіцяних результатів. Група експертного аналізу ENSREG вказала на одну з основних проблем, які характерні для ядерної безпеки в Україні: постійне серйозне затягування впровадження заходів з модернізації.

Як еталон для виявлення обґрунтовано можливих способів поліпшень безпеки для енергоблоків № 1 та № 2 Рівненської АЕС слід використовувати документ WENRA «Цілі безпеки для нових енергетичних реакторів». Однак, у документі по ОВД не згадуються ці цілі безпеки WENRA. Найамбітніша мета безпеки WENRA — зменшити потенційні викиди радіоактивних речовин у довкілля внаслідок аварій із розплавом активної зони реактора. За мету ставиться практично усунути аварії з розплавом активної зони реактора, які призвели б до дочасних або великих викидів. Не можна говорити про практичне усунення послідовності розвитку аварії лише на основі дотримання загальної граничної імовірнісної величини. Навіть якщо ймовірність послідовності розвитку аварії дуже низька, слід застосовувати будь-які додатково обґрунтовані на практиці проєктні особливості, оперативні заходи або процедури управління аваріями для подальшого зниження ризику. Поняття «практична ліквідація» дочасних або великих викидів не згадується у документах по ОВД для Рівненської АЕС.

Аварії, спричинені природними подіями, та оцінка об’єкта

Оцінка безпеки електростанцій враховує такі природні катаклізми: повені, екстремальні опади, аномально низький рівень води (відсутність води для охолодження), торнадо, землетруси, сильні вітри, тумани, грози, хуртовини (снігове навантаження) та екстремальні температури. Крім того, обговорюються карстування та суфозія (включаючи карстування та суфозію, спричинені діяльністю людини).

Оцінка природних явищ, які можуть мати негативний вплив на безпеку АЕС, обмежена невеликою кількістю видів катаклізмів. В документі по ОВД не продемонстровано, що в процесі оцінки об’єкта визначено всі природні катаклізми, які стосуються об'єкта. Повна оцінка, включаючи зазначені нижче етапи, передбачені WENRA (2014a, Літера «Т»), не здійснювалася.

- перевірка катаклізмів і визначення комбінацій катаклізмів
- оцінка катаклізмів
- визначення подій, що включені до проєктних основ
- розробка концепції захисту
- аналіз умов запроєктної роботи реактора

Перевірка катаклізмів і визначення комбінацій катаклізмів повинні починатися з вичерпного переліку природних катаклізмів (наприклад, WENRA 2015; DECKER & BRINKMAN 2017), щоб продемонструвати, що розглядаються всі відповідні катаклізми та комбінації катаклізмів.

Згідно з вимогами WENRA (2014) був визначений ступінь небезпеки катаклізмів для вірогідності виникнення 10-4 на рік за допомогою оцінки катаклізмів для декількох, але не всіх катаклізмів, розглянутих у Документі по ОВД. Однак результати цього визначення не виконуються, щоб визначити події, включені до проєктних основ, та чітко розробити адекватні концепції захисту, які б відповідали Довідковим рівням безпеки WENRA для існуючих реакторів (2014). Особливо це стосується зовнішніх затоплень через екстремальні опади, низький рівень води (відсутність води для охолодження), сильний вітер, торнадо, снігове навантаження/снігові бурі та екстремальні температури. Тому наразі відсутній належний захист від кількох катаклізмів, що є критично для:

- Затоплення внаслідок екстремальних опадів. Нинішній проєкт захищає лише від подій із ймовірністю виникнення 10E-1 на рік. Очікується, що події, що перевищують поточний проєкт, призведуть до серйозних наслідків для енергосистеми. Ця ймовірність перевищення у 10E3 разів більша за частоту перевищення для подій, що включені до проєктних основ, яку вимагає застосовувати WENRA.
- Сильний вітер, щодо якого Документ по ОВД свідчить, що шторми з імовірністю виникнення 1,40E-3 можуть призвести до виходу з ладу основної системи водопостачання.
- Посуха та відсутність річкової води для охолодження.

Ми повинні припустити, що низька стійкість охолоджувальної системи проти вітрових навантажень та інших метеорологічних катаклізмів є важливою причиною високої умовної ймовірності пошкодження активної зони внаслідок відмови основної системи водопостачання. Ця ймовірність вказана з індексом 6,93E-03. Таке високе значення частоти пошкодження активної зони реактора є неприйнятним у порівнянні з нормами та очікуваннями безпеки для існуючих АЕС, які діють у більшості європейських країн .

Карстування та суфозія становлять значну загрозу для безпеки Рівненської АЕС через можливу дестабілізацію ґрунту, на якому встановлені корпуси та захисні оболонки реакторів, будівлі, в яких розміщуються відповідні споруди, системи та компоненти безпеки, важливі для безпеки підземні трубопроводи та градирні. Інформація, надана в Документі по ОВД, доводить, що експлуатація АЕС призводить до тривалого просочування великої кількості технічної води, яка потенційно може збільшити карстування та суфозію і дестабілізувати ґрунти. Оскільки для спричинених людиною карстування та суфозії властиві механізми саморозвитку, можна очікувати, що значення їхньої безпеки зростатиме під час майбутньої експлуатації АЕС.

Наявний Документ ОВД містить лише недостатню інформацію про обсяги міцності реакторів щодо різних типів природних катаклізмів. Умови запроєктної роботи реактора (УЗР) не аналізуються, що суперечить вимозі WENRA про те, що аналіз УЗР повинен проводитися з метою подальшого підвищення безпеки існуючих атомних електростанцій та підвищення їх здатності протистояти складнішим подіям або умовам, ніж ті, що розглядаються в проєкті. Відповідні вимоги та процедури передбачені WENRA (2014a) та WENRA (2014b). Австрійська група експертів рекомендувала розширити зусилля щодо аналізу природних катаклізмів і розробити адекватні концепції захисту від природних катаклізмів відповідно до підходу WENRA до УЗР.

Аварії за участі третіх сторін та факторів техногенного впливу

Терористичні атаки та диверсійні дії можуть мати значний вплив на ядерні об’єкти та спричинити серйозні аварії, зокрема, і на Рівненській АЕС. Однак, вони не згадуються в Документі по ОВД. У порівняльних документах по ОВД такі події розглядалися певною мірою.

Хоча запобіжні заходи проти диверсійних дій та терактів не можуть бути детально обговорені в процедурі ОВД з міркувань конфіденційності, необхідні законодавчі вимоги повинні бути викладені в Документі по ОВД.

Інформація про терористичні атаки представляла б великий інтерес, враховуючи значні наслідки потенційних атак. Зокрема, Документ по ОВД повинні містити детальну інформацію про вимоги до проєктування на випадок цільової катастрофи комерційного літака. Ця тема має особливе значення, оскільки корпуси енергоблоків № 1 та № 2 Рівненської АЕС вразливі до терактів (включаючи аварію літака).

Нещодавня оцінка ядерної безпеки в Україні вказує на недоліки у порівнянні з необхідними вимогами: Індекс безпеки ядерних матеріалів NTI-2020 оцінює умови ядерної безпеки, пов’язані із захистом ядерних об’єктів. Отримавши загальний бал 65 зі 100 можливих, Україна посіла лише 29 місце серед 47 країн, що свідчить про низький рівень захисту. Слід зазначити, що низькі бали у категоріях «Запобігання внутрішній загрозі» та «Кібербезпека» вказують на недоліки у цих питаннях. Рекомендується запросити Міжнародну консультативну службу з фізичного захисту (IPPAS) МАГАТЕ, яка надавала допомогу державам у процесі зміцнення національних режимів, систем і заходів у царині ядерної безпеки.

Транскордонні впливи

Використовуване джерело радіоактивності для Цезію-137 (30 ТБк) позапроєктної аварії був визначений на основі обмеженої величини викиду відповідно до вимог безпеки європейських операторів. Припущення такого відносно помірного джерела радіоактивності не є виправданим. Це обмежене джерело радіоактивності може використовуватися лише у тому випадку, якщо електростанція була спроєктована чи модернізована відповідним чином. У випадку з енергоблоками № 1 та № 2 Рівненської АЕС про таке проєктування чи модернізацію не йдеться. У ході проєкту оцінки ризиків було здійснено оцінку джерела радіоактивності, яка для енергоблоків № 1 та № 2 Рівненської АЕС встановила можливе джерело радіоактивності для Цезію-137 на рівні 76 500 ТБк. Таке джерело радіоактивності пов'язане з функціонуванням електростанції у випадку сильної аварії та можливого викиду.

Для енергоблоків № 1 та № 2 Рівненської АЕС не можна виключати сильні аварії з викидами значно вищими, ніж передбачається в Документі по ОВД. Такі найгірші випадки повинні бути включені в оцінку, оскільки їхні наслідки можуть широко розповсюджуватися та бути довготривалими, а від них можуть постраждати навіть країни, які безпосередньо не межують з Україною, наприклад, Австрія.

Оскільки не було проведено аналізу найгірших сценаріїв, висновок Документа по ОВД щодо транскордонних наслідків не можна вважати достатньо доведеним.

Результати проєкту оцінки ризиків показали, що після сильної аварії середнє значення відкладення Цезію-137 у ґрунт на більшості територій Австрії можуть бути вищими за поріг, встановлений для заходів сільськогосподарського втручання (наприклад, дочасний збір урожаю, закриття теплиць). Тож Австрія може суттєво постраждати від сильної аварії на енергоблоках № 1 та № 2 Рівненської АЕС.

1 INTRODUCTION

The nuclear power plant Rivne is located near the town of Varash in the Rivne Oblast, Ukraine. At the Rivne site, four reactors are in operation. Rivne1&2 are the oldest of these reactors, they were connected to the grid in 1980 and 1981, respectively. While Rivne 1&2 are VVER-440/213 reactors, Rivne 3&4 are VVER-1000/320 with grid connection in 1986 and 2004.

The NPP is owned by the State Enterprise "National Nuclear Energy Generating Company Energoatom", in short Energoatom.

For the lifetime extension of Rivne 1&2, the Ukrainian side is conducting an Environmental Impact Assessment (EIA) under the Espoo Convention. Austria has been notified by Ukraine and decided to participate in the EIA. In Austria, the public can comment on the EIA Document until 15 January, 2021.

The competent EIA authority in Ukraine is the Ministry of Environmental Protection and Natural Resources, the project developer is Energoatom.

The Austrian Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology commissioned the Environment Agency Austria to provide the expert statement at hand assessing the submitted EIA Document.

The objective of the Austrian participation in the EIA procedure is to minimise or even eliminate possible significant adverse impacts on Austria which might result from this project.

2 OVERALL AND PROCEDURAL ASPECTS OF THE ENVIRONMENTAL IMPACT ASSESSMENT

In this chapter overall and procedural aspects of the Environmental Impact Assessment (EIA) procedure are discussed, including the evaluation of the completeness of the provided documents and the fulfilment of the requirements of the Espoo Convention.

An EIA Document consisting of seven books was provided by the Ukrainian side in form of a pdf with 1,463 pages. It is available at the website of the Environment Agency Austria (https://www.umweltbundesamt.at/uvpkkwrivne12).

The seven books are quoted in this expert statement as follows:

- EIA Report Book1-7 (2018)

Book No. 3 is additionally divided into five volumes (some volumes are called sectors), these are quoted as follows:

- EIA Report Book 3 Vol 1-5 (2018)

2.1 Treatment in the EIA Document

Procedure

No information was given in the EIA Document on the further steps of the EIA procedure including the final decision, and on following steps of the licensing procedure.

Alternatives

The decision for the Rivne site before construction start has been taken for the following reasons: low fertility of sandy land and large distance from densely populated areas. In 1973, the density of population in this territory was 55 persons/km^2, while today's population in Varash is 3,684 persons/km^2. (EIA REPORT BOOK6 2018, p. 1390)

Each year, the Rivne NPP generates about 13 % of the total electricity amount generated in Ukraine, it is also a heat source for the nearby industry.(EIA REPORT BOOK6 2018, p. 1390) No further data on electricity demands and supplies in the Ukraine were provided in the EIA Document.

2.2 Discussion

Procedure

The EIA Document did not provide information on the procedure, neither the EIA procedure nor the following steps of the licensing procedure.

The current license for Rivne 1&2 is valid until 31 December 2031. It was issued in 2010 after an application of Energoatom for lifetime extension of 20 years after the end of the 30 year original lifetime. Ukraine did not undertake an Environmental Impact Assessment (EIA) in 2010. This approach was found to be in violation of the Espoo Convention. (UNECE 2014) The EIA procedure, which the Espoo Implementation Committee demanded in 2014, is conducted now, after long delays.

Under the Espoo Convention case "EIA/IC/CI/4 Ukraine"[5] more information on the procedure is available.

In 2014, the Espoo Implementation Committee recommended:

(f) Invite Ukraine to notify potentially affected Parties – taking into account that "potential impacts extend not only to neighbouring countries, but may also be long-range (cf. MP.EIA/WG.1/2003/3, para. 8) – about the extension of the lifetime of reactors 1 and 2 of the Rivne NPP, as required under the Convention, in due time, before the next periodic safety review due in 2020, and to undertake all subsequent steps, as appropriate, in line with the Convention;" (UNECE 2014, p. 23)

The Meeting of the Parties to the Espoo Convention agreed that Ukraine needs to conduct an EIA for the lifetime extension of Rivne 1&2. In 2017, Ukraine notified potentially affected parties, among them Austria, on the EIA. (UNECE 2017, p. 6) In 2018, Austria had indicated to Ukraine its wish to participate in the transboundary procedure and had requested Ukraine to expand the scope of the environmental impact assessment to include in sufficient detail the extent to which Austria could be affected by severe accidents. (UNECE 2018a, p. 7)

In 2020, Ukraine provided Austria with the EIA Document and in November 2020 the public participation phase started.

The Espoo procedure is still open. The Espoo Implementation Committee asked Ukraine in several documents for more clarity about the proposed lifetime extension activity and the subsequent steps, for provision of time-frames and for more information on public participation. Also clarification of the nature of the proposed decision was asked for.(UNECE 2018a, p. 7; UNECE 2018b, p. 8)

The current state of this Espoo procedure is Draft Decision VIII/4e which has been discussed at the Meeting of the Parties in December 2020. Again, Ukraine was asked to complete the trans-boundary EIA procedure and to conclude consultations with the affected parties (including Austria). Noteworthy is that Ukraine is asked to *"revis[ing] its final decision on the lifetime extension of reactors 1 and 2 of the Rivne nuclear power plant, taking due account of the outcomes of the environmental impact assessment procedure, including the environmental impact assessment documentation and comments received from the affected Parties"*, and to *"provid[ing] the revised final decision to the affected Parties, along with the reasons and considerations on which it was based*" (UNECE 2020, p. 2f.)

This Espoo Decision shows that it is still not clear if and how the results of the ongoing EIA procedure will be taken into account by the Ukrainian side.

In 2010, a periodic safety review for Rivne 1&2 had been conducted before the license was prolonged after the original 30 years of operation. (UNECE 2014,

[5] https://unece.org/environment-policyenvironmental-assessment/eiaicci4-ukraine, seen 2021-01-05

p. 21) In Ukraine, every ten years such a periodic safety review (PSR) has to be undertaken. Therefore, in 2020 the next PSR was due. According to the website of the State Nuclear Regulatory Inspectorate of Ukraine (SNRIU) a safety reassessment has been undertaken in November 2020. (SNRIU 2020c)

On 16 December 2020, SNRIU already decided upon amendment of the EO 000943 series license for Rivne 1 until 22 December 2030. (SNRIU 2020b) But the Espoo Implementation Committee had recommended to conduct and finalise the EIA before the next PSR was finished, that would have been before the license was prolonged.

Alternatives

In every EIA, alternatives have to be discussed and assessed for their environmental impacts. However, in this EIA Document alternatives were not discussed. Data on the future energy demand were not presented.

Concerning the site, it was mentioned that the population density of the Varash region now is 67-fold higher than in 1973. The number of 3,684 persons per km^2 is high when compared to the region of Aachen (in the vicinity of the Doel NP site) of 783 persons per km^2.[6] The city of Vienna has an average population density of about 4,000 persons/km^2.[7] Such a high population density should be an argument for re-considering if the site is still suitable for a NPP.

2.3 Conclusions, questions and preliminary recommendations

The original license has been issued for 30 years and was prolonged in 2010 until December 2030. The project of the lifetime extension of Rivne 1&2 is violating the Espoo Convention because the Environmental Impact Assessment has not been conducted in 2010. The “EIA/IC/CI/4 Ukraine” case under the Espoo Convention started in 2011 and is still open. In December 2020, the Meeting of the Parties to the Espoo Convention asked Ukraine to revise its final decision on the lifetime extension of Rivne 1&2, taking due account of the outcomes of the EIA procedure.

This Espoo procedure shows that it is not clear if and how the results of the ongoing EIA procedure will be taken into account by the Ukrainian side. Furthermore, the next steps of the licensing procedure are not clear.

According to the Espoo Convention a description and an assessment of reasonable alternatives and also the no-action alternative have to be included in the environmental impact assessment documentation. In this regard the EIA documentation is not sufficient.

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[6] https://ugeo.urbistat.com/AdminStat/de/de/demografia/dati-sintesi/stadteregion-aachen--einschl--stadt-aachen-/5334/3, seen 2021-01-06

[7] https://www.wien.gv.at/statistik/pdf/wieninzahlen-2020.pdf, seen 2021-01-06

Questions

1. *How will the results of the EIA be taken into account?*
2. *What are the further steps in the licensing procedure?*

Preliminary recommendation

1. Energoatom and the State Nuclear Regulatory Inspectorate of Ukraine SNRIU should provide adequate information on the EIA procedure and the further licensing procedure.
2. Alternatives of the lifetime extensions and the no-action alternative should be included in the EIA Document.
3. It is recommended to enable public participation in environmental assessments of nuclear projects according to the requirements of the Espoo Convention at a time when all options are still open.

3 SPENT FUEL AND RADIOACTIVE WASTE

In this chapter the planned management of the spent fuel and radioactive waste generated by the lifetime extension of Rivne 1&2 is assessed.

3.1 Treatment in the EIA Document

Radioactive waste of the Rivne NPP is currently not transferred to long-term storages. The facility for the long-term storage of conditioned radioactive waste TsPPVV (in the Chernobyl exclusion zone) is not prepared to receive the radioactive waste yet. (EIA REPORT BOOK 5 2018, p. 1202)

For conditioning of the solid radioactive waste, the "complex for radioactive waste processing (CRWP)" is being built. The CRWP is jointly constructed with the European Commission under the framework of TACIS. In 2018, the "hot test phase" was planned to be conducted, which should be followed by start of operation (EIA REPORT BOOK 2 2018, p. 240) The planned operation time is until the end of the lifetime of Rivne-4. (EIA REPORT BOOK 2 2018, p. 242)

Spent fuel is stored in the spent fuel pool near the reactor for a certain time span. According to an agreement between Ukraine and the Russian Federation from 14 January 1993, the spent fuel is afterwards transported to the Russian Federation for reprocessing in the Mayak facility. Ukraine is obliged to take back the vitrified high level waste (HLW) resulting from reprocessing. (EIA REPORT BOOK 2 2018, p. 260)

Due to economic assessments the storage of spent fuel in the Ukraine was justified as the preferable option compared to transport to Russia in 2009. The construction of an interim storage facility for spent fuel is planned and has been licensed in 2017. Energoatom has signed a contract with the US company Holtec International for construction of the centralized spent fuel storage facility (CSFSF) in the Chernobyl exclusion zone. This interim storage facility will be used for the spent fuel from Rivne, Khmelnitsky and South Ukraine NPPs, the total capacity will be 12,500 spent fuel assemblies from VVER-1000 and 4,000 from VVER-440. It will be operating for 100 years. (EIA REPORT BOOK 2 2018, p. 258f.)

No final repository for the spent fuel and HLW is planned yet, the Ukraine defers this decision to a later point in time. (EIA REPORT BOOK 2 2018, p. 258)

3.2 Discussion

The Espoo Convention specifies that the EIA Report has to include information on the potential environmental impact of the proposed activity, and on the mitigation measures to keep adverse environmental impacts to a minimum. (ESPOO-CONVENTION 1991 Appendix 2) Spent fuel and radioactive waste can cause adverse negative impacts on the environment, which need to be avoided or mitigated by a nuclear waste management fulfilling international safety and security standards.

The EIA Document did not provide volumes and activities for radioactive waste and spent fuel arising from the lifetime extension and the following decommissioning of the reactors. The inventory of the vitrified high level waste from reprocessing of the spent fuel that has been transported to the Mayak facility in the Russian Federation was also not given.

Once the transport to the Russian Federation will have come to an end, the spent fuel will have to be stored in an interim storage facility. The EIA Document did not explain the status of the planned interim storage facility CSFSF that is constructed by Holtec International in the Chernobyl exclusion zone. Will it be ready when needed, will it have enough capacity?

No information is given on the final repository for spent fuel and HLW.

No information is given on availabilities and capacities of interim and final storages for low and intermediate radioactive waste.

It will be welcomed if the Ukrainian side provides more information on its national nuclear waste management plan that is in force, and the status of its implementation, including information how the necessary resources will be made available.

3.3 Conclusions, questions and preliminary recommendations

The EIA Document is lacking important information on the management of the spent fuel and radioactive waste from Rivne 1&2. The expected inventory of spent fuel and radioactive waste resulting from the lifetime extension is not given.

Information on the status of the central interim storage where the spent fuel from Rivne 1&2 shall be stored (CSFSF) is lacking. No information on the final repository of spent fuel and high level waste, including the vitrified HLW resulting from reprocessing in Mayak/Russian Federation, was given.

Spent fuel and radioactive waste can cause adverse environmental impacts and therefore it will be welcomed if the Ukrainian side provides more information on its national nuclear waste management plan..

Questions

1. *What is the expected inventory of spent fuel and radioactive waste from the lifetime extension of Rivne 1&2?*
2. *What is the status of the central interim storage facility for spent fuel (CSFSF)?*
3. *Is an international cooperation for final disposal of spent fuel and/or radioactive waste planned?*
4. *Which interim and final storages for radioactive waste are in operation in Ukraine, will their capacity be sufficient to dispose of all radioactive waste from the lifetime extension and decommissioning of Rivne 1&2?*
5. *How can the safe storage of spent fuel and radioactive waste be ensured if the interim storages and final disposals will not be ready in time?*

Preliminary recommendation

1. To demonstrate the safe management of nuclear waste detailed information on the interim storages and final disposals should be provided; also alternative nuclear waste management solutions, if these facilities will not be operable in time.

4 LONG-TERM OPERATION OF REACTOR TYPE VVER 440

4.1 Treatment in the EIA Document

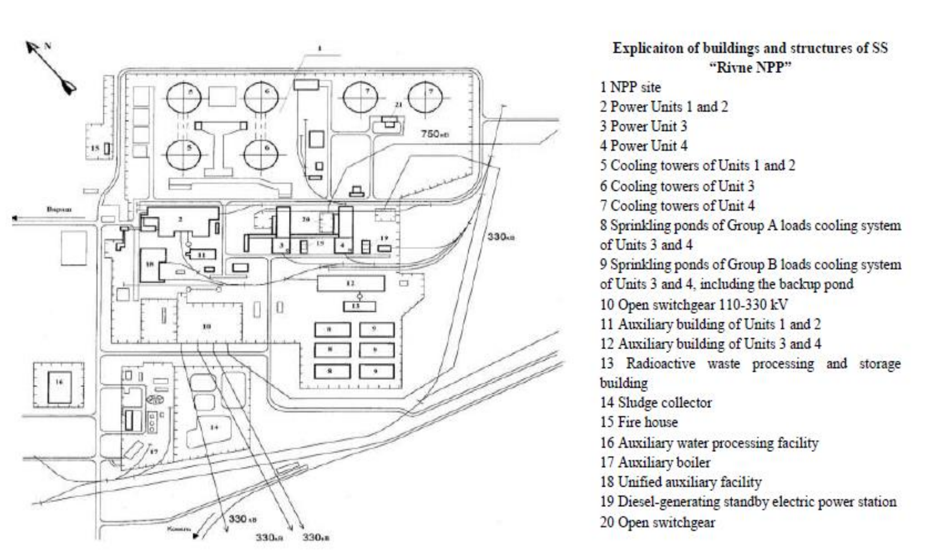
Book 2 deals with the general characteristic of the Rivne NPP. In the introduction nuclear energy is called a reliable source of power supply and that is has a leading role in addressing energy needs of Ukraine. The nuclear power plants produce about 50% of the electricity consumed in the country. The lifetime extension of the operating nuclear power units is defined in the “Energy Strategy of Ukraine for the period up to 2030” as one of the necessary conditions for implementation of goals and tasks of this strategy. (EIA REPORT BOOK2, 2018)

The entity SS Rivne NPP is a separate subdivision of the state enterprise “National Nuclear Generating Company “Energoatom” (SE NNEGC Energoatom) which the operating company responsible for safety of all nuclear power plants in Ukraine.

The Rivne NPP is located in the western Polissya, in the northern west of Rivne Oblast, nearby the Styr River.

Figure 1 shows the layout of the buildings of the Rivne NPP

Figure 1: Layout of Rivne NPP site



Source: EIA REPORT BOOK 2 2018

In 1971, the design work for the Western Ukrainian NPP started, later it was renamed Rivne NPP. The power plant supplies the western part of the country with electricity. Rivne NPP is delivers heat not only for the plant site but also the town of Varash and the village Zabolottya.

Rivne NPP was the first nuclear power plant in Ukraine with a water-water power reactor of the VVER-440 type. The unit’s construction started in 1973. The two units with VVER-440/V213 reactors were put into operation in 1980-1981, and the third power unit with VVER-1000/320 reactor was commissioned in 1986.On

October 16, 2004 the power unit 4 of Rivne NPP was put into operation.[8]The design lifetime of all operating power units of Ukraine is 30 years.

The plant design includes the following basic safety principles according to the EIA Document:

- establishment of the physical barriers on the way of radioactive material release (fuel matrix, fuel element cladding, reactor coolant boundaries, containment of the reactor facility, biological shielding);
- availability of special safety systems, which are designed on the principle of parallel trains that perform one and the same function;
- introduction of the principles of independence, redundancy, physical division and consideration of every incident during establishment of the safety system;
- high technical characteristics of localization system that prevents of radioactive releases into the environment;
- high level of process control and automation system, including elimination of emergencies during the most responsible phase (primary) of the accident without personnel actions;
- safety provision under the conditions of external impacts, specific for the sites under consideration, including natural and man-made impacts;
- application of the conservative approach to selection of the technical solutions that influence the safety;
- introduction of measures and technical solutions aimed at:
  - protection of the isolation systems during design-basis accidents;
  - prevention of the initiating event transition into the design-basis accident;
  - mitigation of accident consequences which were not prevented;
- possibility to verify and test the safety related equipment and systems to maintain them in an operable state;
- design and set-up of the controlled area and surveillance zone;
- ensure the quality as per requirements of the relevant regulatory documentation.

The system of technical and organizational activities, implemented in the plant design, has five levels:

- Level 1: Establishment of conditions to prevent violation of plant normal operation;
- Level 2: Prevention of design-basis accidents using normal operation systems;
- Level 3: Prevention of accidents using safety systems;
- Level 4: Management of beyond design-basis accidents;
- Level 5: Planning of activities for personnel and public protection.

The conclusion that the designs of the operating Ukrainian NPPs take into account all possible external extreme natural impacts was based on the results of

[8] Construction of the power unit 4 of Rivne NPP started in 1984, however, because of the Moratorium on prohibition to construct nuclear objects on the territory of Ukraine, the further works were suspended. After cancellation of the moratorium the power unit was examined, the program for its modernization was developed.

the “stress-tests” and the “Action Plan for unscheduled target assessment and further safety improvement of Ukrainian NPPs taking into account events at Fukusima-1”. It was conducted at the request of the State Nuclear Regulatory Inspectorate of Ukraine (SNRIU) and European Nuclear Safety Regulators Group (ENSREG). The plant safety, with all considered external extreme natural impacts in the design, is justified in the Safety Analysis Report. The results of additional reviews and walkdowns did not indicate the presence of any additional factors, which influence the operability of the equipment that ensures safety of the plant; operating Ukrainian NPPs have a safety margin with respect to external extreme natural impact.

The conducted equipment qualification confirmed that the external hazards characteristics are above the design values; to ensure long-term heat removal under the conditions of extreme hazards the NPPs apply additional options of power supply in case of loss of power and implement special activities for long-term emergency heat removal.

The **Safety Review** Reports are periodically developed (in compliance with the regulatory requirements). These contain the analysis of 14 Safety Factors (SF):(EIA REPORT BOOK1, 2018)

– SF-1 “Power unit design”;

– SF -2 “Current state of power unit systems, structures and components”;

– SF -3 “Equipment qualification”;

– SF -4 “Structures, systems and components ageing”;

– SF -5 “Deterministic safety analysis”;

– SF -6 “Probabilistic safety analysis”;

– SF -7 “Analysis of internal and external impacts”;

– SF -8 “Operational safety”;

– SF -9 “Use of other NPP experience and scientific research results”;

– SF -10 “Organization and management”;

– SF -11 “Operating documentation”;

– SF -12 “Human factor”;

– SF -13 “Emergency preparedness and planning”;

– SF -14 “Impact of NPP operation on the environment”.

4.2 Discussion

Nuclear power plants undergo two types of adverse time-dependent changes:

- Physical Ageing of structures, system and components (SSCs), which results in gradual deterioration in their physical characteristics.
- Conceptual and Technological Ageing: obsolescence of technologies and design, i.e. the plants becoming out of date in comparison with current knowledge, standards and technology.

Although aging is a safety issue for Rivne 1&2, it is not addressed in the EIA Report. Only "Structures, systems and components aging" are mentioned as a safety factor (SF) within the PSR.

Physical Ageing and Ageing Management

The term ‘physical ageing’ encompasses the time-dependent mechanisms that result in degradation of a component’s quality. Unexpected combinations of various adverse effects such as corrosion, embrittlement, crack progression or drift of electrical parameters may result in the failure of technical equipment, leading to the loss of required safety functions. Life-limiting processes include the exceeding of the designed maximum number of reactor trips and load cycle exhaustion.

Even though the fundamental ageing mechanisms are well-known in principle, their potential to lead to incidents and accidents may not be fully recognized before the actual events take place. In particular in old NPPs several undetected failures exist, some of these failures threaten the safety of the plant. Failures caused by ageing of material have the potential to aggravate an accident situation or trigger an incident.

Choice of materials, design and manufacturing process influence the occurrence and acceleration of ageing mechanisms. Due to lack of operational experience in the earlier years of construction of nuclear power plants, the choice of materials and production processes was not always the best choice.

To limit ageing-related failures at least to a certain degree, a comprehensive ageing management program (AMP) is necessary. AMPs include programs with accelerated samples, in-service inspections, monitoring of thermal and mechanical loads, safety reviews and also the precautionary maintenance or even exchange of components, if feasible. Furthermore, it includes optimizing of operational procedures to reduce loads.

In case of obvious shortcomings, the exchange of the components is the only possibility to prevent a dangerous failure. Even large components like steam generators and reactor pressure vessel heads can be exchanged. All components crucial for safety can be replaced – apart from the reactor pressure vessel (RPV), and the containment structure.

In many cases, non-destructive examinations permit to monitor crack development, changes of surfaces and wall thinning. But changes of mechanical properties often cannot be recognised by non-destructive examinations. Therefore, it is difficult to get a reliable, conservative assessment of the actual state of materials. Furthermore, the limited accessibility due to the layout of components and/or high radiation levels does not permit sufficient examination of all components. Therefore, it is necessary to rely on model calculations in order to determine the loads and their effects on materials.

The measures of the intensification of plant monitoring and/or more frequent examinations, coupled with appropriate maintenance both rely on the optimistic assumption that cracks and other damage and degradation will be detected before they lead to failure. However, this is not always realistic. Tracking the condition of all the equipment is a complicated task for systems as complex as NPP. Once the reactors have passed their design lifetime, the number of failures could start to increase.

Ageing management programs (AMPs) so far implemented have not been sufficient to avoid the occurrence of serious ageing effects.

Topical Review of Ageing Management

The Topical Peer Review (TPR) as set out in Article 8e of Directive 2014/87/EURATOM (EU 2014) has been carried out in 2017. The first TPR focused on the Overall Ageing Management Programmes and four thematic areas: electrical cables, concealed pipework, reactor pressure vessels and calandria, and concrete containment structures. All participating countries made a self-assessment and reported results in their National Assessment Reports .In the course of the TPR, national results have been evaluated through the peer review process, complementing the national assessments. The review identified generic findings, namely good practices and expectations to enhance ageing management (ENSREG 2018):

- Good practice is an aspect of ageing management which is considered to go beyond what is required in meeting the appropriate international standard.
- TPR expected level of performance for ageing management is the level of performance that should be reached to ensure consistent and acceptable management of ageing throughout Europe

Ageing Management in Ukraine

The following section summarizes the SNRIU (2017) findings and ENSREG peer review assessment of the TPR on Ageing Management.

Overall Ageing Management

The Standard AMP was developed by the operator in 2004, and implementation of ageing management approaches at Ukrainian NPPs has begun then.

According to SNRIU (2017), the Standard AMP is the main document of the operator and establishes overall requirements for the procedure for ageing management of components and structures and determines the scope and sequence of LTO activities. The main drawback of the Standard AMP is that it combines aspects of AM and LTO, while they should be governed by separate documents of the operator. This drawback has been practically removed by the operator through development of two separate industry standards that govern AM and LTO.

SNRIU conducts continuous oversight and monitoring of AMP implementation at Ukrainian NPPs. The operator annually submits reports on AMP implementation to SNRIU. SNRIU assesses and checks information provided in the operator's reports during scheduled inspections at NPPs, particularly in assessment of issues related to ageing management.

The Peer review team criticized the methodology for scoping the SSCs subject to ageing management: The scope of the AMP is not reviewed and, if necessary, updated, in line with the new IAEA Safety Standard after its publication. (ENSREG 2018)

Ageing management of electrical cables

Inspection findings for cables used in the containment are mainly positive. Some cables that show unsatisfactory mechanical and capacity characteristics of insulation in laboratory tests after accelerated thermal and radiation ageing are replaced.

The Automated Ageing Management System for Power Unit Components (AAMS) is implemented, which is a separate software application integrated with the lists, directories and classifiers of the Ukrainian equipment reliability database.

SNRIU states that the proper attention is paid to the ageing management of electrical cables at NPP units both during the design-basis life and in the LTO period.

In addition, in the framework of measures related to replacement of equipment in instrumentation and control systems and electrical equipment, control and power cables have been or are going to be replaced with fire retardant ones and those in automated firefighting systems and emergency power supply systems with fireproof ones.

Ageing management of concealed pipework

Preventive and remedial measures for concealed pipework are established based on TCA activities, technical examination and monitoring individually for each power unit. TCA activities performed at Ukrainian NPPs revealed insignificant worsening of underground piping condition.

The activities performed by the operator regarding ageing management of concealed pipework meet the regulatory requirements at the same time taking into account that the contactless diagnostics methods are constantly improved, in particular in terms of improving accuracy of determining parameters, the SNRIU recommended the operator to continue the following measures on a permanent basis:

- analyze current research and development whose purpose is to perform adequate assessment (diagnostics) of current technical condition for piping, which is deepened in the ground and is not easily accessible for examination;
- analyze current international experience in assessing the current technical condition of these piping;
- involve specialized organizations having experience in designing, operating and repairing similar piping in other industries, etc.

The peer review team criticized in regard of the AM of concealed pipework: Inspection of safety-related pipework penetrations through concrete structures are not part of ageing management programmes, unless it can be demonstrated that there is an active degradation mechanism. The peer review criticized also the scope of the concealed pipework included in the AMP because non-safety-related pipework which when failing might impact SSCs performing safety functions are not included. On top critic was directed toward the opportunistic inspection of concealed pipework for not being undertaken whenever the pipework becomes accessible for other purposes. (ENSREG 2018)

Ageing management of RPV

The Reactor Pressure Vessel (RPV) is a component that cannot be replaced and its current and estimated technical condition affects long-term operation of the power unit. Given this issue, both the operator and regulator pay special attention to RPV ageing management. According to the specified aspects, new systems of remote NDI of RPV metal condition are implemented at Ukrainian NPPs. There are improvements in the methodology for calculation of fluence, thermo-hydraulic parameters and strength calculation, which are reflected in TLAA used to justify safety of reactor pressure vessel long-term operation.

To provide more reliable results of tests for the surveillance specimens already removed from the reactor, the operator uses the reconstruction technology to increase the number of specimens to plot serial curves of bending tests and improve the accuracy and reliability of the mechanical properties of irradiated RPVs.

The operator developed and is implementing the Integrated Program in order to receive additional data on regular, modernized and new surveillance programs to improve reliability of the assessment of changes in RPV metal properties. According to this program, the surveillance specimens are irradiated in the beltline region. At the same time, the applied use of the results of implementing this program is complicated by a number of factors that are still not resolved by the operator.

The process of RPV AM continues to be improved on the basis of accumulated national and international experience and results of the implementation of research and development programs.

The Peer Review criticized regarding the Non-destructive examination (NDE) that comprehensive NDE is not performed in the base material of the beltline region in order to detect defects. Additionally, it is criticized that fatigue analyses have not taken into account the environmental effect of the coolant.(ENSREG 2018)

Ageing management of concrete containment structures

The experience gained with activities conducted on TCA based on the results of instrumental, visual inspection and calculation of strength and carrying capacity indicates that the revealed defects and damages have no effect on the carrying capacity of the structures. Further operation (for the period of LTO) of containment structures is allowed in the design mode without restrictions, but on condition of the implementation of ageing management measures.

One of the important factors affecting the determination of tendon tension is the level of design-basis earthquake. In this case, it is necessary to note that the seismic level of NPP sites was reevaluated over the past 10 years and the new level is actually two or three times higher than the design level. Such a calculation, as a rule, is performed with activities on power unit preparation to LTO separately for each power unit, since the seismic level of sites varies and every containment has its own specifics, so the calculation is performed individually. Relevant measures on AM are developed according to the calculation results.

According to the Peer Review, the Pre-stressing forces are monitored on a periodic basis to ensure the containment fulfils its safety function, this is assessed as good performance. (ENSREG 2018)

All in all, the TPR revealed several shortcomings in the Ageing Management of the Ukrainian NPPs.

Interesting to compare: In 2013 the Finnish Nuclear Regulator (STUK) published a guide dedicated to ageing management. In addition, an expert group dedicated to ageing management has been established in the authority (STUK) to oversee how the licensees perform their duties in the ageing management of SSCs. (UMWELTBUNDESAMT 2020)

Conceptual and technological ageing

The development of science and technology continuously produces new knowledge about possible failure modes, properties of materials and verification, testing and computational methodologies. This leads to technological ageing of the existing safety concept applied in nuclear power plants. At the same time, as a result of lessons learnt in particular by major accidents at Three Mile Island, Chernobyl and Fukushima Daiichi, earlier safety concepts are becoming obsolete. Furthermore the 9/11 terror attacks showed the need for increasing the protection against external hazards. Older nuclear power plants have not been designed to withstand the impact of commercial aircraft or other terror attacks.

The safety design of nuclear power plants is very important to prevent as well as to deal with incidents or accidents. Therefore, a risk assessment of a nuclear power plant has to consider the design base including the operational experience of all other comparable plants. The Fukushima accident raised new concerns since it revealed that the old units could have basic safety problems dating back from the sixties or seventies when they were designed.

The old reactor types VVER-440/V213 have several design weaknesses, which cannot be resolved by performing back-fitting measures. The VVER-440 reactors are designed as twin units, sharing many operating systems and safety systems, for example the emergency feedwater system, the central pumping station for the essential service water system, and the diesel generator station. The sharing of safety systems increases the risk of common-cause failures affecting the safety of both reactors at the same time.

All VVER-440 type reactors (with the exception of Loviisa in Finland) have only a basic level of containment. External hazards such as earthquakes, chemical explosions or aircraft impacts were not taken into account in the original design of these plants. To overcome major shortcomings of the design, both Finnish VVER-440/V213 reactors are equipped with Western-type containment and control systems.

The first units in Ukraine that have reached their original 30-year operation time were the units 1 and 2 of the Rivne NPP. Although safety relevant issues, identified in 1999, were not completely solved, the State Nuclear Regulatory Inspectorate of Ukraine (SNRIU) granted 20-year lifetime extensions in December 2010. The plant operator noted that more than USD 300 million has been invested in the modernization of Rivne- 1&2 since 2004 (OECD 2012).

The stress tests revealed that Ukrainian NPPs are compliant only with 172 of the 194 requirements according to the IAEA Design Safety Standards published in 2000.[9] Meanwhile, even this IAEA document is outdated; in January 2012 new safety requirements were published by IAEA (IAEA 2012).

The lack of compliance with the IAEA Safety Standards is remarkable, because during the last decade, the European Commission, the EBRD, EURATOM and the IAEA supported the safety analysis of VVER reactors and provided significant funds to enhance the safety of these plants[10]:

During the first safety upgrade program (2002 – 2005), only 35% of the envisaged 89 measures were implemented. The second program (2006 – 2010) was supposed to complete the safety measures from the former program and to adopt the new requirements formulated by international organisations (IAEA and WENRA). But only 80% of 253 pilot measures and 37% of 472 adopted measures were implemented by 2010 (WENISCH & LORENZ 2012).

Taking into account the results of the implementation of former safety upgrade programs, the outcomes from joint IAEA-EU-Ukraine projects and strengthening national regulatory requirements, the United Safety Upgrade Program (2010 – 2017) has been developed (BOZHKOA et al. 2009). The implementation of necessary improvements is on-going in the framework of the recently adopted Upgrade Package (e.g. (C(I)SIP). According to SNRIU (2016), the implementation of measures should be finished at the end of 2017. However, completion of the improvements was re-scheduled to 2023.

WENRA Safety Reference Level

In 2014, the Western European Nuclear Regulators Association (WENRA) published a revised version of the Safety Reference Levels (RLs) for existing reactors developed by the Reactor Harmonisation Working Group (RHWG). The objective of the revision was to take into account lessons learned of the TEPCO Fukushima Daiichi accident. (WENRA RHWG 2014a) Note: SNRIU participated in WENRA activities as an observer since 2009.

A major update of the RLs was the revision of Issue F "Design Extension of Existing Reactors" introducing the concept of Design Extension Conditions (DEC).The term design extension condition (DEC) has been introduced to achieve consistency with the IAEA SSR-2/1 safety standard (IAEA 2016).

Occurrence of conditions more complex and/or more severe than those postulated as design basis accidents (DBA) cannot be neglected in safety analyses. These conditions shall be investigated as Design Extension Conditions (DEC) so

[9] Under the framework of joint IAEA-EC-Ukraine projects a design evaluation was carried out to conduct an overall evaluation of the compliance of the design of the Ukrainian NPPs with the IAEA Safety Standards “Safety of Nuclear Power Plants: Design” (NS-R-1) published in 2000.

[10] In March 2013 the European Bank for Reconstruction & Development (EBRD) announced a EUR 300 million loan for comprehensive reactor safety upgrading to the end of 2017, matching EUR 300 million from EURATOM. The project should include up to 87 safety measures addressing design safety issues comprising the replacement of equipment in safety relevant systems, improvements of instrumentation and control for safety relevant systems and the introduction of organizational improvements for accident management. (EBRD 2013)

that any reasonably practicable measures to improve the safety of a plant are identified and implemented. (RL F1.1) RL F1.2 defines two categories of DEC:

- DEC A for which prevention of severe fuel damage in the core or in the spent fuel storage can be achieved; and
- DEC B with postulated severe fuel damage.

WENRA RHWG (2018a) reports on the implementation of the revised RLs in the national regulatory frameworks of WENRA countries. RHWG suggested and WENRA agreed to restrict the review to the implementation of the RLs that were updated and developed after the accident at Fukushima Dai-ichi NPP. Figure 2 lists the new and revised WENRA RL.

Figure 2: Revised or new WENRA reference Levels

Issue	No. RLs
Issue A: Safety Policy	1
Issue B: Operating Organization	1
Issue C: Management System	3
Issue D: Training and Authorization of NPP Staffs	1
Issue G: Safety Classification of SSCs	1
Issue N: Contents and Updating of SAR	4
Issue O: PSA	2
Issue P: PSR	5
Issue S: Protection against Internal Fires	1
Issue E: Design Basis Envelope	13
Issue F: Design Extension	25
Issue LM: EOPs and SAMGs	13
Issue R: On-site Emergency Preparedness	12
Issue T: Natural Hazards	19

Source: WENRA RHWG 2018a

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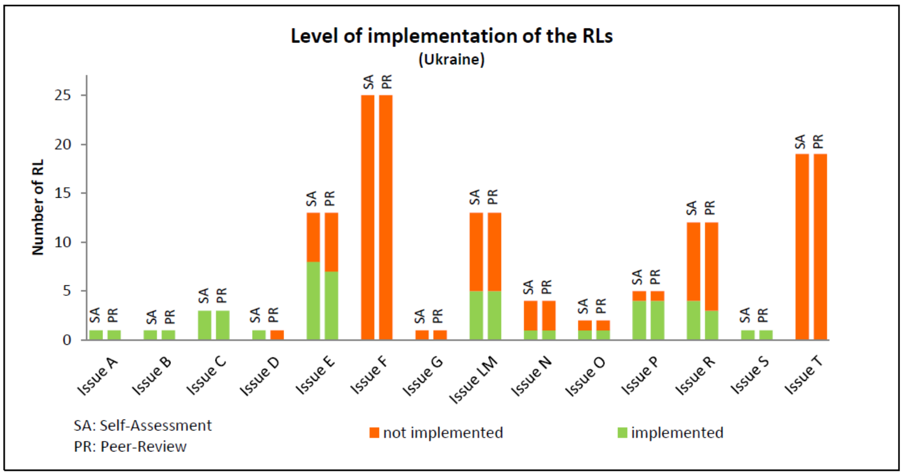
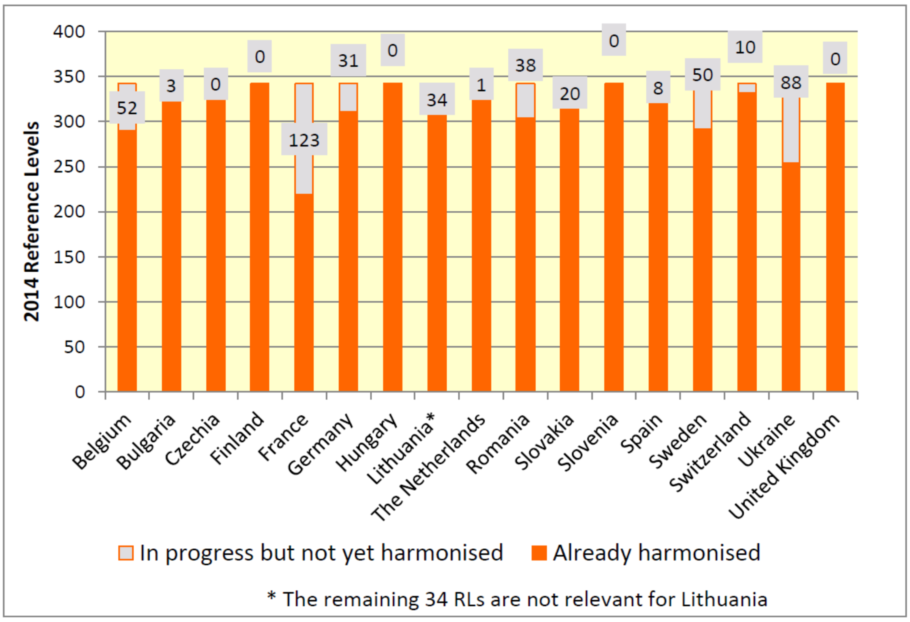
The State Nuclear Regulatory Inspectorate of Ukraine (SNRIU) performed the self-assessment of issues A, B, C, D, G, N, O, P, S. Figure 3 shows the status of the self-assessment (November 2015) and the result of the peer-review (March 2016). It illustrates that at that time Ukraine had not implemented the new RL F and T in the regulations.



Source: WENRA RHWG 2018a

Figure 3: Status of implementation of new and revised RL in Ukraine

Ukraine announced the full implementation of the remaining 74 RLs into the national regulation until March 2018. However, it has to be noted that Ukraine has not implemented 88 RL of the 342 as of 1 January, 2019, see **Fehler! Verweisquelle konnte nicht gefunden werden.**. (WENRA RHWG 2020a)



Source: WENRA RHWG 2020a

Figure 4: Reported status of implementation of 2014 RL in 2020

4.3 Conclusions, questions and preliminary recommendations

Although ageing of the 40 years old structures, buildings and equipment is a safety issue for the Rivne 1&2, it is not addressed in the EIA Report. It only refers to "Structures, systems and components aging" being a safety factor (SF) within the periodic safety review (PSR). The adverse effect of ageing depends also on the inspection, restoration and protection measures taken. A comprehensive ageing management program (AMP) is necessary to limit ageing-related failures at least to a certain degree. However, information of an ageing management programme (AMP) is also not provided in the EIA Report.

Ukraine participated in the Topical Peer Review (TPR) "Ageing Management" in the framework of the implementation of the Nuclear Safety Directive 2014/87/EURATOM, carried out in 2017/18. Several "areas for improvement" were identified, i.e. deviation of the TPR expected level of performance for ageing management that should be reached to ensure consistent and acceptable management of ageing throughout Europe. The results of the TPR and the activities to remedy the weaknesses should be presented in the EIA Report, in particular the very important safety issue of the RPV embrittlement should be discussed.

Although conceptual ageing is also an issue for the Rivne 1&2, the EIA Documentation does not deal with any of the known safety issues of the VVER-440/V213 reactors. VVER 440/V213 units have several design weaknesses: the reactor building and the spent fuel pool building are relatively vulnerable against external events. VVER-440 reactors are designed as twin units, sharing many operating systems and safety systems. The sharing of safety systems increases the risk of common-cause failures affecting the safety of both reactors at the same time.

This NPP design developed in the 1980s, only partly meets modern design principles such as redundancy, diversity and physical separation of redundant subsystems or the preference for passive safety systems. The EIA Document neither provides a description of the safety-relevant systems, nor information about the capacities, redundancies and physical separation.

In December 2010, although safety relevant issues are not completely solved, the State Nuclear Regulatory Inspectorate of Ukraine (SNRIU) granted 20-year lifetime extensions for Rivne 1&2. The stress tests revealed 2011 that Ukrainian NPPs are compliant only with 172 of the 194 requirements according to the IAEA Design Safety Standards published in 2000.[11]. Implementation of necessary improvements is on-going under the Upgrade Package. This includes the Comprehensive (Integrated) Safety Improvement Program(C(I)SIP). The completion of the program was postponed several times. Completion is now scheduled for 2023.

SNRIU participates in the Western European Nuclear Regulators Association (WENRA) activities as an observer since 2009. In 2014, WENRA published a

[11] Under the framework of joint IAEA-EC-Ukraine projects a design evaluation was carried out to conduct an overall evaluation of the compliance of the Ukrainian NPPs design with the IAEA Safety Standards "Safety of Nuclear Power Plants: Design" (NS-R-1) published in 2000.Meanwhile, even this IAEA document is outdated; in January 2012 new safety requirements were published by IAEA (2012).

revised version of the Safety Reference Levels (RLs) for existing reactors developed by the Reactor Harmonisation Working Group (RHWG). The objective of the revision was to take into account lessons learned of the TEPCO Fukushima Daiichi accident. A major update of the RLs was the revision of Issue F "Design Extension of Existing Reactors" introducing the concept of Design Extension Conditions (DEC). However, it has to be noted that Ukraine has not implemented 88 RL of the 342 as of 1 January 2019.

Questions

1. *What is the time schedule for the necessary improvement of the ageing management programme (AMP) based on the findings of the Topical Peer Review (TPR) based on Article 8e of EU Directive 2014/87/EURATOM?*
2. *What are the specific findings of the ageing management programme for Rivne 1&2?*
3. *What are the results of Safety Factor (SF) 4 (structures, systems and components ageing) of the last periodic safety review?*
4. *What are the results of the embrittlement of the reactor pressure vessels (RPVs)?*
5. *Is the preparation of a systematic evaluation of the Rivne 1&2 design deviations from the current international safety standards and requirements envisaged?*
6. *Which safety systems and Severe Accident Management (SAM) systems are shared between the units?*
7. *To which extent were and will international documents (IAEA, WENRA) be applied in a binding manner for the lifetime extension?*
8. *When will the WENRA RL be fully implemented in the Ukrainian regulations? Is the application of the RL binding?*
9. *When will be conducted a review on whether the Rivne 1&2 meets the WENRA RL requirements?*

Preliminary Recommendations

1. It is recommended to implement all available design improvements of VVER-440/V213 reactor at the Rivne 1&2.
2. It is recommended to compare the design and features of the Rivne 1&2 with all requirements of WENRA RL F. In case of deviations, the reasons for this should be explained.
3. It is recommended to provide the following further information:
    a. detailed descriptions of the safety systems, including information on requirements for the important safety-relevant systems and components. Furthermore, detailed description of the measures taken to control severe accidents or to mitigate their consequences.
    b. Information about the applied national requirements and international recommendations.

c. comprehensible presentation and overall assessment of all deviations from the current state-of-the-art of science and technology. This presentation should include:
   - All deviations from the modern requirements for redundancy, diversity and independence of the safety levels.
   - Incompleteness of the database and plant documentation used.
   - Presentation of all safety assessments or parameter definitions by personal expert assessments ("engineering judgement").
   - Presentation of the general approach in dealing with uncertainties and non-knowledge and its effects on risk
   - Deviations from the state-of-the-art of science and technology with regard to the detection methods used, the technical estimates and calculation procedures.
   - Safety margins available for the individual safety-relevant components and their respective ageing related changes compared to the original condition.
d. Information about the ageing management program including:
   - The national action plan relating to the Topical Peer Review (TPR) "Ageing Management" under the Nuclear Safety Directive 2014/87/EURATOM and its progress.
   - The very important safety issue of the ageing of the RPVs (embrittlement), including definition and justification of appropriate safety margins.

5 ACCIDENT ANALYSES

5.1 Treatment in the EIA Document

Book 3, Volume 2 contains calculations of the radiation impact of radioactive releases from Rivne NPP on the environment and the population during normal operation and accidents. Calculations have been performed using PC COSYMA software suite developed for emergency cases by the National Radiological Protection Board (UK).(EIA REPORT BOOK 3VOL. 2, 2018)

It is explained that all calculations have been performed for conservative conditions of impurity propagation and radiation dose formation (at maximum doses).

Design basis accidents

The radiological effects of the following design basis accidents (DBA) were determined:

- Maximum DBA (MDBA) The radioactive release of Cs-137 is 5E+11 Bq, the total activity of the release is 7.17E+13 Bq.
- DBA: "*Steam Generator Header Cover Lift-Up--Emergency Spike*". The release of Cs-137 is 5.30E+11 Bq, the total activity of the release is 4.35E+15 Bq.
- DBA: "*Steam Generator Header Cover Lift-Up Pre-Emergency Spike*". The release of Cs-137 is 5.30E+11 Bq, the total activity of the release is 2.59E+14 Bq.
- DBA: "*Hydraulic Lock Drop in the Spent Fuel Pool*". The release of Cs-137 is 5.8E+11 Bq, the total activity of the release is 5.34E+14 Bq.
- DBA: "Fuel Assembly Drop on the Reactor Core and FA Top Nozzles in the Spent Fuel Pool". Radioactive release of Cs-137 is6.50E+10Bq; total activity of release is 1.05E+14Bq.
- DBA: "*Spent Fuel Container Drop from Height of more than 9 meters*". Radioactive release of Cs-137 is 7.3E+11 Bq, the total activity of release is 2.45E+12 Bq.
- DBA: "*Fuel Assembly Drop on the Reactor Core in the Reactor*". Radioactive release of Cs-137 is 8.2E+11Bq, the total activity of release is: 1.21E+14 Bq.
- DBA: "*Impulse Tube Rupture beyond the Containment*". The activity of the Cs-137 release is 7.40E+09Bq, the total activity of release is 1.32E+14 Bq.
- DBA: "*Planned Cool Down Line Rupture*". The activity of the Cs-137 release is 3.70E+07Bq, the total activity of release is 6.80E+12Bq.

The MDBA with the dose of 0.316 mSv is the most hazardous DBA for humans within a 1-year period. The DBA "Fuel assembly drop on the reactor core in the rector" with the dose of 3.18 mSv is the most hazardous DBA for humans within a 50-year period.

It continues by stating that in case of design basis accidents, the levels of unconditionally justified emergency intervention in case of acute exposure are not exceeded, the levels of prevented doses do not exceed the levels of unconditional justification, there is no need for planning of basic urgent countermeasures, support countermeasures at such a level of prevented doses are not appropriate;

equivalent individual doses for 1 year for the thyroid gland in children by inhalation and for the entire body due to external exposure at the most adverse conditions at the border and beyond the sanitary protection zone do not exceed the threshold values of 0.3 Sv/year and 0.1 Sv/year, respectively.

Beyond Design Accident (BDBA)

Chapter 12 of the Book 3 Volume 2 described the impact of the radioactive releases in case of a beyond design accident (BDBA). The activity of the Cs-137 release is 3.0E+13Bq (30 TBq), the total activity of release is 1.25E+18Bq.(EIA REPORT BOOK 3, VOL. 2, 2018)

It is concluded that in case of a beyond design basis accident (BDBA), the levels of unconditional justification for urgent countermeasures are not exceeded, therefore no countermeasures of any type are necessary.

It is stated that based on the calculation data, within 2 weeks of a BDBA at the border of the SPZ (2.5 km) lower justifiability limits are exceeded, and shelter, iodine prophylaxis in children and limited stay outside for both children and adults may be needed, while at the border of the OZ (30 km), shelter and limited stay outside are required.

In Book 2 of the EIA Report, it is explained that analysis of the radiation consequences during the beyond design-basis accidents was performed in the framework of the periodic safety review and during development of the severe accident guidelines. (EIA REPORT BOOK 2, 2018)

During the development of the severe accident guidelines, analysis of the radiation consequences was performed for the following severe accidents:

- Loss of coolant accident (LOCA), Dn2×850 mm, with combination of loss of all AC-power;
- LOCA, Dn×850 mm, with combination of loss of all AC-power, not considering the “failure” of ionizing chambers with filtered releases from the containment;
- Loss of all AC-power;
- Primary-to-secondary leak, Dn2×13 mm, with combination of loss of all 6kV busses of emergency power supply system;
- Primary-to-secondary leak, Dn100 mm, with loss of all 6kV busses of emergency power supply system. (EIA REPORT BOOK 2, 2018)

5.2 Discussion

The “Safety Objectives for New Power Reactors” published by the reactor harmonization working group (RHWG) Western European Nuclear Regulator’s Association (WENRA) can be seen as the state of the art. These safety objectives, formulated in a qualitative manner to drive design enhancements for new plants, should be also “used as a reference for identifying reasonably practicable safety improvements for existing plants in case of periodic safety reviews”. (WENRA RHWG 2013)

The most ambitious safety objective is to reduce potential radioactive releases to the environment from accidents with core melt. (Safety objective O3) Accidents with core melt which would lead to early releases without enough time to implement off-site emergency measures or large releases which would require protective measures for the public that could not be limited in area or time have to be practically eliminated.Even if the probability of an accident sequence is very low, any additional reasonably practicable design features, operational measures or accident management procedures to lower the risk further should be implemented. (WENRA RHWG 2013)

Although a continuous effort to increase the scope of the severe accidents that have been taken into consideration and to reduce their off-site consequences was undertaken, a further reduction of the potential radiological consequences is an important goal for new and operating NPPs. In that context, the concept of "practical elimination" of early or large releases is defined. Occurrence of certain severe accident conditions can be considered as practically eliminated *"if it is physically impossible for the conditions to occur or if the conditions can be considered with a high degree of confidence to be extremely unlikely to arise"*. (IAEA 2016)

The concept of "extremely unlikely with a high degree of confidence" constitutes an essential element of the concept of "practical elimination", as defined by the IAEA. The demonstration that an accident is extremely unlikely with a high degree of confidence should take account of the assessed frequency of the condition and of the degree of confidence in the assessed frequency. The uncertainties associated with the data and methods should be evaluated, including the use of sensitivity studies, in order to support the degree of confidence claimed. The demonstration should not be claimed solely based on compliance with a general cut-off probabilistic value.

Although probabilistic targets can be set, "practical elimination" cannot be demonstrated by showing the compliance with a general probabilistic value. No probabilistic value can be accepted as a justification for not implementing reasonable design or operational measures. The "practical elimination" can be demonstrated by deterministic and/or probabilistic considerations, taking into account the uncertainties due to the limited knowledge of some physical phenomena. The low probability of occurrence of an accident with core melt is not a reason for not protecting the containment against the conditions generated by such accident.

The accident sequences that have a potential to lead to early or large releases involve both severe damage of the reactor core and the loss of the containment integrity or containment by-pass. The consideration of severe accidents should be aimed at practically eliminating the following conditions (IAEA 2016b):

- "Severe accident conditions that could damage the containment in an early phase as a result of direct containment heating, some steam explosions or large hydrogen detonation;
- Severe accident conditions that could damage the containment in a late phase as a result of basemat melt-through or containment excessive pressure;
- Severe accident conditions with an open containment – notably in shutdown states;
- Severe accident conditions with containment bypass, such as conditions relating to the rupture of a SG tube or an interfacing system LOCA".

Containment integrity

According to ENSREG (2015), maintaining containment integrity under severe accident conditions remains an important issue for accident management. Filtered containment venting is a well-known approach to prevent containment overpressure failure in most light water reactor (LWR) and has already been implemented in several countries. It is not implemented at Rivne 1 and 2 yet.

Different approaches for cooling and stabilizing molten core are available. For some of the smaller reactors in Europe the installation of in-vessel retention (IVR) is considered for some plants. The modifications should enable the in-vessel retention of corium by external cooling of the RPV. The IVR measure will be implemented at Rivne 1&2 in the next years.

Then, the Rivne1&2 severe accident management (SAM) strategy strongly will rely on retaining corium inside the pressure vessel. However, if all means to cool corium inside the pressure vessel fail, a situation might arise, where the bottom part of the reactor pressure vessel is damaged and molten corium falls into the reactor cavity. Primary circuit depressurisation prevents high pressure scenarios and vessel failure itself should not jeopardize the containment integrity in case the reactor cavity is dry. But if water is present in the reactor cavity, it is pressurized by interaction between molten corium and water.

The EIA Report should explain how the above-mentioned safety issues that endanger the containment integrity (containment bypass scenarios, cliff-edge effects in shutdown states) of the IVR concept are solved.

Stress test

In June 2011, Ukraine joined the European initiative of conducting stress tests at nuclear power plants in EU member states and neighbouring countries. The stress tests were performed at Ukrainian NPPs in compliance with the stress test specifications agreed by the European Commission (EC) and ENSREG. The State Nuclear Regulatory Inspectorate of Ukraine (SNRIU) submitted the National Report developed in line with ENSREG recommendations to the EU Stress Test Secretariat on 30 December 2011.

The peer review country report for Ukraine concluded that the National Report of Ukraine complied with the ENSREG specifications, provided sufficient information to understand the design basis for external natural events, and identified adequate measures to compensate for safety deficiencies revealed. In addition, it was pointed out that previously planned NPP safety improvements should be completed.

In order to monitor the implementation of safety improvements at Ukrainian NPPs identified in the stress test and peer review processes, the SNRIU Board convened on 20 November 2012 to hold an open meeting. The SNRIU Board identified additional safety improvements related to severe accident management to take into account peer review recommendations.

The National Action Plan (NAcP) was developed at the beginning of 2013 to implement recommendations of the peer review of stress tests at Ukrainian NPPs. The National Action Plan is revised and updated by the SNRIU on a permanent basis. For this purpose, the information set forth in the NAcP was updated in 2015, 2017 and 2020. (SNRIU 2020a)

The Ukrainian NAcP of 2013 listed 32 measures. A new measure (No. 33: Implementation of a Reactor Pressure Vessel External Cooling System) was added to the NAcP in 2020. The deadline of the new measure is 31 December 2021. (SNRIU 2020a)

A number of measures were defined before the Fukushima event and are subject to the on-going "Comprehensive (Integrated) Safety Improvement Program for Ukrainian NPPs" (C(I)SIP). Measures identified from the lessons of the Fukushima accident and of the ENSREG stress tests review have been incorporated into the C(I)SIP. The program was extended by the Cabinet of Ministers of Ukraine in 2019 until 2023 because of delays in obtaining the EBRD/Euratom loan for partial funding of C(I)SIP, difficulties in tenders for equipment purchase and expansion of the program with post-Fukushima measures. (SNRIU 2020a)

Taking into account the current situation and the relationship between measures under the NAcP and C(I)SIP, timeframes for a number of measures in the Updated NAcP were extended. In 2013, the envisaged end of implementation was December 2017. (SNRIU 2013) The envisaged end of implementation is now 2024. (SNRIU 2020a)

Contrary to statements made in the EIA Report, the evaluation of the Ukrainian NPPs in the light of the Fukushima accident and in accordance with the ENSREG stress tests specification has revealed a number of serious shortcomings.

Re-assessment of the **seismic hazard** has been carried out between 1999 and 2010. The recently accepted design basis of 0.1g is in compliance with the IAEA recommendation. However, the seismic evaluations for some parts of the equipment, piping, buildings and structures important to safety are not yet completed; furthermore, not all envisaged seismic safety upgrading measures are implemented. Detailed analyses of seismic impacts are envisaged within PSA for external hazards as well as additional seismic investigations of NPP sites are necessary.

The seismic hazard at the NPP sites is one of the issues the Ukrainian operator and regulator did not devote the necessary attention to. But also after implementing the envisaged back-fitting measures the protection against earthquake probably is not sufficient. Further back-fitting will prove necessary after the PSA systematically will have analyzed the threat of external hazards including floods and fires that may be induced by seismic impacts. The same applies to the resistance of the plant, because measure No 2 of the NAcP "*Seismic resistance of structures, systems and components important to safety"* is still ongoing (Deadline 2023).Measure No 2 is intended to ensure resistance to earthquakes for equipment, piping, buildings and structures required to perform critical safety.

Regarding **extreme weather events**, the peer review team pointed out that special attention should be paid to defining vulnerability in case of beyond design basis tornado. Furthermore, safety margins with respect to extreme wind and extreme snow are not evaluated. According to the NAcP, the impact of severe weather conditions is to be considered in more detail within periodic safety review (PSR). However, these will take place outside the scope of the stress tests process.

The stress tests revealed that in case of **Station Blackout (SBO)** reliable measures to prevent core damage do not exist. In case of loss of all power supply (SBO) the time span for operator actions to prevent core damage is only 10 hours.[12] The time available until the fuel stored at the Spent Fuel Pool (SFP) heats up and reaches temperatures above the design limits is 16 hours.

Based on the stress test results, approaches were developed for alternative cooling and heat removal. Measures have been developed to use mobile diesel generators and pumping units (MDGPUs) for alternative emergency power supply, makeup of steam generator (SGs) and spent fuel pools (SFPs) and emergency water supply to safety relevant critical equipment. The following measures are completed:

- Emergency power supply in long-term loss of power was implemented
- Measures to ensure SG makeup from mobile pumping units (MDGPUs) in case of Station Blackout (SBO) were implemented
- Measures to ensure SFP makeup from mobile pumping units (MDGPUs) in case of SBO were implemented
- Detailed analyses of primary system makeup in case of loss of power and/or ultimate heat sink were to be performed.
- The functionality of safety relevant equipment was to be ensured.
- Symptom-oriented emergency operating procedures (EOPs) for management of design-basis and beyond design-basis accidents in low power and shutdown states were to be developed and implemented.
- Additional instrumentation was to be installed and existing instrumentation was to be improved.

The impact of an accident on the Main and Emergency Control Rooms (MCR and ECR) has not been analyzed and may be a relevant cause of a cliff-edge-effect in the case of evacuation. Meanwhile, necessary iodine filters were installed to ensure the habitability of MCR and ECR during accidents.

The stress tests revealed that for severe accidents neither hardware provisions (e.g. for prevention of hydrogen explosions) nor Severe Accident Management Guidelines (SAMGs) had been implemented. Meanwhile SAMGs (including low power and shutdown states, and accidents in the spent fuel pools) were developed. Furthermore, only the following measures were completed since 2011:

- Containment hydrogen control systems for beyond design-basis accidents were implemented.

The implementation program of the important measures is still on-going:

- Development and implementation of hydrogen mitigation measures for beyond design-basis accidents (Deadline 2023)
- Implementation of a reactor pressure vessel external cooling system (Deadline 2021)
- Implementation of a containment venting system (Deadline 2023)

It should be noted that in Hungary an external reactor pressure vessel (RPV) cooling to contain the molten corium in the RPV was a pre-condition for lifetime extension at Paks NPP (same reactor type). (UMWELTBUNDESAMT 2020)

[12] The modernization of Instrumentation and Control (I&C) and DC-power supply was planned within the C(I)SP, which increases the discharge time of batteries (1 hour to 8 hours) and thus prolongs the coping times.

Furthermore, the following analysis are only planned, the time schedules for necessary back-fitting are not mentioned:

- Analysis of the need and possibility to qualify power unit components that may be involved in severe accident management for harsh environments is ongoing (Deadline 2021) (postponed from 2015)
- Detailed analysis and development of conceptual solutions on management with large volumes of contaminated water is ongoing (Deadline 2022) (postponed from 2016)
- Analysis of severe accident phenomena based on available experimental data and improvement of computer models is planned (Deadline 2024) (postponed from 2017)

Overall the next years will be the prolongation of the status quo: An external event can result in a severe accident, but at the same time the staff will not be able to cope with a severe accident. This might result in very serious consequences: Large radioactive releases from the reactor cores and the spent fuel pools.

Spent fuel pools

As mentioned in chapter 4, the spent fuel pools of the Rivne 1&2 are vulnerable against external impacts (e.g. earthquakes or terror attacks).

The threat of a large breach of the spent fuel pool (SFP) was highlighted during the Fukushima accident in 2011. To consider the (radiological) consequences of an attack or extreme hazards it is important to distinguish two different scenarios:

- To a):
  If the SFP remains intact, but the pool cooling system fails and water gradually boils off, it will take days or weeks (depending on amount and age of the spent fuel in the pool) until the tops of the fuel assembles are exposed. During this period of time, intervention could provide sufficient cooling of the fuel. In case that the entire core has been unloaded into the pool at the time of the attack intervention measures would have to be implemented during a few hours.
- To b):
  If an external event resulting in major damage to the SFP and loss of water and refilling of water is not foreseen or possible, very severe radioactive releases begin within hours. This leads to a dangerous challenge: As soon as the water has drained out of the pool, not only the cooling, but also the shielding effect of the water is lost. Fuel that has been extracted only a short time earlier from the reactor would generate a relatively high amount of heat and can reach a temperature of 900 °C within a few hours. At that temperature, the fuel cladding made of zircaloy would burn in the air. The fire is very hot and cannot be extinguished with water. Within the cooling pool it could spread to older fuel assembles that would otherwise not heat up so rapidly. Thus, the entire inventory of the cooling pool could melt. (ALVAREZ et al. 2003).

  In this situation, the population would have to be evacuated during an extremely short time. Severe damage to the cooling pools would lead to considerable release of radioactive substances. During the storage time of the spent fuel the shorter-lived radionuclides are reduced, in particular the highly volatile iodine-131. However, the inventory of the relevant radionuclide caesium-137 remains high. According to a recent U.S. study, about 75 percent (10-90 percent) percent of the caesium-137 inventory could be mobilized in the plume from the burning spent fuel pool. (HIPPEL & SCHOEPPNER 2016)

According to Safety Reference Levels F4.1, the plant shall be able to prevent the release of the radioactive material. WENRA Guidance on Issue F requires special efforts to make severe accident in a spent fuel storage extremely unlikely with a high degree of confidence, since measures for sufficient mitigation of severe accident consequences in spent fuel storages could be difficult to realize. (WENRA RHWG 2014b)

Source Term used in the EIA Report

Book 2 of the EIA report states that analyses of the radiological effects of beyond-design-basis accidents were performed as part of the periodic safety review. Several accident scenarios are mentioned. But these source terms are not provided.

Even though the probability of severe accidents with an early and/or large release for existing plants is estimated to be very small, the consequences caused by these accidents are very large. The accident analyses in the EIA Report should use a possible source term derived by the calculation of the current PSA 2.

The used source term of a beyond design basis accident (BDBA) was chosen on the basis of the limit value of the release of Cs-137 in the amount of 30 TBq according to the safety requirements of the European operators for the design of a light water reactors (LWR). However, this limited source term can only be assumed if the plant has been designed or retrofitted accordingly. As explained above, this is not the case for the Rivne 1&2.

5.3 Conclusions, questions and preliminary recommendations

Maintaining containment integrity under severe accident conditions is an important issue for accident management. The Rivne 1&2 severe accident management (SAM) strategy will rely on retaining corium inside the pressure vessel (in-vessel retention - IVR). However, these measures are not implemented yet. Furthermore, if this feature could be realized it would only reduce the risk of radioactive release in most but not in all severe accident scenarios

A systematic analysis of beyond design basis accidents (BDBA) is not presented in the EIA Document. To calculate the possible (trans-boundary) consequences, it was assumed that the containment integrity will be kept up. This assumption is not justified. The used source term of a beyond design basis accident (BDBA) was chosen on the basis of safety requirements of the European operators for the design of a light water reactors (LWR). However, this limited source term can only be assumed if the plant has been designed or retrofitted accordingly. This is not the case for the Rivne 1&2.

The accident analyses in the EIA Report should use a possible source term derived from the calculation of the current PSA 2. Even though the probability of severe accidents with an early and/or large release for existing plants is estimated to be very small, the consequences caused by these accidents are very serious.

In any case, the EIA Report should contain a comprehensible justification for the source term used. In principle, possible Beyond Design Basis Accidents should be part of the EIA, irrespective of their probability of occurrence.

In order to assess the consequences of BDBAs, it is necessary to analyse a range of severe accidents, including those with containment failure and containment bypass. These kinds of severe accidents are possible for the VVER 440/V213 reactor type.

The results of the EU stress tests have revealed a lot of shortcomings of the severe accident management (SAM) (i.e. the prevention of severe accidents and the mitigation of its consequences) at the Ukrainian NPPs. Comprehensive improvements are required by the regulator; however, further improvements are recommended by the ENSREG peer review team. This is one example for the gap between the Ukraine and the EU safety standards and requirements.

The stress tests showed that after decades of safety programs, Ukrainian reactors remain to be plants posing exceptionally high risk. The continuous upgrading programs did not deliver the promised results. The ENSREG peer review team pointed to one of the main problems, which are characteristic of nuclear safety in the Ukraine: the constant severe delay of the implementation of upgrading measures.

The WENRA "Safety Objectives for New Power Reactors" should be used as a reference for identifying reasonably practicable safety improvements for the Rivne 1&2. However, the EIA Document does not mention these WENRA safety objectives. The most ambitious WENRA safety objective intends to reduce potential radioactive releases to the environment from accidents with core melt. Accidents with core melt which would lead to early or large releases would have to be practically eliminated. Practical elimination of an accident sequence cannot be claimed solely based on compliance with a general cut-off probabilistic value. Even if the probability of an accident sequence is very low, any additional reasonably practicable design features, operational measures or accident management procedures to lower the risk further should be implemented.The concept of "practical elimination" of early or large releases is not mentioned for Rivne NPP in the EIA Document.

Questions

1. *What are the source terms of the calculated BDBA in the PSA 2 including releases from the spent fuel pools?*
2. *Which requirements have the filtered venting systems to fulfil, particularly regarding earthquake resistance?*
3. *What is the currently valid time schedule for the implementation of all required SAM features for the Rivne 1&2?*
4. *What are the parameters of the maximum aircraft crash (plane mass and speed) the buildings of the Rivne 1&2 can withstand?*
5. *What is the technical justification of the BDBA that is chosen to calculate possible trans-boundary consequences?*

Preliminary recommendation

1. It is recommended to use the WENRA Safety Objectives for new NPP to identify reasonably practicable safety improvements for Rivne 1&2. It is recommended to use the concept of practical elimination for this approach.
2. It is recommended to provide the following information concerning accident analyses and the results of the PSA (Level 1, 2 und 3):
    a. Core damage frequency (CDF) and large (early) releases frequency (L(E)RF)
    b. Contribution of internal events as well as internal and external hazards to CDF and L(E)RF
    c. List of the beyond design basis accidents (BDBAs)
    d. Source terms of the BDBAs including releases from the spent fuel pools
    e. Time spans to restore the safety functions after the loss of heat removal and/or station-blackout and cliff edge effects.

6 ACCIDENTS INITIATED BY NATURAL EVENTS AND SITE ASSESSMENT

6.1 Treatment in the EIA Document

The EIA REPORT BOOK 1 (2018, p. 78) identifies the following hydro-meteorological processes and phenomena which could occur at the Rivne NPP site:

- floods;
- ice phenomena on water sources (ice gorges, ice jams);
- water resources (extremely low flow, abnormal reduction of water level)
- tornados;
- strong winds;
- precipitation;
- extreme snow fall (heavy snow);
- extreme air temperature;
- ground surface icing;
- lightning;
- water intake facility blocking.

A screening of the site-specific hazards ("preliminary exclusion") is carried out using simple logical considerations without complex calculations and detailed evaluations to decide whether the impact of a certain hazard type endangers the SS Rivne NPP or not.

Screening considers the following criteria (p. 78):

- distance from the source of hazard to SS "Rivne NPP";
- low frequency of the natural hazard (how assessed without calculation?
- "non-significance of expected EH contribution to the accidents at SS "Rivne NPP""[13]

In the following chapters EIA REPORT BOOK 1 (2018), EIA REPORT BOOK 3VOLUME 3 (2018) and EIA REPORT BOOK 4 (2018) provide the following information on natural hazards present at the site:

Flooding by the river Styr: River floods of the river Styr that passes next to the NPP site are described to *"usually rise for 2.5-3.0 m. The greatest amplitude of variation of levels 3.74 m"*. Maximum flood heights are determined for occurrence probabilities reaching to 10^{-5} per year, for 10^{-4} a value of 168.8 m is given. These extremes also cover floods initiated by ice barriers (EIA REPORT BOOK 12018, p. 79ff).It is concluded that river floods pose no threat to the NPP which is sited on an elevated terrace about 20 m above the Styr flood plain.

Flooding by extreme precipitation: Precipitation water is drained by gravity via water drains and an industrial sewage system at the site (EIA REPORT BOOK 12018, p. 82). Design standards for the design of water drain systems for buildings and industrial sewage systems are defined by the building codes SNiP (СНиП) 2.04.01-85 (Domestic water supply and plumbing system) and 2.04.03-

[13] The criterion should probably be understood as "physical impacts of hazardous events have no implication on the safety of the NPP".

85 (Sewage system. Public utilities) in which the design flow of rainwater is determined based on the intensity of rain for 20 minutes. For the Rivne NPP site this design criterion is 100 litres/s*h or 0.6 mm/min. Data listed in Table 3.4 (p. 84) indicates that this precipitation intensity was exceeded repeatedly and significantly in the last about 100 years in the Ukraine. Reported values reach up to 3 mm/min.

For flooding by extreme rainfall exceeding the design values EIA REPORT BOOK 1 (2018, p. 87) expects *"that the normal power supply equipment of the power unit may fail due to rainwater leakage through the roofs and openings … of the turbine hall building, deaerator compartment and electrical equipment stacks."*

EIA REPORT BOOK 1 (2018, p. 87)finally concludes: *"When determining in the frequencies of emergency events based on the processing of statistics of actually recorded events during the operation of power units, various initiators were taken into account, including cases in which the initiating events of emergency situations were triggered by external factors. Thus, the influence of heavy showers on NPPs is excluded from further consideration."*

Drought and lack of cooling water: The impact of low water level of the river Styr on the cooling functions of NPP Rivne are discussed in EIA REPORT BOOK 1 (2018, p. 88-90). It is said that in case of insufficient supply from the river cooling water may be drawn from different resources within the plant. The conditional probability of core damage in the event of the failure of the cooling systems due to an abnormal decrease of the water level in the river Styr is stated as 9.17E-08.

Tornado hazards including the impact of wind-transported particles ad missiles are extensively described in EIA REPORT BOOK 1 (2018, p. 90-94). Probabilistic analyses are based on data from the region within a radius of 200 km from the NPP covering about 80 years of observation time. The assessment reveals an annual probability of a tornado passing through any point within a radius of 30km around the NPP of 9.25×10^{-7} reactor/year. The value refers to an *"estimated intensity class of probable tornado … 1.92* [according to the Fujita tornado rating system]".The reactor "*compartment*" [sic; containment?] is said to withstand tornados of intensity 3 and 4. Possible impacts of tornados are further evaluated for the emergency diesel generator building, the pump station, ventilation systems and the spray cooling ponds.

The EIA document concludes that a combination of the loss of essential service water as a result of a tornado passing over the spray cooling ponds and a possible simultaneous loss of power supply would have severe consequences for the NPP. It is therefore planned to investigate the conditional probability of a simultaneous impact of tornado on the listed SSCs.

Earthquake: The seismic hazard for the Rivne site was originally determined in 1974 and re-evaluated in 1986 in the course of the feasibility study for the second construction phase of Rivne NPP. The evaluation is apparently based on a regional seismic hazard map (Temporary schematic map of seismic zonation of the European part of former Soviet Union, VSR-87).

EIA REPORT BOOK 4 (2018, p. 1029; repeated in EIA REPORT BOOK 5 2018, p. 1131 and EIA REPORT NON-TECHNICAL SUMMARY, P. 1390) states that *"According to SNiP P-7-81 "Construction in Seismic Areas", the industrial area of SS Rivne NPP is located in the P3-5, MR3-6 zone. NPP was designed taking into account* *two levels of seismicity (P3) - magnitude 5*[14] *and the maximum estimated earthquake (MRZ)*[15] *- magnitude 6. The recurrence of earthquakes according to the MSK-64 scale is 1 time in 5000 years"*.[16]

EIA REPORT BOOK 1 (2018, p. 95) states that hazard levels for seismic ground shaking are described by the *"project earthquake (PE)*[17] *- 5 points"* and the *"maximum estimated earthquake (MEE)*[18] *- 6 points".*

EIA REPORT BOOK 3Volume 3 (2018, p. 718) repeats the values, but refers to *"an earthquake repetition once per 10,000 years".*

The seismological studies are said to show that the seismic impact on the site from all seismic zones within a 750-km radius of the NPP site is of the *"magnitude"* less than 5.Zones with *"high seismotectonic potential"* are regarded to occur only at a distance of more than 40 km north of the site. A potential of 2.8<M<3.9[19] is assigned to this zone (EIA REPORT BOOK 1 2018, p. 95). Higher seismic impacts are only regarded possible to derive from the Vrancea zone (Romania)[20]. In case of an earthquake in the Vrancea zone with the maximum possible magnitude M=7.6, the intensity of seismic impact can reach the approximate value of 6.This value conforms to the highest intensity recorded at the site related to the 1802 Vrancea earthquake.

Tectonically Rivne NPP is located within the Manevitskiy block which is bordered by the Gorynska (Lutska)-, Kukhotsko-Ratnivska-, Mogyliv-Stokhodska-, Volodymyro-Volynskyy- and the Olexandrivskiy fault zones. It is said that none of these faults moved in the Quaternary period (last 1-2 Million years; EIA REPORT BOOK 3 Volume 3 2018, p. 719).

Strong winds, hurricane: Hazard assessments for high wind use a database of about 80 years from meteorological stations within a radius of about 150 km from the site. Data are analysed by different methods including Gumbel statistics of extreme values. The results in terms of wind speed and wind pressure are shown for occurrence probabilities down to 10^{-6} per year (EIA REPORT BOOK 12018, p. 97). For the occurrence probability of 10^{-4}/year and different calculation methods wind speeds of 44.1 m/s and 45.9 m/s are listed, respectively.

The design basis for wind loads was derived from the location of the site in *"wind zone 2"* and according to SNiPII-6-74. Accordingly, a design basis wind speed of

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[14] It is supposed that the term "magnitude" is not correctly used in this context. The correct term should be intensity with reference to the MSK-64 intensity scale.

[15] The notion is understood that intensity 5 (MSK-64) was used to define SL-1 and intensity 6 was used as the basis for SL-2 and the Design Basis Earthquake as defied by WENRA (2014a, 2015).

[16] Other sources refer to the same value as "probability – once in 10.000 years" (EIA REPORT BOOK 5 2018, p.1226, 1235;);

[17] The "Project Earthquake" is also misleadingly termed "Design Basis Earthquake (DBE)", EIA REPORT BOOK 1Volume 3 (2018), p. 718 ff. Both terms apparently refer to the Safety Level 1 (SL-1) earthquake as defined by IAEA (2010).

[18] The "maximum estimated earthquake" is also termed "Safe Shutdown Earthquake (SSE)", EIA REPORT BOOK 1Volume 3 (2018), p. 718 ff. Both terms seemingly refer to the Safety Level 2 (SL-2) earthquake as defined by IAEA (2010) and.to the Design Basis Earthquake (DBE) as defined b WENRA (2014a).

[19] Here the use of "M" (for magnitude) is supposedly correct.

[20] Area of high and deep-seated seismicity due to on-going mantle subduction in southern Romania.

26.2 m/s was used for the reactor hall, the standby diesel power plant, the turbine hall and other buildings (EIA REPORT BOOK 12018, p. 99). This value corresponds to a recurrence probability of about 10E-1 according to EIA REPORT BOOK 1 (2018, Table 3.12) [21]. Although this discrepancy is honoured by EIA REPORT BOOK 1 (2018), it is stated that *"strong winds do not represent danger to the above mentioned buildings and structures"* (p. 100). It is, however, further concluded that wind speeds of more than 31 m/s can lead to abnormal operation of the essential service water system. The *"probability of speed exceedance of such wind in the plant area is 1.40E-03"*.

Fog, heavy glace, thunderstorm (lightning), hail, dust storm: For fog, heavy glace (icing), hail and dust storm the EIA REPORT BOOK 1 (2018) mostly describes the historical occurrences without discussing occurrence probabilities, possible impacts on the NPP and related protection. Freezing fog and freezing rain is considered as heavy glace referring to ice coatings exceeding 20 mm diameter.

For lightning the EIA REPORT BOOK 1 (2018, p. 102-105) includes a comprehensive and detailed description of the hazardous phenomena connected with the lightning strikes. Damaging lightning strikes at different parts of the NPP are frequent (1.20E-1 to 6.60E-3). The protection concept for preventing damaging impacts of lightning strike includes anti-lightning protection of the buildings using lightning arrester and insulations.

Snow storms, snow loads: For snow cover and snow loads a site-specific hazard assessment using an *"exponential distribution"* determined snow pressures for occurrence probabilities between $10^{-2}$and 10^{-7} per ear with a value of 700 N/m² for the occurrence probability of 10^{-4}/year.

The design basis for snow loads was derived from the location of the site in the *"first snow zone"*. The design criteria in force during the construction of the NPP required accounting for a snow cover weight of 500 N/m^2 for horizontal surfaces, increased by a safety coefficient of 1.4 for the reactor hall and other buildings and installations that contain safety important systems.

The EIA REPORT BOOK 1 (2018, p. 109) further refers to a current normative document without providing more detailed reference. It is said that *"the normative values of the snow load for this region is 140 kgf/m2 (1400 Pa)[22]."* The difference between current requirements and in the regulations in force during NPP design (500 N/m^2) are regarded not critical for the structures, buildings and installations, since *"it is foreseen by Rivne NPP to clean the site from snow across the entire complex of the buildings by the departmental personnel."*

High / low temperature: Maximum[23] and minimum air temperatures and their occurrence probabilities are determined from data of a near-by meteorological station using Weihbull statistics. Data is used for determining the water temperature in the spray ponds which, in turn, is relevant for reactor cooling. It is stated that peak temperature is not the key parameter for assessing the impact on the

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[21] For existing reactors WENRA (2014) requires that exceedance frequencies of design basis events shall not be higher than 10^{-4} per year. Protection shall be provided for design basis events defined on the basis of this exceedance frequency. The value of 10E-1 stated in the EIA Document exceeds this value by a factor of 10^3.

[22] 1400 Pa = 1400 N/m²

[23] Referring to the hottest part of the day over about 14-15 hours.

cooling capacity. Instead, the thermal inertia effects and long-term periods before/after temperature peaks have to be considered. It is concluded that *"the impact of low and high temperatures onto the normal plant operation for Rivne NPP and, consequently, on exclusion of accidents and situations that can negatively influence the environment, can be excluded from further analysis."*(EIA REPORT BOOK 12018, p. 111).

Karst / Suffusion: Although karst processes and suffusion are not included in the site-specific hazard list of the EIA REPORT BOOK 1 (2018, p. 78), information is provided on these phenomena. The EIA REPORT BOOK 3 VOLUME 3 (2018, p. 699-700) describes that surface karst forms such as sinkholes and shallow depressions that derive from the dissolution of Cretaceous chalk and limestone of the so-called Zdolbunivska suite (Turonian-Conjacian) are wide-spread in the Rivne region. The roughly 15 m thick karstified Cretaceous rock units also underlie the NPP site in about 10 to 30 m depth (EIA REPORT BOOK 3 VOLUME 32018, 711-713)

Besides natural karst, man-made karst is recognised as hazard. The activation of karst and suffusion processes caused by water infiltrating from drains or leakages of technical waters from underground pipelines, and their infiltration into the soil on the NPP site is identified as a hazard that could lead to loosening of soils, *"fracturing"* of the Cretaceous layer and formation of sinkholes (*"surface fall-through"*)(EIA REPORT BOOK 3 VOLUME 3 (2018, p.721-722). Listed protective measures are the control of groundwater properties (level, temperature, chemical composition), timely control of water-supplying lines and their repair, and cementing of the Cretaceous layer under the structures of power units 1-3. Power unit 4 is constructed on piles that reach below the karstified Cretaceous layer and are based in underlying basalt.

The EIA REPORT BOOK 3 VOLUME 3 (2018, p.723ff) describes the existing monitoring program to identify adverse effects of groundwater-rock interaction, karstification and suffusion, and includes a detailed proposal for additional investigations and monitoring (p. 730-731).

6.2 Discussion

The assessment of the plant safety with respect to natural hazards is mostly restricted to the hazard types river flooding, extreme precipitation, abnormally low water level of the Styr river, tornado, earthquake, strong winds, extreme temperature, fog and thunderstorm, and snowstorm. Additional assessments are available for karst and suffusion.

River flooding: The flood plain of river Styr has an elevation of about 160 m. The NPP Rivne is located on the second Pleistocene terrace above the floodplain of the river (EIA REPORT BOOK 1 2018, p. 54) which locally has an elevation of about 180-190 m. Flooding by river floods is therefore excluded by the elevation of the site ("dry site" concept),

Extreme precipitation: The protection system for draining precipitation water from the NPP buildings and the site is designed according to general industrial standards or building codes, not according to a design basis event with sufficiently low occurrence probability as required by WENRA 2014a. It appears that no site-specific hazard assessment is available for extreme precipitation (including heavy rain, flash flood, thawing and combinations of thawing and rain). A design basis according to a design basis event with an occurrence probability of 10^{-4}/year has not been developed.

A comparison of the dimensioning of the drainage systems (designed for draining precipitation with 0.6 mm/min) with historical data from Ukraine shows that the design value is far below the recorded precipitation maxima which reach up to about 3 mm/min. Current design therefore is not in line with WENRA requirements (WENRA, 2014a, Safety Reference Level T4.3: *"The design basis events shall be compared to relevant historical data to verify that historical extreme events are enveloped by the design basis with a sufficient margin."*).

For precipitation events that exceed the capacity of the current sewage system the EIA REPORT BOOK 1 (2018, p. 87) expects flooding with severe consequences for the electrical power supply and electrical equipment. Possible accident scenarios for these effects and consequences of possible flooding of the basements of buildings housing safety-relevant SSCs are not further discussed. However, *"the influence of heavy showers on NPPs is excluded from further consideration."*

The Austrian expert team concluded that the hazard of external flooding by extreme precipitation is not adequately addressed. Neither a hazard assessments nor an adequate design basis has been developed in accordance with WENRA (2014a) requirements. It is further concluded that the protection system that is currently in place is insufficient to protect the NPP from precipitation events with intensities that were repeatedly recorded in Ukraine in the last approx. 100 years.

Drought and lack of cooling water: The River Styr is the only source for essential service water and cooling water for the NPP Rivne. Water intake pumps are designed for a minimum drought water level of 158.80 m. Probabilistic assessment indicates a probability of 0.3% per year for the river water level to fall below the critical level. Although the EIA REPORT BOOK 1 (2018, p. 88-90) claims that water from several systems of the NPP may be used as cooling water reserves it is unclear if these reserves suffice to cool all of the four units after a shutdown and maintain the reactors in a safe state. It is also unclear if the present situation with cooling water exclusively derived from the River Styr complies with WENRA Safety Reference Levels (RL), in particular RL F 4.7 requiring that *"there shall be sufficient independent and diverse means including necessary power supplies available to remove the residual heat from the core and the spent fuel."*

Tornado. The assessment of tornado hazard and the possible impact of tornados was developed in the EIA REPORT BOOK 1 (2018). The authors concluded that the hazard of a tornado simultaneously leading to unavailability of essential service water from spray ponds and the loss of power supply needs further evaluation.

Earthquake: The seismic ground shaking hazard for the Rivne site was originally determined in 1974 and re-evaluated in 1986. The assessments were seemingly not based on a site-specific investigation but derived from a seismic zonation map of the European part of the former Soviet Union (VSR-87) at the scale of 1:2,000,000. Hazard at the site is stated in intensity values with intensity 6 (MSK-64) characterizing the *maximum estimated earthquake (MRZ)* which appears to correspond to SL-2 (IAEA 2010). The EIA Document provides contradicting information about the recurrence of this event. Both values of 5000 and 10.000 years are stated as recurrence intervals. It seems that I=VI MSK64 is associated with Peak Ground Acceleration (PGA) of 0.05g (ENSREG 2012, p. 5). ENSREG

(2012) also mentions additional seismic hazard assessments in the early 2000nds. These, however, are not cited in the EIA Document.

A thorough review of the seismic hazard assessment is beyond the scope of this expert statement. It is, however, possible to draw the following conclusions:

- Expressing the seismic design basis in terms of macro-seismic intensity (I=6 MSK64) is outdated and not in line with current state of the art.
- The design basis of I=6 MSK64 equal to PGA=0.05g is below the minimum ground acceleration of PGA=0.1g required by WENRA (2014a, Safety Reference Level T 4.2) for existing NPPs and below the minimum ground acceleration recommended by IAEA (2010).

At this background it is recommended to update the current seismic design basis to the value of 0.1g to align with the requirements of WENRA Safety Reference Level T 4.2 (WENRA, 2014a).

It is further recommended to review seismic hazards and the design basis as recommended by WENRA (2016, p. 25).

Strong winds: For wind loads, hazard assessments show a large discrepancy between the actual design of buildings and internationally accepted safety requirements for existing NPPs.

The design basis for wind loads accounts for the normal building code SNiPII-6-74 resulting in a wind speed of 26.2 m/s that was used for the design of the reactor hall, the standby diesel power plant, the turbine hall and other buildings (EIA REPORT BOOK 12018, p. 99). According to the site-specific hazard assessment for high winds (EIA REPORT BOOK 12018, Table 3.12) this value corresponds to an occurrence probability of about 10^{-1}per year. According to WENRA requirements, however, *"the exceedance frequencies of design basis events shall be low enough to ensure a high degree of protection with respect to natural hazards. A common target value of frequency, not higher than 10^{-4} per annum, shall be used for each design basis event."* WENRA (2014a, Issue T, RL T 4.2). For the occurrence probability of 10^{-4} the site-specific hazard assessment reveals wind speeds of about 45 m/s. It is therefore evident that the current design of the NPP is not in line with the WENRA safety reference levels for existing NPPs.

The importance of re-evaluating the design basis and the protection concept for high winds is underlined by the fact that *"in the last 30 years winds with wind speeds ≥33 m/s were identified in 5 cases on the territory of Rivne NPP, in 9-10 cases on the territory of Volynska and Khmelnitskiy oblasts."* (EIA REPORT Book 1 2018, p. 106). The highest recorded wind speeds reached 34 to 40 m/s. It follows that the current situation is also not in line with WENRA Safety Reference Level T4.3, requiring that *"The design basis events shall be compared to relevant historical data to verify that historical extreme events are enveloped by the design basis with a sufficient margin."*(WENRA, 2014a).

The safety relevance of the apparently insufficient design with respect to wind loads is emphasised by the statement that wind speeds in excess of 31 m/s, can lead to failure of the essential service water system (EIA REPORT BOOK 12018, p. 100). It must be stressed that wind speeds of 31 m/s correspond to an exceedance probability of 1.40E-3 which is much higher than the exceedance probability required for design basis events by WENRA (2014).

Concerning tornado hazards the EIA REPORT BOOK 1 (2018, p. 94) states that *"The conditional probability of core damage due to the failure of the essential service water system is 6,93E-03*".The value is not further discussed. It is assumed that the high vulnerability of the cooling system with respect to high wind is one of the reasons for this unreasonably high CDF value[24].

We conclude that the current design of the NPP Rivne with respect to high wind is insufficient. The current design, based on general industry norms and building codes, only protects against events with an occurrence probability of 10^{-1} per year. Wind speeds with a probability of 1.40E-3 can lead to failure of the essential service water system. This inadequate protection against high wind is assumed to contribute significantly to a CDF which is higher than values accepted by most WENRA countries.

Fog, heavy glace, thunderstorm (lightning), hail, dust storm: The EIA Document provides a sound description of the possible impacts of lightning and the protection concept.

No information is provided on occurrence probabilities, possible safety-relevant impacts on the NPP, and related protection measures for fog, heavy glace (icing), hail and dust storm. Adverse effects caused by these hazards include the loading of structures (electric power lines and switchyard), blocking of air intakes with ice or dust and the contamination of external high-voltage insulation. Design basis requirements and protection concepts, however, are not developed for these hazards.

Snow storms, snow loads: For snow cover and snow loads the results of the site-specific hazard assessment revealed a snow pressure value of 700 N/m² for the occurrence probability of 10^{-4}/year for horizontal surfaces. This seems to be in line with the original design basis for the reactor hall and other buildings and installations that contain safety important systems. The original design for snow loads required accounting for a pressure of 700 N/m² (derived from a general requirement of 500 N/m²increased by a safety coefficient of 1.4). Selecting the design basis value from a design basis event with an occurrence probability of 10^{-4}/year does comply with WENRA requirements (WENRA, 2014a). It seems, however, that current Ukrainian normative documents require the much higher value of 1,400 Pa (= 1,400 N/m²) for snow loads. Available information does not allow assessing this apparent discrepancy further.

High/low temperature: The site of Rivne NPP is exposed to continental climate with the possibility of long-lasting periods of both high and low temperatures. The probabilities of high/low peak temperatures and the probabilities of extended periods of extremely high/low temperatures were established by a site-specific hazard assessment. This includes the determination of parameters (peak temperature, duration of extreme temperature) for occurrence probabilities of 10^{-4}/year that, by definition of WENRA, constitute design basis parameters. The EIA REPORT BOOK 1 (2018) however, fails to show that the design of the reactors is adequate to cope with these design basis parameters. This is the case for both,

[24] CDF Inthe majority of WENRA countries and Ukraine the Core Damage Frequency (CDF) shall not exceed the value of 10^{-4} per year. Some WENRA countries require CDF ≤ 10^{-5} per year.

showing that cooling capacity is adequately ensured during extremes of high temperature, and that (liquid) cooling water is available during periods or peaks of extremely low temperature.

Both extremely high and low temperatures are predictable hazards and progress slowly. A suitable protection concept therefore could include automatically initiated active safety measures that trigger power reduction or shut-down upon the exceedance of pre-set temperature limits for air/cooling water. At the minimum, administrative measures should be developed to respond to hazardous temperature extremes.

High groundwater: The hazard is not included in the site-specific hazard list of EIA REPORT BOOK 1 (2018, p. 78). Although high groundwater may not be regarded as a hazard by itself, it poses potential hazards to the site in combination with karstification and suffusion (see below).

EIA REPORT BOOK 3 VOLUME 3 (2018, p. 742-745) provides ample information about the development of the ground water level at the NPP site. It is reported that ground water levels increased for about up to 10 m after the start-up of the NPP and fluctuated significantly during its operation, mainly due to infiltration of water from the cooling towers, the inlet- and outlet canal and an unnamed underground channel.

The described increase and fluctuation of the site groundwater level indicate very significant and lasting infiltration of cooling water into the subsoil leading to the formation of a "*ground water dome"*. Infiltration has been continuing through the last about 5 decades. It is unclear how this concentrated infiltration affects dissolution, karstification and suffusion at the site, and, particularly, in the infiltration area next to the cooling towers (see paragraph below).

Karst and suffusion: Geological data prove that the foundation soil of the Rivne NPP site includes a layer of around 15 m of Turonian chalk ("Nyzhniozdolbunivska suite" – lower Zdolbunivska unit) which is intensively karstified and includes karstic cavities and voids partly filled with chalk suspension (EIA REPORT BOOK 3 VOLUME 3 2018, p. 710). Descriptions of "*flow and fluid-plastic chalk, occasionally soft-plastic"* indicate very low quality of the foundation soil (EIA REPORT BOOK 3 VOLUME 3 2018, p. 712, 715).

In this context the activation of karst-suffusion processes by drains or leakages of technical waters is identified as a hazard that could lead to the loosening of soils, *"fracturing"* of the Cretaceous layer and formation of sinkholes (*"surface fall-through"*) (EIA REPORT BOOK 3 VOLUME 3 (2018, p.721-722).

EIA REPORT BOOK 3 VOLUME 3 2018, p. 759 concludes that the *"occurrence of the karst processes was not identified on the territory of the plant, but their activation is possible in case of violated hydrodynamic regime"*. This conclusion appears remarkable since the same report provides plentiful evidence of major changes of the hydrodynamic regime due to the infiltration of water into the karstified layer caused by the operation of the NPP (EIA REPORT BOOK 3 VOLUME 32018, p. 742-745). This infiltration has been continuing since the construction of the plant in the 1970ies. Although the infiltration of water leaking from cooling towers, the inlet- and outlet canal is monitored, no or only insufficient action was undertaken to prevent such infiltration (see paragraph on high groundwater above).

The Austrian experts concluded that karstification and suffusion pose significant threats to the safety of the NPP due to the possible destabilization of the foundation soil of the reactor buildings (including containment), buildings that house safety-relevant SSCs, safety-relevant underground piping and the cooling towers.

6.3 Conclusions, questions and preliminary recommendations

The assessment of natural phenomena that may have adverse effects on the safety of Rivne NPP is restricted to a rather small number of hazard types. The EIA Document fails to demonstrate that the site assessment considered all natural hazards that apply to the site. A thorough assessment including the steps

- hazard screening including the identification of hazard combinations
- hazard assessment
- definition of a design basis
- development of a protection concept
- analysis of design extension conditions

as required by WENRA (2014a, Issue T) has not been performed.

The Austrian expert team recommended the use of a generic list of natural hazards as a start for hazard screening and the identification of relevant hazard combinations (e.g., WENRA, 2015; DECKER & BRINKMAN 2017) to demonstrate that all relevant hazards and hazard combinations are addressed.

Hazard severities for occurrence probabilities of 10^{-4} per year have been determined for several, but not all hazards considered in the EIA Document. These results, however, are not followed-up to define design basis events and develop adequate protection concepts in a strict way. This is particularly the case for external flooding by extreme precipitation, drought/lack of cooling water, high wind, tornado, snow load/snow storm and extreme temperatures.

Adequate protection against several hazards is currently not in place. This is most important for:

- flooding by extreme precipitation for which the current design only protects against events with occurrence probabilities of 10^{-1} per year;
- high wind for which the EIA Document shows that storms with occurrence probabilities of 1.40E-3 can lead to failure of the essential service water system;
- drought and lack of riverine cooling water.

We assume that the low withstand of the cooling system against wind loads and other meteorological hazards are important factors for the high CDF value[25] described in the EIA Document (*"The conditional probability of core damage due to the failure of the essential service water system is 6,93E-03*").Such a high CDF value seems unacceptable when compared to regulations and safety expectations for existing NPPs that are in place in most of the WENRA countries.

[25] In the majority of WENRA countries and in the Ukraine the Core Damage Frequency (CDF) shall not exceed the value of 10^{-4} per year. Some WENRA countries require CDF≤10^{-5} per year.

Karstification and suffusion pose significant threats to the safety of the NPP Rivne by the possible destabilization of the foundation soil of the reactor buildings and containments, buildings that house safety-relevant SSCs, safety-relevant underground piping and the cooling towers. Information provided by the EIA Document proves that the operation of the NPP leads to the lasting seepage of large amounts of technical water that has the potential to increase karstification and suffusion, and to destabilize foundation soils. Human-made karstification and suffusion are slow but self-enhancing. Both processes were set off by the start-up of the NPP in the 1970ies. The Austrian experts expect that the intensity of the erosion of the foundation soil increases with time, and that the safety relevance of karstification and suffusion will increase during the continued operation of the NPP.

Design Extension Conditions (DEC) are not analysed in the available EIA Document. This is in violation of the WENRA requirement that DEC analysis shall be undertaken with the purpose of further improving the safety of existing nuclear power plants and enhancing their capability to withstand more challenging events or conditions than those considered in the design basis. Related requirements and procedures are provided by WENRA (2014a) and WENRA (2014b). The Austrian experts recommended extending the efforts with respect to natural hazard analysis and develop adequate protection concepts for natural hazards in line with the WENRA DEC approach.

Questions

1. *Why has flooding due to extreme precipitation been excluded from the further consideration of natural hazards?*
2. *The probability of the water level of the River Styr to drop below the critical value of 158.80 m in case of drought is stated with 0.3% per year. Would the dropping of the water level even lower result in the full unavailability of cooling water from the River Styr?*
3. *Are the water reserves at the primary and secondary circuits of the WWER units large enough to cool all four reactors after shutdown from full power and maintain cooling until a safe state is reached in cases when no cooling water is available from River Styr?*
4. *Is it intended to equip the Rivne NPP with a second, independent cooling water supply such as ground water wells to ensure the availability of cooling water/essential service water in case of low river water levels and drought?*
5. *With respect to snow loads the EIA REPORT BOOK 1 (2018, p. 109) refers to a "current normative document" that sets the normative values of the snow load for the Rivne region to 1,400 Pa. This value is above the original design. What are the consequences of this discrepancy between the status as-built and the current requirements for buildings housing safety-relevant SSCs of the Rivne reactors?*
6. *TERMINOLOGY USED FOR THE DESCRIPTION OF SEISMIC HAZARDS IN THE EIA REPORT BOOK 3 VOL 3 (2018, P. 718ff) appears unclear. The Austrian experts had to assume that the "design basis earthquake (DBE)", also termed "Project Earthquake (PE)", refers to SL-1 as used by IAEA (2010) and the "safe shutdown earthquake (SSE)", also termed "maximum esti-*

mated earthquake (MEE)", refers to SL-2 (IAEA, 2010) or the Design Basis Earthquake (WENRA, 2014a; 2015). Also they assumed further that terms like "5 point", "6 point", "magnitude 5", "magnitude 6" refer to intensity (MSK-64 scale) instead of magnitude. Is this correct?

7. *EIA includes contradicting information about the recurrence interval of "maximum estimated earthquake" (also termed "safe shutdown earthquake") with I=6. Both, values of 5,000 and 10,000 years are stated as recurrence intervals. The Austrian experts ask for the clarification of this contradiction.*
8. *It appears that I=VI MSK64 is associated with Peak Ground Acceleration (PGA) of 0.05g. What is the basis for such a correlation between macroseismic intensity and ground acceleration?*
9. *The IEA document mentions additional seismic hazard assessments that were performed in the late 1990ies and early 2000nds. These, however, are not further explained in the EIA Document. The Austrian experts ask to provide those references and results of these investigations for the Rivne NPP site.*
10. *Karstification and suffusion are listed as hazardous phenomena destabilizing the soil under the NPP site, also under the reactor buildings. According to the EIA REPORT BOOK 3 VOLUME 3, (2018, p.721-722) the foundations for unit 4 are laid on piles reaching below the karstified layer into basalt.*

    Are the foundations of the other reactor units constructed in the same way?

    Are the concrete injections sufficient to stabilize fundaments of the other blocks?

    How is the stability of foundations secured for other buildings housing safety-relevant equipment and safety-relevant underground piping?
11. *How is sewage water removed from the site? Is it secured that concentrated seepage of sewage water from surface runoffs and/or direct infiltration of sewage water does not lead to extended man-made karstification and suffusion?*
12. *The formation of a "ground water dome" at the site proves the continued outflow of large amounts of water from the hydro-engineering installations. How is it secured that these outflows do not destabilize the foundation soil by increased karstification and suffusion?*

    Are the cooling towers, cooling water channels and pipes, which are supposed to be the sources of infiltrating water, subjected to a monitoring program to secure their stability? Are those structures made of watertight concrete or lined with other impermeable materials?

    What are the measures envisaged to reduce or prevent the infiltration of technical water and reduce karstification / suffusion processes?

Preliminary recommendation

1. The list of natural hazards assessed in the EIA REPORT BOOK 1 (2018) is not complete. The Austrian expert team recommends the use of the "Non-exhaustive List of Natural Hazard Types" (WENRA, 2015) as a starting point to ensure that all site-specific hazards are addressed.

2. Natural hazard assessment does not address hazard combinations as required by WENRA (2014a) and further explained by WENRA (2015). The Austrian expert team recommended the use of a hazard correlation chart (e.g., DECKER & BRINKMAN, 2017) as a starting point to ensure that all relevant combinations are addressed.
3. The Austrian expert team recommends the selection of design basis parameters from design basis events with occurrence probabilities of 10^{-4} per year for all natural hazards that apply to the site and use the derived parameters to develop adequate protection concepts. This is particularly important for, but should not be limited to the following hazards: high wind, external flooding by extreme precipitation, snow storm and snow load.
4. The Austrian expert team recommends the upgrade of the protection against wind loads to ensure that SSCs important to safety and buildings that house SSCs important to safety withstand wind speeds with occurrence probabilities of 10^{-4} per year.
5. The Austrian expert team recommends the upgrade of the capacity of the sewer systems to ensure that precipitation intensities with occurrence probabilities of 10^{-4} per year do not lead to (a) water ingress into buildings that house SSCs important to safety (b) flooding of the basement of such buildings.
6. The Austrian expert team recommends the re-evaluation of the occurrence probability of extreme precipitation that leads to the flooding of the site and compare the results to the capacity of the sewer system. These evaluations should consider the possible contribution of thaw water and combinations of thawing and rain. The precipitation intensity corresponding to the occurrence probability of 10^{-4} per year should be taken as the design basis for the capacity of the sewer system (IAEA, WENRA), and the sewer systems for individual buildings and the site as a whole should be upgraded accordingly.
7. The Austrian expert team recommends the evaluation of the possible safety benefits of an independent ultimate heat sink in addition to the River Styr (e.g., ground water wells) to further reduce hazards arising from drought and low river water level.
8. The Austrian expert team recommends to implement the additional investigations and monitoring measures to identify and mitigate adverse effects karstification and suffusion suggested in the EIA REPORT BOOK 3 VOLUME 3 (2018), pages 730-731.
9. The Austrian expert team recommends to further analyse the sources of technical water infiltrating into the karstified aquifer in the foundation soil of the Rivne NPP site (e.g., from cooling towers and connected water channels) and to prevent further infiltration by adequate measures. The recommended action should prevent the continued degradation of the foundation soil by man-made karstification and suffusion.
10. The Austrian expert team recommends the implementation of automatically initiated active safety measures that trigger power reduction or shutdown upon the exceedance of pre-set temperature limits for maximum and minimum air and/or cooling water temperatures. At the minimum, administrative measures should be developed to respond to hazardous temperature extremes. The protection concept should take into account

the advantage that both, extremely high and low temperatures are predictable hazards and progress slowly.

11. The Austrian expert team recommends an update of the current seismic design basis to the value of 0.1g to fulfil the minimum requirements of WENRA Safety Reference Level T 4.2 (WENRA, 2014a).
12. The Austrian expert team recommends to use the procedures for the life time extension of Rivne NPP for a periodic review the site-specific seismic hazard as recommended by WENRA (2016, p. 25). This review should take advantage of the rapid development of science and technology in the fields of geology, seismology and paleo-seismology that were achieved in the last decades and include targeted assessments of the major faults closest to the site. Up-to-date fault investigations include, for instance, reflection seismic and paleo-seismological techniques.
13. The Austrian expert team recommends to apply the WENRA approach of analysing Design Extension Conditions (DEC) for natural hazards and updates of the protection concepts against natural hazards. DEC are not analysed in the available EIA Document. This is in violation of the WENRA requirement that DEC analysis shall be undertaken with the purpose of further improving the safety of existing nuclear power plants and enhancing their capability to withstand more challenging events or conditions than those considered in the design basis.

7 ACCIDENTS WITH INVOLVEMENT OF THIRD PARTIES AND MAN-MADE IMPACTS

7.1 Treatment in the EIA Document

Chapter 3.2, book 1 of the EIA Document deals with man-made extreme impacts. (EIA REPORT BOOK 1, 2018)

Explosions

The following was analyzed as possible sources for an air shock wave at the RNPP site:

- vessels/tanks that are operated under pressure:
- nitrogen receivers and recipients and oxygen receivers at the nitrogen-oxygen station of 2nd line:
- storage facility for combustibles:
- transportation (tank lorries at the site – fuel transportation lorry.

The performed analysis showed the following results:

- receivers with the explosive environment (hydrogen, oxygen) are located at the distance of more than 800 m from the installations that contain safety important installation (The safety radius of 10 kPa is 260 m);
- warehouse with barrels for storage of the liquefied gas is located at the significant distance from important facilities (about 550 m);
- tanks with the diesel fuel are equipped with the flame arresters, that is why the steam explosion in it is unlikely, but even with the conservative assumptions that such an event can take place, the underground siting of these tanks at the depth of 2.5 m from the ground level excludes the possibility for shock wave spreading and effect;
- warehouse of storage of combustibles and lubricants is at the distance of about 600 m from the facilities containing the safety important systems.

It is concluded that the forecasted level of the external impact by the shock wave from the sources of the plant site onto the facilities that contain safety important systems, environment and people, does not represent a potential danger.

Fires

The fire sources are located further away than the safe distances. Thus, they do not pose the danger of direct thermal impact for the buildings and installations and main plant equipment; they are no danger for the safe operation of the power units.

The likelihood of causing danger due to smoke in the rooms from the supply ventilation systems and affecting the operating personnel is not possible, since supply of the external air to the Main Control Room (MCR), Emergency Control room (ECR) is not performed the fumes occur. Thus, it is concluded: *external fires that may occur outside and inside the NPP site do not affect the safety important facilities and can be excluded from further analysis, since they do not impose negative impact on the environment and people*. (EIA REPORT BOOK 1, 2018)

Leakage of chemical and toxic gases

On the territory of Rivne and Volynska oblasts, there are no gas pipelines, oil pipelines, factories and chemical plants within the 30-km area of Rivne NPP.

During accidents, dangerous releases can occur in case of breaking of steady-state canisters with toxic substances (chloride, ammonia, hydrazine hydrate, sulfuric acid).

At the NPP site, there are steady-state canisters where chemically dangerous materials are stored. The facility is located outside the restricted area at the distance of 280 m from the power unit.

Arrangement of the reagent warehouse, methods of storage and foreseen measures with regard to elimination of the accident consequences at this warehouse exclude the likelihood of having a big amount of vapors. A large specific weight of the substances prevents creation of the dangerous concentrations in the locations of air suction by the ventilation and air conditioning systems, which are used for the MCR and ECR.

The dangerous chemical materials stored at the reagent warehouse do not pose danger, because

- they are stored in specially designed tanks equipped with the natural and emergency protection system
- they are served by the personnel who received a special training on management of the chemically dangerous substances;
- these are low-volatile materials, their vapors are heavier than the air and are lifted by the raising air flows insignificantly;
- the depth of the cloud spreading of the sulfuric acid that is stored in the steady-state canisters at the open site of the reagent warehouse is less than the distance to the power unit.

The impact by chloride related to the accidents in the chlorinator does not pose danger, because:

- tanks with the chloride are stored in the specially designed facility equipped with the emergency protection system;
- tanks with the chloride are served by the personnel who received a special training on management of the chemically dangerous substances;
- the substances are low-volatile, their vapors are heavier than the air and are lifted by the raising air flows insignificantly.

Accidents associated with the releases of the chemically dangerous substances, the chlorinator and reagent warehouse do not pose danger and are excluded from further analysis.

Aircraft crashes

To identify the frequency of the aircraft crashes on the main buildings and installations at the Rivne NPP site, which can result in accidents and have negative consequences for the environment and people, the aircrafts are divided into three types:

- aircraft of commercial aviation;
- aircraft of general aviation;
- aircraft of military aviation.

Due to absence of the representative statistics on aviation events in Ukraine with regard to the aircrafts of commercial aviation, the frequency of crashes of the commercial aviation aircraft was taken from the literature sources. For calculations, the frequency for commercial class aircraft crash was used, which constitutes $1.74 \times 10^{-9} km^{-1}$.

The statistical data on the aviation events on the territory of Ukraine with the aircrafts of civil aviation aircrafts and military aircrafts are provided in Table 3.30 of the EIA REPORT (BOOK 1, 2018). Based on these data, the frequency of small aviation aircraft crashes was defined for different aviation types and aircrafts per 1 km² of the territory of Ukraine.

According to the performed analysis, the frequency of calculated aircraft crashes on the objects of power units and facilities of Rivne NPP site are the following:

- reactor hall – 9.82E-08 per year,
- main building – 9.02E-08 per year,
- standby diesel power station – 3.14E-08 per year,
- power unit pump station – 1.96E-08 per year,
- spray ponds of the essential service water system – 2.27E- 07 per year,
- open facility of transformers – 7.11E-08 per year,
- open switchgear-750/330 kV – 2.10E-06 per year.

Since the frequencies of aircraft crashes on the main facilities of power units except for the open switchgear are lower than the ones established in the methodological recommendations for exclusion using the frequency criteria (1E-07 per year), external impacts associated with the aircraft crashes at the Rivne NPP site can be excluded.

Accidents with involvement of third parties (sabotage or terror attacks) are not mentioned in the EIA Report.

7.2 Discussion

Nuclear power plants are in general vulnerable to a broad spectrum of possible attacks. Terrorist attacks or acts of sabotage on Rivne NPP may have significant impacts. However, in the EIA report malicious acts of third parties against the Rivne NPP and their possible effects are not discussed. In comparable EIA procedures such events were addressed to some extent. (UMWELTBUNDESAMT 2018)

The terror threat to nuclear power plants has received considerable public attention in the last twenty years. This attention has – for obvious reasons – focused on the hazard of the deliberate crash of a large airliner.

After the 9/11 terror attack, the consequences of an intentional crash of a commercial airplane were considered. For such a crash WENRA assumes that a core melt can be avoided and would cause only a minor radiological impact as defined in the Safety Objective O2 for new nuclear power plants. (WENRA RHWG 2013)

According to the Finnish regulator STUK, the reactor buildings at the Loviisa NPP (which is the same reactor type but with a containment) are not designed to withstand an airplane crash and improvements are not "practically reasonable".

Studies about the consequences of a deliberate aircraft crash against Rivne 1&2 are not available. It is, however, possible to draw conclusions from the results of studies carried out in other countries e.g. Germany and general considerations regarding the possible effects of such an aircraft crash. A generic study commissioned by the German Federal Environment Ministry revealed, that even a small commercial aircraft (e.g. an Airbus A320) would cause major damage to the reactor building with a wall thickness of 0.6 to 1 metres. (BMU 2002)

Certain protective measures against terror attacks are conceivable. However, their use appears to be rather limited. However, there are plant-specific differences, for example regarding vulnerability of spent fuel pools, robustness of the reactor building. Because of the importance of this topic, and because of the existing variations between NPPs regarding vulnerability that give rise to the requirement of plant-specific analyses, the issue of terror attacks and sabotage should be considered in the further course of the environmental impact assessment of Rivne 1&2.

Although precautions against terror attacks cannot be discussed in detail in public in the EIA procedure for reasons of confidentiality, the necessary legal requirements should be set out in the EIA Report.

Furthermore, additional attack scenarios demand attention: Experts voiced concerns that cyber security has not been fully anticipated as indicated by the nuclear security index of the Nuclear Threat Initiative (NTI). Recent attacks against banking and commerce systems, private companies, and national governments highlight the growing gap between the threat and the ability to respond to or manage it. (NTI 2018)

In SNRIU (2016), it is stated: Taking into account ongoing military actions in eastern Ukraine, the SNRIU together with relevant ministries and administrations continued efforts on improving physical protection of nuclear installations. At present, available law enforcement institutes are able to ensure NPP protection against external actions, such as military aggression, sabotages and terroristic acts, criminal assaults. In 2015, exercises were held at all NPPs to train actions in case of sabotage under different situations. All special forces keeping guard at NPPs participated with relevant rotation in the anti-terrorist operation to gain field experience for service. The documents on protection of the most important facilities have been revised and improved at all Ukrainian NPPs.

However, the assessment of the protection against sabotage recognized shortcomings compared to necessary requirements: The Nuclear Threat Initiative (NTI) assesses measures taken by countries to reduce the risk of sabotage. The NTI Nuclear Security Index ranks countries based on a range of nuclear security measures by analysing factors such as government policy and regulation. It does not conduct direct observations of security measures at individual sites.

The 2020 NTI Index assesses nuclear security conditions related to the protection of nuclear facilities against acts of sabotage. This ranking includes 47 countries where an act of sabotage against a nuclear facility could result in a significant radiological release similar in scale to the release in Japan in 2011 when a tsunami hit the Fukushima Daiichi Nuclear Power Plant. (NTI 2020)

In the NTI Index scores of 100 represent the highest possible score. Ukraine with a total score of 65 points only ranked 29 out of 47 countries, which indicates a low protection level. Table 1:

The 2020 Nuclear Security Index for Ukraine (NTI 2020) shows some details about the NTI Index for Ukraine.

Table 1: The 2020 Nuclear Security Index for Ukraine (NTI 2020)

	Scores	Scores
1) NUMBER OF SITES		**60**
2) SECURITY AND CONTROL MEASURES		**66**
2.1) On-site Physical Protection	60	
2.2) Control and Accounting Procedures	75	
2.3) Insider Threat Prevention	45	
2.4) Response Capabilities	88	
2.5) Cybersecurity	50	
3) GLOBAL NORMS		**94**
4) DOMESTIC COMMITMENTS AND CAPACITY		**78**
5) RISK ENVIRONMENT		**14**
5.1) Political Stability	10	
5.2) Effective Governance	13	
5.3) Pervasiveness of Corruption	0	
5.4) Group(s) Interested in Committing Acts of Nuclear Terrorism	35	
Overall score		**65**

It has to be pointed out that the low scores for “Insider Threat Prevention” and “Cybersecurity” indicate deficiencies in these issues.[26]

Furthermore, the score for section “Risk Environment” is very low, in particular because of the shortcomings in “Political Stability”, “Pervasiveness of Corruption” and “Effective Governance”. In addition, the presence of “Group(s) Interested in Committing Acts of Nuclear Terrorism” raises the risk of sabotage of nuclear facilities.

Physical protection

The IAEA plays a key role in helping states to protect their civilian nuclear materials and facilities. It supports states by undertaking and organizing advisory security assessment and peer-review missions through its **International Physical Protection Advisory Service (IPPAS**). An IPPAS mission is an assessment of the existing practices in a state, in the light of relevant international instruments and IAEA nuclear security publications, and an exchange of experience and accepted international practices aimed at strengthening the nuclear security organization, procedures and practices being followed by a State. (IAEA 2014) To date, no International Physical Protection Advisory Service (IPPAS) has been conducted in Ukraine. (IAEA 2020)

The analyses of man-made impacts do not provide information on the behaviour of the plant and on possible releases due to terrorist attacks or sabotage. The

[26] The lack of cybersecurity is confirmed by the following: In March 2018, Ukrainian police opened a criminal case on the fact of unauthorized intervention in work of computer networks Zaporizhia NPP. (WN 2019)

man-made impacts were excluded from further analyses; cliff-edge effects were not identified.

7.3 Conclusions, questions and preliminary recommendations

Terrorist attacks and acts of sabotage can have significant impacts on nuclear facilities and cause severe accidents – also on the Rivne NPP. Nevertheless, they are not mentioned in the EIA Document for the Rivne NPP. In comparable EIA documents such events were addressed to some extent.

Although precautions against sabotage and terror attacks cannot be publicly discussed in detail in the EIA procedure for reasons of confidentiality, the necessary legal requirements should be set out in the EIA Document.

Information regarding the issue of terror attacks would be of great interest, considering the large consequences of potential attacks. In particular, the EIA Document should include detailed information on the requirements for the design against the targeted crash of a commercial aircraft. This topic is of particular importance, because the reactor building of Rivne 1&2 is vulnerable against terror attacks (including airplane crash).

A recent assessment of the nuclear security in Ukraine points to shortcomings compared to necessary requirements for nuclear security: The 2020 NTI Index assesses nuclear security conditions related to the protection of nuclear facilities against acts of sabotage. With a total score of 65 out of 100 points, Ukraine ranked only 29 out of 47 countries, which indicates a low protection level. It has to be pointed out that the low scores for "Insider Threat Prevention" and "Cybersecurity" indicate deficiencies in these issues. It is recommended to invite this International Physical Protection Advisory Service (IPPAS) of the IAEA that assisted states, in strengthening their national nuclear security regimes, systems and measures.

Questions

1. *What are the requirements with respect to the planned NPP design against the deliberate crash of a commercial aircraft?*
2. *Against which external attacks must the reactor building and other safety relevant buildings be designed? Is this protection still guaranteed despite adverse ageing effects?*
3. *Is a peer-review mission of the IAEA International Physical Protection Advisory Service (IPPAS) planned?*

Preliminary recommendations

1. The EIA Document should present the general requirements with respect to the protection against the deliberate crash of a commercial aircraft and other terror attacks and acts of sabotage.
2. In light of the special situation in Ukraine, the impact caused by third parties (terrorist attacks or acts of sabotage of the plant) should be given high priority. Protection against cyber-attacks and insiders should be improved. The IAEA's International Physical Protection Advisory Service (IPPAS) should be used to improve the security.

8 TRANS-BOUNDARY IMPACTS

8.1 Treatment in the EIA Document

Accident scenarios and source term

The radiation impact of Rivne NPP was analyzed based on the following **maximum design basis accident (MDBA)**: an accident caused by double-ended rupture of the cooling system pipeline (loss-of-coolant accident) at normal energy level. (EIA REPORT BOOK 7, 2018)

Table 2: Radionuclide release activities during the MDBA (EIA REPORT BOOK 7, 2018) shows radionuclide release parameters during the MDBA. The accident duration is taken to be 60 minutes. Other accidents that result in lower radionuclide releases are omitted.

Table 2: Radionuclide release activities during the MDBA (EIA REPORT BOOK 7, 2018)

Radionuclide	Release during MDBA in Bq
Kr-88	2.00E+13
Sr-90	3.10E+11
Ru-103	4.50E+12
Ru-106	6.60E+11
I-131	4.98E+12
I-132	2.70E+12
I-133	4.00E+12
I-135	2.30E+12
Cs-134	7.80E+11
Cs-137	5.00E+11
La-140	8.40E+12
Ce-141	1.40E+13
Ce-144	8.60E+12

The radionuclide release during the **beyond design basis accident (BDBA)** was determined based on the limit value of environmental release of Cs-137 at the level of 30 TBq in accordance with the safety requirements of European operators for designs of nuclear power plants with light water reactors (LWR). Cs-137 isotope was chosen due to its prevalent value for long-term environmental pollution as well as its health impact. Other isotopes in the form of aerosol are released into the environment proportionately to this value, even if these isotopes are released into the atmospheric air.

The total list of radionuclides that may be released in the environment includes other radioisotopes from the same group, which are present in the general member in proportion equal to that of the sum of decay products in the reactor core with respect to the illustrative isotope.

Primary radionuclides and their respective releases in case of the BDBA are listed in Table 3: Radionuclide release during the BDBA at RNPP (EIA REPORT BOOK 7, 2018).

Table 3: Radionuclide release during the BDBA at RNPP (EIA REPORT BOOK 7, 2018)

Radionuclide	Release amount, TBq	Radionuclide	Release amount, TBq
Xe-133	3.50E+05	Cs-136	1.50E+01
Kr-85	2.10E+03	Te-131m	2.00E+01
Kr-85m	5.30E+04	Te-129m	8.00E+00
Kr-87	1.10E+05	Te-132	2.00E+02
Kr-88	1.40E+05	Sb-127	1.60E+01
Xe-131m	2.10E+03	Sb-129	4.60E+01
Xe-133m	1.10E+04	Sr-90	5.00E+00
Xe-135	1.10E+05	Sr-89	6.00E+01
Xe-135m	7.70E+04	Sr-91	7.50E+01
Xe-138	3.20E+05	Ru-103	3.00E+00
I-131	1.00E+03	Mo-99	4.00E+00
I-132	1.50E+03	La-140	5.00E+00
I-133	2.10E+03	Y-91	4.00E+00
I-134	2.30E+03	Ce-141	4.00E+00
I-135	2.00E+03	Ce-144	3.00E+00
Cs-137	3.00E+01	Np-239	4.80E+01
Cs-134	6.00E+01	Ba-140	1.00E+02

The EIA Document came to the conclusion that under both normal and accident conditions the planned activity does not have major trans-boundary impacts. (EIA REPORT BOOK 7 2018, p. 1380.)

The distance to the Austrian border was determined to be 700 km. Calculated doses under normal operation at the Austrian border were assessed as 0.15 nSv/year for infants and 0.13 nSv/year for adults. (EIA REPORT BOOK 7 2018, p. 1330f.)

For the Beyond Design Basis Accident, resulting 50 year effective doses for Austria are given which are about 0.1 mSv. (EIA REPORT BOOK 7 2018, p. 1340)

8.2 Discussion

A source term of 30 TBq Cs-137 for a beyond design basis accident (BDBA) is not the largest possible source term for a severe accident in Rivne NPP.

This source term of a BDBA was determined on the basis of the limit value of the release of Cs-137 in the amount of 30 TBq according to the safety requirements of the European operators for the design of a light water reactors (LWR). However, this limited source term can only be assumed if the plant has been designed or retrofitted accordingly. This is not the case for the Rivne NPP.

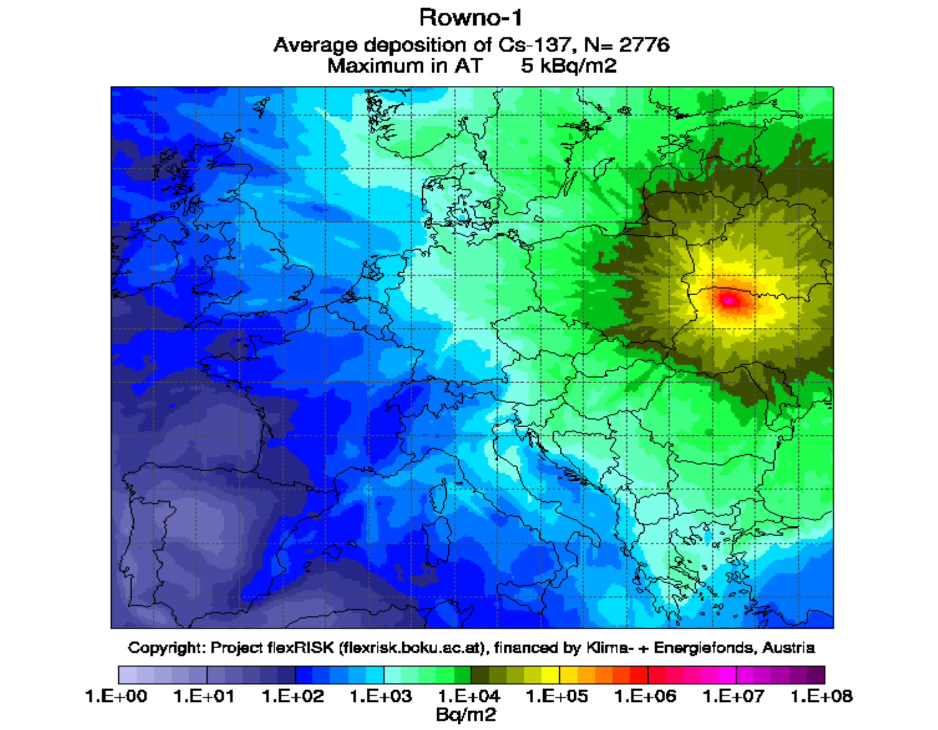
As already explained in chapter 5, the assumption of this relatively moderate source term is not justified in any way. The measures to limit the release in case of a severe accident have not yet been implemented.

The project flexRISK made an assessment of source terms and identified for Rivne 1 and 2 a possible source term of 76,500 TBq Cs-137, which is about a factor 2,000 more than assumed in the EIA Document. (FLEXRISK 2013) This source term is calculated with respect to the behavior of the plant in case of a severe accident and the possible release.

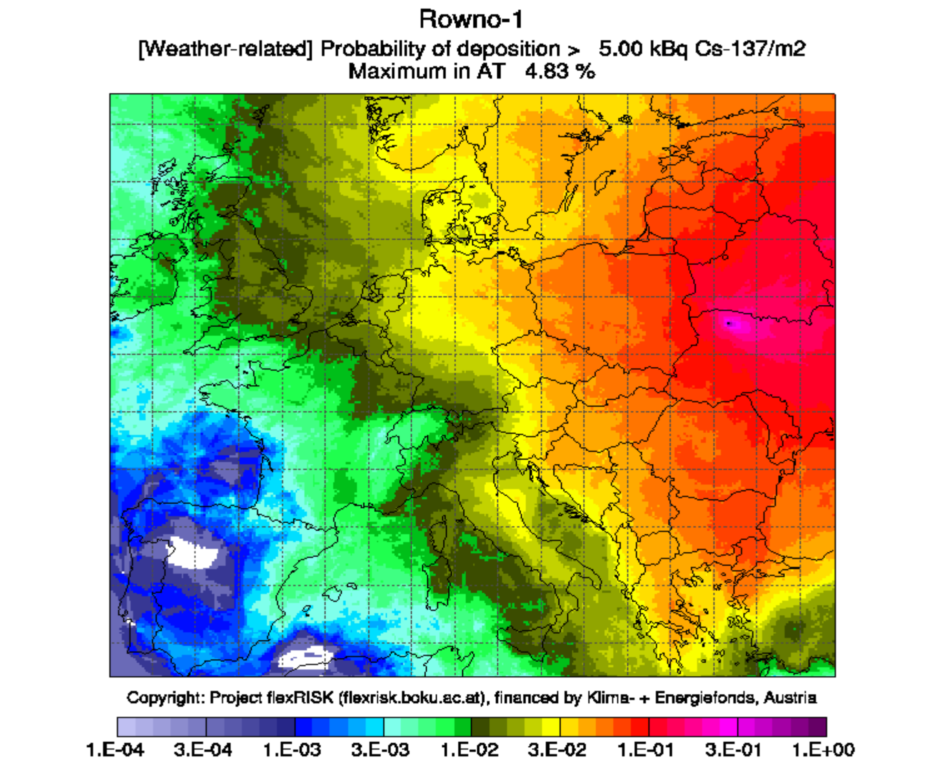
Calculations of the flexRISK project can be used for the estimation of possible impacts of trans-boundary emission of Rivne 1&2. The flexRISK project modelled the geographical distribution of severe accident risk arising from nuclear power plants in Europe. Using source terms and accident frequencies as input, for more than 2,000 meteorological situations the large-scale dispersion of radionuclides in the atmosphere was simulated.

Figure 5: Average deposition of Cs--137 after a hypothetical BDBA in Rivne-1. illustrates the average deposition of Cs-137 after a severe accident at Rivne-1 with the Cs-137 release of 76.5 PBq. Such an accident could result in a considerable contamination of the Austrian territory; the average deposition of Cs-137 in the simulation is up to 5,000 Bq/m².

Figure 5: Average deposition of Cs--137 after a hypothetical BDBA in Rivne-1.



Source: http://flexrisk.boku.ac.at/en/evaluationAggUnit.phtml umweltbundesamt



Source: http://flexrisk.boku.ac.at/en/evaluationAggUnit.phtml#form umweltbundesamt

Figure 6: Weather-related probability for a contamination exceeding 5 kBq Cs-137/m2by a severe accident at Rivne-1.

flexRISK determined the weather-related probability for a contamination of Austrian territory with more than 5 kBq Cs-137/m² with 4.83% (see Figure 6: Weather-related probability for a contamination exceeding 5 kBq Cs-137/m2by a severe accident at Rivne-1.). The weather-related probability for a contamination with more than 37 kBq Cs-137/m² is 2.2%, for more than 185 kBq Cs-137/m² 0.68%, and for more than 1,480 kBq Cs-137/m² 0.04%, respectively.

These probabilities might be low, but in Austria even lower contamination triggers agricultural countermeasures. These measures include earlier harvesting, closing of greenhouses and covering of plants, putting livestock in stables etc. A catalogue of countermeasures for radiological crisis situations is used (BMLFUW 2014), which requires the introduction of agricultural protection measures even in the case of low levels of contamination. This catalogue includes, among others, measure A07 ("Immediate harvesting of marketable products, in particular of storable products") with its associated (forecast) levels:

Table 4: Levels for the agricultural countermeasures A07 (BMLFUW 2014)

	I-131 Bq*h/m³	**I-131 Bq/m²**	**Cs-137 Bq*h/m³**	**Cs-137 Bq/m²**
Start of measure A07	170	700	350	650

A contamination of 5 kBq Cs-137/m² like in Table 4: Levels for the agricultural countermeasures A07 (BMLFUW 2014) is much higher than the level for the Cs-137 contamination in the above table, therefore agricultural countermeasures could be necessary on Austrian territory in case of a severe accident at the Rivne site.

To exclude the possibility of transboundary severe impacts, including the necessity of agricultural countermeasures, dispersion calculations and dose calculations should be performed for distances beyond 700 km, with the goal to compare the results to the Austrian levels from the catalogue of countermeasures (BMLFUW 2014), but also the dose levels specified in the Austrian Emergency Plan[27] (BMK 2020).

Also proof has to be provided that accident releases over 30 TBq Cs-137 are excluded; otherwise calculations with the highest possible source term and under the assumption of the most negative weather condition for Austrian territory are necessary.

8.3 Conclusions, questions and preliminary recommendations

The used source term for Cs-137 (30 TBq) of a beyond design basis accident (BDBA) was determined on the basis of the limited value of the release according to the safety requirements of the European operators. The assumption of this relatively moderate source term is not justified. This limited source term can only be used if the plant has been designed or retrofitted accordingly. This is not the case for the Rivne 1&2 NPP. The project flexRISK made an assessment of source terms and identified for Rivne 1 and 2 a possible source term for Cs-137 (76,500 TBq). This source term is related to the behaviour of the plant in case of a severe accident and the possible release.

Severe accidents with releases considerably higher than assumed in the EIA Document therefore cannot be excluded for Rivne 1&2. Such worst case accidents should be included in the assessment since their effects can be widespread and long-lasting and even countries not directly bordering Ukraine, like Austria, can be affected.

Because of the lack of analysis of the worst case scenarios, the conclusion of the EIA Document concerning trans-boundary effects cannot be considered sufficiently proven.

The results of the flexRISK project indicated that after a severe accident, the average Cs-137 ground depositions in most areas of the Austrian territory could be higher than the threshold for agricultural intervention measures (e.g. earlier harvesting, closing of greenhouses). Therefore, Austria could be significantly affected by a severe accident at Rivne 1&2.

[27] The criteria for intervention measures in the new Austrian Emergency Plan (BMK 2020) are the same as in the former Intervention Regulation (IntV 2017, attachment 1). In the new Intervention Regulation (IntV 2020) the values are no longer published, but a reference is made to the Austrian Emergency Plan. The Austrian Emergency Plan will be available online in 2021. The link to IntV (2017) is documented in the References.

Questions:

1. *Please provide the quantitative results of the calculated ground deposition of I-131 and Cs-137 for the distance to Austria.*

Preliminary recommendations

1. It is recommended to perform a dispersion calculation using a source term that is based on specific severe accident analyses of the Rivne1&2.

9 SUMMARY OF QUESTIONS AND PRELIMINARY RECOMMENDATIONS

9.1 Overall and procedural aspects of the Environmental Impact Assessment

Questions

1. *How will the results of the EIA be taken into account?*
2. *What are the further steps in the licensing procedure?*

Preliminary recommendation

1. Energoatom and the State Nuclear Regulatory Inspectorate of Ukraine SNRIU should provide adequate information on the EIA procedure and the further licensing procedure.
2. Alternatives of the lifetime extensions and the no-action alternative should be included in the EIA Document.
3. It is recommended to enable public participation in environmental assessments of nuclear projects according to the requirements of the Espoo Convention at a time when all options are still open.

9.2 Spent fuel and radioactive waste

Questions

1. *What is the expected inventory of spent fuel and radioactive waste from the lifetime extension of Rivne 1&2?*
2. *What is the status of the central interim storage facility for spent fuel (CSFSF)?*
3. *Is an international cooperation for final disposal of spent fuel and/or radioactive waste planned?*
4. *Which interim and final storages for radioactive waste are in operation in Ukraine, will their capacity be sufficient to dispose of all radioactive waste from the lifetime extension and decommissioning of Rivne 1&2?*
5. *How can the safe storage of spent fuel and radioactive waste be ensured if the interim storages and final disposals will not be ready in time?*

Preliminary recommendation

1. To demonstrate the safe management of nuclear waste detailed information on the interim storages and final disposals should be provided; also alternative nuclear waste management solutions, if these facilities will not be operable in time.

9.3 Long-term operation of reactor type VVER 440

Questions

1. *What is the time schedule for the necessary improvement of the ageing management programme (AMP) based on the findings of the Topical Peer Review (TPR) based on Article 8e of EU Directive 2014/87/EURATOM?*
2. *What are the specific findings of the ageing management programme for Rivne 1&2?*
3. *What are the results of Safety Factor (SF) 4 (structures, systems and components ageing) of the last periodic safety review?*
4. *What are the results of the embrittlement of the reactor pressure vessels (RPVs)?*
5. *Is the preparation of a systematic evaluation of the Rivne 1&2 design deviations from the current international safety standards and requirements envisaged?*
6. *Which safety systems and Severe Accident Management (SAM) systems are shared between the units?*
7. *To which extent were and will international documents (IAEA, WENRA) be applied in a binding manner for the lifetime extension?*
8. *When will the WENRA RL be fully implemented in the Ukrainian regulations? Is the application of the RL binding?*
9. *When will be conducted a review on whether the Rivne 1&2 meets the WENRA RL requirements?*

Preliminary Recommendations

1. It is recommended to implement all available design improvements of VVER-440/V213 reactor at the Rivne 1&2.
2. It is recommended to compare the design and features of the Rivne 1&2 with all requirements of WENRA RL F. In case of deviations, the reasons for this should be explained.
3. It is recommended to provide the following further information:
   a. detailed descriptions of the safety systems, including information on requirements for the important safety-relevant systems and components. Furthermore, detailed description of the measures taken to control severe accidents or to mitigate their consequences.
   b. Information about the applied national requirements and international recommendations.
   c. comprehensible presentation and overall assessment of all deviations from the current state-of-the-art of science and technology. This presentation should include:
      - All deviations from the modern requirements for redundancy, diversity and independence of the safety levels.
      - Incompleteness of the database and plant documentation used.

- Presentation of all safety assessments or parameter definitions by personal expert assessments ("engineering judgement").
- Presentation of the general approach in dealing with uncertainties and non-knowledge and its effects on risk
- Deviations from the state-of-the-art of science and technology with regard to the detection methods used, the technical estimates and calculation procedures.
- Safety margins available for the individual safety-relevant components and their respective ageing related changes compared to the original condition.

d. Information about the ageing management program including:

- The national action plan relating to the Topical Peer Review (TPR) "Ageing Management" under the Nuclear Safety Directive 2014/87/EURATOM and its progress.
- The very important safety issue of the ageing of the RPVs (embrittlement), including definition and justification of appropriate safety margins.

9.4 Accident Analyses

Questions

1. *What are the source terms of the calculated BDBA in the PSA 2 including releases from the spent fuel pools?*
2. *Which requirements have the filtered venting systems to fulfil, particularly regarding earthquake resistance?*
3. *What is the currently valid time schedule for the implementation of all required SAM features for the Rivne 1&2?*
4. *What are the parameters of the maximum aircraft crash (plane mass and speed) the buildings of the Rivne 1&2 can withstand?*
5. *What is the technical justification of the BDBA that is chosen to calculate possible trans-boundary consequences?*

Preliminary recommendation

1. It is recommended to use the WENRA Safety Objectives for new NPP to identify reasonably practicable safety improvements for Rivne 1&2. It is recommended to use the concept of practical elimination for this approach.
2. It is recommended to provide the following information concerning accident analyses and the results of the PSA (Level 1, 2 und 3):

a. Core damage frequency (CDF) and large (early) releases frequency (L(E)RF)

b. Contribution of internal events as well as internal and external hazards to CDF and L(E)RF

c. List of the beyond design basis accidents (BDBAs)

d. Source terms of the BDBAs including releases from the spent fuel pools

e. Time spans to restore the safety functions after the loss of heat removal and/or station-blackout and cliff edge effects.

9.5 Accidents initiated by natural events and site assessment

Questions

1. *Why has flooding due to extreme precipitation been excluded from the further consideration of natural hazards?*
2. *The probability of the water level of the River Styr to drop below the critical value of 158.80 m in case of drought is stated with 0.3% per year. Would the dropping of the water level even lower result in the full unavailability of cooling water from the River Styr?*
3. *Are the water reserves at the primary and secondary circuits of the WWER units large enough to cool all four reactors after shutdown from full power and maintain cooling until a safe state is reached in cases when no cooling water is available from River Styr?*
4. *Is it intended to equip the Rivne NPP with a second, independent cooling water supply such as ground water wells to ensure the availability of cooling water/essential service water in case of low river water levels and drought?*
5. *With respect to snow loads the EIA REPORT BOOK 1 (2018, p. 109) refers to a "current normative document" that sets the normative values of the snow load for the Rivne region to 1,400 Pa. This value is above the original design. What are the consequences of this discrepancy between the status as-built and the current requirements for buildings housing safety-relevant SSCs of the Rivne reactors?*
6. *TERMINOLOGY USED FOR THE DESCRIPTION OF SEISMIC HAZARDS IN THE EIA REPORT BOOK 3 VOL 3 (2018, P. 718ff) appears unclear. The Austrian experts had to assume that the "design basis earthquake (DBE)", also termed "Project Earthquake (PE)", refers to SL-1 as used by IAEA (2010) and the "safe shutdown earthquake (SSE)", also termed "maximum estimated earthquake (MEE)", refers to SL-2 (IAEA, 2010) or the Design Basis Earthquake (WENRA, 2014a; 2015). Also they assumed further that terms like "5 point", "6 point", "magnitude 5", "magnitude 6" refer to intensity (MSK-64 scale) instead of magnitude. Is this correct?*
7. *EIA includes contradicting information about the recurrence interval of "maximum estimated earthquake" (also termed "safe shutdown earthquake") with I=6. Both, values of 5,000 and 10,000 years are stated as*

recurrence intervals. The Austrian experts ask for the clarification of this contradiction.

8. *It appears that I=VI MSK64 is associated with Peak Ground Acceleration (PGA) of 0.05g. What is the basis for such a correlation between macro-seismic intensity and ground acceleration?*
9. *The IEA document mentions additional seismic hazard assessments that were performed in the late 1990ies and early 2000nds. These, however, are not further explained in the EIA Document. The Austrian experts ask to provide those references and results of these investigations for the Rivne NPP site.*
10. *Karstification and suffusion are listed as hazardous phenomena destabilizing the soil under the NPP site, also under the reactor buildings. According to the EIA REPORT BOOK 3 VOLUME 3, (2018, p.721-722) the foundations for unit 4 are laid on piles reaching below the karstified layer into basalt.*

    Are the foundations of the other reactor units constructed in the same way?

    Are the concrete injections sufficient to stabilize fundaments of the other blocks?

    How is the stability of foundations secured for other buildings housing safety-relevant equipment and safety-relevant underground piping?
11. *How is sewage water removed from the site? Is it secured that concentrated seepage of sewage water from surface runoffs and/or direct infiltration of sewage water does not lead to extended man-made karstification and suffusion?*
12. *The formation of a "ground water dome" at the site proves the continued outflow of large amounts of water from the hydro-engineering installations. How is it secured that these outflows do not destabilize the foundation soil by increased karstification and suffusion?*

    Are the cooling towers, cooling water channels and pipes, which are supposed to be the sources of infiltrating water, subjected to a monitoring program to secure their stability? Are those structures made of watertight concrete or lined with other impermeable materials?

    What are the measures envisaged to reduce or prevent the infiltration of technical water and reduce karstification / suffusion processes?

Preliminary recommendation

1. The list of natural hazards assessed in the EIA REPORT BOOK 1 (2018) is not complete. The Austrian expert team recommends the use of the "Non-exhaustive List of Natural Hazard Types" (WENRA, 2015) as a starting point to ensure that all site-specific hazards are addressed.
2. Natural hazard assessment does not address hazard combinations as required by WENRA (2014a) and further explained by WENRA (2015). The Austrian expert team recommended the use of a hazard correlation chart (e.g., DECKER & BRINKMAN, 2017) as a starting point to ensure that all relevant combinations are addressed.
3. The Austrian expert team recommends the selection of design basis parameters from design basis events with occurrence probabilities of 10^{-4}

per year for all natural hazards that apply to the site and use the derived parameters to develop adequate protection concepts. This is particularly important for, but should not be limited to the following hazards: high wind, external flooding by extreme precipitation, snow storm and snow load.

4. The Austrian expert team recommends the upgrade of the protection against wind loads to ensure that SSCs important to safety and buildings that house SSCs important to safety withstand wind speeds with occurrence probabilities of 10^{-4} per year.
5. The Austrian expert team recommends the upgrade of the capacity of the sewer systems to ensure that precipitation intensities with occurrence probabilities of 10^{-4} per year do not lead to (a) water ingress into buildings that house SSCs important to safety (b) flooding of the basement of such buildings.
6. The Austrian expert team recommends the re-evaluation of the occurrence probability of extreme precipitation that leads to the flooding of the site and compare the results to the capacity of the sewer system. These evaluations should consider the possible contribution of thaw water and combinations of thawing and rain. The precipitation intensity corresponding to the occurrence probability of 10^{-4} per year should be taken as the design basis for the capacity of the sewer system (IAEA, WENRA), and the sewer systems for individual buildings and the site as a whole should be upgraded accordingly.
7. The Austrian expert team recommends the evaluation of the possible safety benefits of an independent ultimate heat sink in addition to the River Styr (e.g., ground water wells) to further reduce hazards arising from drought and low river water level.
8. The Austrian expert team recommends to implement the additional investigations and monitoring measures to identify and mitigate adverse effects karstification and suffusion suggested in the EIA REPORT BOOK 3 VOLUME 3 (2018), pages 730-731.
9. The Austrian expert team recommends to further analyse the sources of technical water infiltrating into the karstified aquifer in the foundation soil of the Rivne NPP site (e.g., from cooling towers and connected water channels) and to prevent further infiltration by adequate measures. The recommended action should prevent the continued degradation of the foundation soil by man-made karstification and suffusion.
10. The Austrian expert team recommends the implementation of automatically initiated active safety measures that trigger power reduction or shutdown upon the exceedance of pre-set temperature limits for maximum and minimum air and/or cooling water temperatures. At the minimum, administrative measures should be developed to respond to hazardous temperature extremes. The protection concept should take into account the advantage that both, extremely high and low temperatures are predictable hazards and progress slowly.
11. The Austrian expert team recommends an update of the current seismic design basis to the value of 0.1g to fulfil the minimum requirements of WENRA Safety Reference Level T 4.2 (WENRA, 2014a).

12. The Austrian expert team recommends to use the procedures for the life time extension of Rivne NPP for a periodic review the site-specific seismic hazard as recommended by WENRA (2016, p. 25). This review should take advantage of the rapid development of science and technology in the fields of geology, seismology and paleo-seismology that were achieved in the last decades and include targeted assessments of the major faults closest to the site. Up-to-date fault investigations include, for instance, reflection seismic and paleo-seismological techniques.
13. The Austrian expert team recommends to apply the WENRA approach of analysing Design Extension Conditions (DEC) for natural hazards and updates of the protection concepts against natural hazards. DEC are not analysed in the available EIA Document. This is in violation of the WENRA requirement that DEC analysis shall be undertaken with the purpose of further improving the safety of existing nuclear power plants and enhancing their capability to withstand more challenging events or conditions than those considered in the design basis.

9.6 Accidents with involvement of third parties and man-made impacts

Questions

1. *What are the requirements with respect to the planned NPP design against the deliberate crash of a commercial aircraft?*
2. *Against which external attacks must the reactor building and other safety relevant buildings be designed? Is this protection still guaranteed despite adverse ageing effects?*
3. *Is a peer-review mission of the IAEA International Physical Protection Advisory Service (IPPAS) planned?*

Preliminary recommendations

1. The EIA Document should present the general requirements with respect to the protection against the deliberate crash of a commercial aircraft and other terror attacks and acts of sabotage.
2. In light of the special situation in Ukraine, the impact caused by third parties (terrorist attacks or acts of sabotage of the plant) should be given high priority. Protection against cyber-attacks and insiders should be improved. The IAEA's International Physical Protection Advisory Service (IPPAS) should be used to improve the security.

9.7 Trans-boundary impacts

Questions:

1. *Please provide the quantitative results of the calculated ground deposition of I-131 and Cs-137 for the distance to Austria.*

Preliminary recommendations

1. It is recommended to perform a dispersion calculation using a source term that is based on specific severe accident analyses of the Rivne1&2.

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13 GLOSSARY

AAMS .... Automated Ageing Management System
AM .... Ageing Management
AMP .... Ageing Management Programme
BDBA .... Beyond Design Basis Accident
Bq .... Becquerel
C(I)SIP .... Comprehensive (Integrated) Safety Improvement Program
CDF .... Core Damage Frequency
CRWP .... Complex for radioactive waste processing
CSFSF .... Centralized spent fuel storage facility (interim storage for spent fuel)
Cs-137 .... Caesium-137
DBA .... Design Basic Accident
DEC .... Design Extension Conditions
EBRD .... European Bank for Reconstruction and Development
EC .... European Commission
ECR .... Emergency Control Room
EIA .... Environmental Impact Assessment
ENSREG .... European Nuclear Safety Regulators Group
EOP .... Emergency Operating Procedures
EU .... European Union
EUR .... European Utility Requirements
g .... Gravitational Acceleration
I&C .... Instrumentation and Control
I-131 .... Iodine-131
IAEA .... International Atomic Energy Agency
IPPAS .... International Physical Protection Advisory Service
IVMR .... In-Vessel Melt Retention
IVR .... In-Vessel Retention
LOCA .... Loss of Coolant Accident
LRF .... Large Release Frequency
LTO .... Long-Term Operation
LWR .... Light Water Reactor
MCR .... Main Control Room
MDBA .... Maximum Design Basis Accident
MDGPU .... Mobile Diesel Generators and Pumping Unit
NAcP .... National Action Plan
NDE .... Non-Destructive Examination
NDI .... Nondestructive Inspection
NPP .... Nuclear Power Plant

NTI .... Nuclear Threat Initiative
OBE.................... Operating Base Earthquake
OZ .... Observation Zone (30km)
PGA.................... Peak Ground Acceleration
PSA .... Probabilistic Safety Assessment
PSR .... Preliminary Safety Report
PWR................... Pressurized Water Reactor
RHWG................ Reactor Harmonization Working Group
RL....................... Reference Level
RPV.................... Reactor Pressure Vessel
SAM .... Severe Accident Management
SAMG................. Severe Accident Management Guideline
SBO.................... Station Black Out
SC .... Sealed Containment
SE NNEGC .... State Enterprise National Nuclear Generating Company
SEA .... Strategic Environmental Assessment
SF....................... Safety Factors
SFP .... Spent Fuel Pool
SG .... Steam Generator
SNRIU .... State Nuclear Regulatory Inspectorate of Ukraine
SPZ .... Sanitary Protection Zone (2.5km)
SS Rivne NPP .... Separate subdivision “Rivne nuclear power plant”
SSC.................... Structure, Systems and Components
SSE .... Safe Shutdown Event
TBq..................... Tera-Becquerel, E12 Bq
TCA .... Technical Condition Assessment
TLAA .... Time Limited Ageing Analysis
TPR .... Topical Peer Review
UNECE............... United Nations Economic Commission for Europe
VVER .... Water-Water-Power-Reactor, Pressurized Reactor originally developed by the Soviet Union
WENRA.............. Western European Nuclear Regulators´ Association

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