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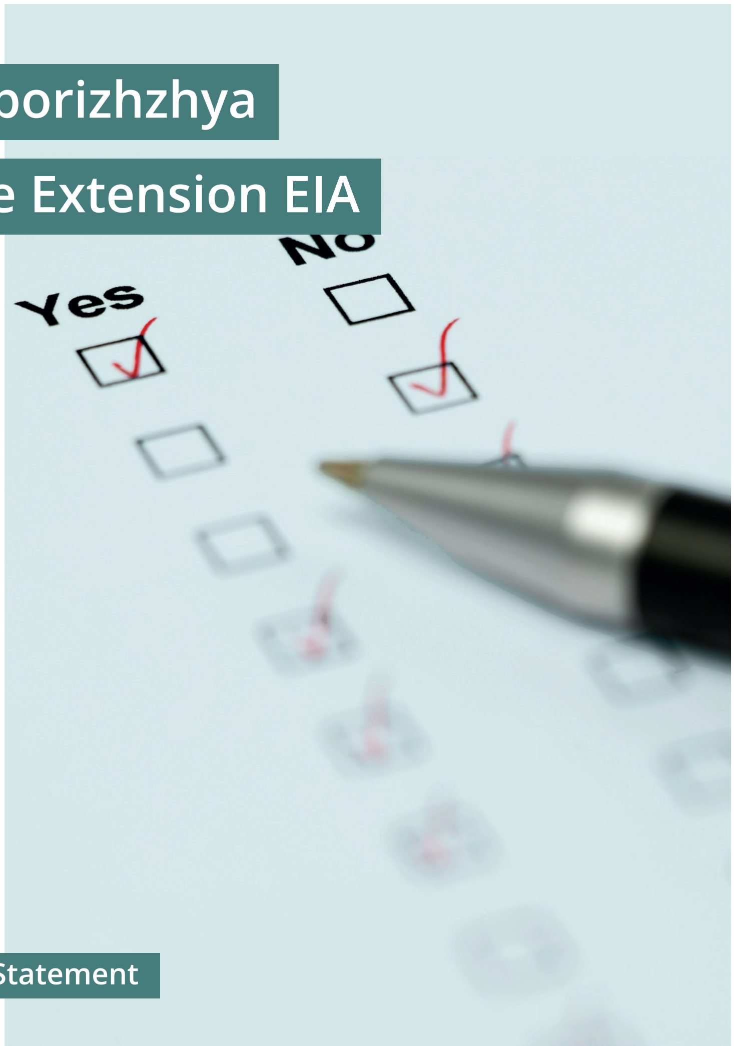
NPP Zaporizhzhya

Lifetime Extension EIA



Final Expert Statement

Federal Ministry
Republic of Austria
Climate Action, Environment,
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Innovation and Technology

pulswerk
Das Beratungsunternehmen des
Österreichischen Ökologie-Instituts

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NPP ZAPORIZHZHYA LIFETIME-EXTENSION ENVIRONMENTAL IMPACT ASSESSMENT

Final Expert Statement

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SUMMARY

The Ukrainian nuclear power plant Zaporizhzhya (ZNPP) is located at the Dnepr River on the left bank of the Kakhovka water reservoir. The site is located in the Zaporizhzhya oblast. At the Zaporizhzhya site, six VVER-1000 reactors are in operation. The reactors were connected to the grid between 1984 and 1995. The NPP is owned by the State Enterprise "National Nuclear Energy Generating Company Energoatom", in short Energoatom. SE ZNPP is a separate entity of Energoatom.

For the lifetime extension of Zaporizhzhya 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.

The Austrian Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology commissioned the Environment Agency Austria to coordinate the assessment of the submitted EIA Documents in the framework of an expert statement (UMWELTBUNDESAMT 2021). In this expert statement, questions and preliminary recommendations were formulated.

In September 2021, the Ukrainian side provided answers to these questions in written form. (ZNPP ANSWERS 2021) The final expert statement at hand assesses these answers and gives final recommendations.

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.

Procedure and alternatives

While Ukraine initially notified Austria an Environmental Impact Assessment (EIA) for lifetime extension of ZNPP units 3-6, it has now been clarified that this EIA is conducted for all 6 ZNPP units.

In the EIA documents, a life-time extension of 15 years was defined for the ZNPP units. But in ZNPP ANSWERS (2021) a life-time extension of *"no less than 20 years"* was announced. This is a significant change of the information submitted initially. Furthermore, the maximum lifetime extension has not been clarified to date.

The EIA documents that were submitted to Austria are from 2015 and therefore did not reflect the development of the last years and need to be updated. According to the Espoo Convention it shall be ensured that the opportunity to participate provided to the public of the affected Party is equivalent to that provided to the public of the Party of origin. (ESPOO CONVENTION 1991, Art. 2.6) This was not the case in this EIA because only an incomplete set of documents was provided. The Ukrainian public received more documents, among those also newer documents (e.g.: the non-technical Summary for ZNPP-5 is from 2020). No updated EIA documents or additional EIA documents have been delivered during consultations.

The licenses for the lifetime extensions for ZNPP 1-5 have been issued before the trans-boundary EIA has been finished. According to the Espoo Convention an EIA has to be conducted prior to a decision to authorize the proposed activity. (ESPOO CONVENTION 1991, Art. 2.3) The provided answers during consultations did not clarify if the envisaged review of the results of the trans-boundary EIA undertaken by the responsible Ukrainian Ministry of Environment and Natural Resources will also concern the licenses issued earlier.

The assessment of reasonable alternatives and the no-action alternative is lacking.

Spent fuel and radioactive waste

Information on the volume of radioactive waste generated during the life-time extension was provided but does not allow a comparison with the available capacities for interim and final storage because of lack of data.

Spent fuel is stored at the on-site interim dry storage DSFSF; capacities are sufficient for the lifetime extension. As a possible back-end management strategy the long-term operation beyond the 50 years of interim storage period is being evaluated.

The containers in the DSFSF are not placed in a building but simply surrounded by a wall. Proof showing that this type of dry storage is designed to withstand external hazards and airplane crashes is necessary, covering not only events with the highest probability but also with maximum impact.

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

Long Term operation of the reactor type

Although ageing of the up to 38 years old structures, systems and components is a safety issue for the ZNPP units, it is not addressed in the provided EIA documents. A comprehensive ageing management program (AMP) is necessary to limit ageing-related failures at least to a certain degree. Information about an ageing management programme (AMP) is also not given in the EIA documents. In the ZNPP ANSWERS (2021) some general information about the AMP is provided.

According to the ZNPP ANSWERS (2021), the evaluation of the aging of structures, systems and components (safety factor (SF) 4) within the framework of the last periodic safety review proved that safe operation is possible until 05.03.2027 (Unit 3), until 04.04.2028 (Unit 4), until 27.05.2030 (Unit 5) respectively. The re-assessment of Unit 6 has not been completed yet.

However, the Topical Peer Review (TPR) "Ageing Management" under the Nuclear Safety Directive 2014/87/EURATOM, carried out in 2017/18, identified several deviations of the TPR expected level of performance that should be reached to ensure an acceptable ageing management throughout Europe. The results of the TPR and the activities to remedy the weaknesses were not presented in the EIA documents, in particular the very important safety issue of the embrittlement of the reactor pressure vessels (RPVs). According to SNRIU (2021a), the National Action Plan to address the deficiencies identified in the TPR will be completed in December 2024.

Although conceptual ageing is also an issue for the ZNPP, the EIA documents do not deal with any of the safety issues of the VVER-1000 reactors. NPP designs that were developed in the 1980s, like the VVER-1000 reactors, only partly meet modern design principles concerning redundancy, diversity and physical separation of redundant subsystems or the preference of passive safety systems. The old VVER reactor type has several design weaknesses, which cannot be resolved by performing back-fitting measures. The containment basement is located at a higher level in-side the reactor building. In case of a severe accident, melt-through can occur within approx. 48 hours. The containment atmosphere will then blow down in-to parts of the reactor building that are not leak-tight resulting in high releases. Another weakness is the protection against external hazard. The reactor buildings are only designed against accidents of small aircrafts.

The EU Stress Tests had revealed already in 2011 that Ukrainian NPPs are compliant only with 172 of the 194 requirements according to the IAEA Design Safety Standards published in 2000. Implementation of necessary improvements is on-going in the framework of the Comprehensive (Integrated) Safety Improvement Program (C(I)SIP). The completion of the program was postponed several times. As of 31/03/2021 still a lot of measures have to be implemented. In spite of some progress, the program ran into a long delay. From a safety point of view, it is incomprehensible that the completion of the measure was not a prerequisite for the lifetime extension. But lifetime extension is already granted for ZNPP units 1-5.

SNRIU is a member of the Western European Nuclear Regulators' Association (WENRA). In 2014, WENRA published a revised version of the Safety Reference Levels (RLs) for existing reactors to take into account lessons learned from the Fukushima Daiichi accident. Ukraine has not implemented 88 RL out of the 342 until January 1, 2021. 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). This concept is not applied for the ZNPP. All in all, a significant gap remains between the required safety standard and the actual safety level of the ZNPP units. The document ZNPP ANSWERS (2021) indicated that the IAEA Documents but not WENRA Documents are used in the frame of the lifetime extension. The implementation of the WENRA RL into Ukrainian legislation has not taken place yet.

Accident Analysis

The provided EIA documents give information about Design Basis Accidents (DBA) including the scenarios, the releases and the consequences. The information about Beyond Design Basis Accidents (BDBA), however, is very limited. Neither the possible accident scenarios nor the source terms are provided.

It is stated in the ZNPP ANSWERS (2021) that in accordance with Ukraine regulatory documents, BDBA and Severe Accident scenarios were not analysed as part of the EIA procedure. It is also pointed out that the radiation impact on the surveillance zone (30 km) has been evaluated. However, the source term for this calculation is not given.

The accident analyses in the EIA documents should use a possible source term derived from the calculation of the current probabilistic safety analyses PSA level 2. Even though the calculated probability of severe accidents with a large release is low, the consequences caused by these accidents are potentially enormous. Although a lot of information is provided in ZNPP ANSWERS (2021), the most important information for the evaluation of the possible impact on Austria is missing: possible releases (source terms) in case of a severe accident.

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-1000 reactor type. ZNPP ANSWERS (2021) confirmed that there are several accident scenarios which can cause a loss of the containment integrity: accidents with containment integrity loss at early stage; accidents with containment bypass; and accidents with containment integrity loss at a late stage (due to hydrogen burning; overpressure or core melt reaction with concrete).

The conclusion of SNRIU that the units are operating safely with an acceptable level of risk cannot be agreed on the basis of the provided information. There is still a high probability that accident scenarios will develop into a severe accident that threatens the integrity of the containment and result in a large release.

The Core Damage Frequency (CDF) and the Large Release Frequency (LRF) values show that that most of the core melt accidents result in large early releases: about 53 % (unit 1), 58 % (unit 2), 87 % (unit 3) 84 % (unit 4), 63 % (unit 5) and 83 % (unit 6). Fuel damages in the spent fuel pools caused by an external event result almost always in a large and early release. Because of the outdated design of the VVER-1000, there are no effective measure in place to avoid a large release after a core melt accident.

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, but it is not implemented at any unit of the ZNPP yet. Furthermore, there is no system for cooling and stabilizing a molten core for the ZNPP available. In the framework of the Stress Tests a strategy for possible corium confinement within the reactor pressure vessel has to be analyzed by 2023. The deadline was postponed from 2015.

The results of the EU Stress Tests have revealed many shortcomings in the prevention of severe accidents and the mitigation of its consequences. 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. There is a constant delay of the implementation of safety upgrading measures.

Furthermore, and even more important, state of the art safety standards like consideration of "design extension condition" are still not envisaged. Thus, even after the implementation of all measures there will remain a considerable gap between the safety level agreed in Europe and the safety level of the ZNPP.

It is also state of the art to use the WENRA "Safety Objectives for New Power Reactors" as a reference for identifying reasonably practicable safety improvements. However, the EIA documents do not mention this WENRA safety objectives. According to the WENRA safety objective core melt accidents which would lead to early or large releases would have to be practically eliminated. Even as the WENRA Safety objective are not implemented in the Ukraine regulations, they could be used to identify reasonably practicable design features, operational measures or accident management procedures to lower the risk further should be implemented for ZNPP.

Accidents due to external hazards

The Ukrainian side's written replies added information on how natural hazards were considered in safety analyses of ZNPP. The expert team concluded that external hazards were analysed in the Probabilistic Safety Analyses (PSAs) which were performed for all ZNPP power units. Core Damage Frequencies (CDF) derived from PSA for the units 1, 3 and 4 suggested that the reactors are adequately protected from the effects of those natural hazards that were considered in the PSA. For those units CDF values between $5.00x10^{-6}$ and $9.72x10^{-6}$ were identified. No values have been provided for units 2, 4 and 6. The PSAs apparently did not consider seismic hazards. Based on hazard assessments, seismic PSAs were developed independently. These PSAs were based on hazard assessments that revealed a seismic design basis of PGA=0,17g. Results of the seismic PSA were not communicated. External flooding hazards posed by river floods of the Dnepr and/or dam breaks were analysed and screened out by the unlikeliness of floods reaching up to the elevation of the NPP site.

Available information does not allow judging as to whether all natural hazards relevant to the site were taken into account in the recent assessments, e.g., all types of extreme meteorological phenomena including climate change effects. The same is true for hazard combinations. The team of experts therefore recommends ensuring that all relevant hazards and hazard combinations are taken into account.

Whether the LTO project included an analysis of the Design Extension Conditions (DEC) for natural hazards remained unclear. WENRA (2021) and IAEA (2012; 2016) require 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 events or conditions more challenging than those considered in the design basis. The expert team recommended using the LTO process for comprehensive DEC analyses with respect to external hazards to achieve higher levels of safety with respect to natural hazards. It is of relevance, since Austria can be affected by the consequences of accidents caused by natural hazards.

Accidents with third parties' involvement

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

Even if the current physical protection system that was increased significantly the probability of terror acts and sabotage is considered being low, this kind of attacks is possible. Although precautions against sabotage and terror attacks cannot be discussed in detail in the EIA procedure for reasons of confidentiality, the necessary legal requirements should be set out in the EIA documents.

Information regarding the issue of terror attacks would be of great interest, considering the large consequences of potential attacks. In particular, the EIA documents 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 buildings of all ZNPP units are vulnerable against airplane crashes. The ZNPP ANSWERS (2021) confirmed that the units can only withstand a crash of a military aircraft (10 tons, 215 m/s).

A recent assessment of the nuclear security in Ukraine points to shortcomings compared to necessary requirements for nuclear security: The 2020 Nuclear Threat Initiative (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 29th 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 the International Physical Protection Advisory Service (IPPAS) of the IAEA that assisted states, in strengthening their national nuclear security regimes, systems and measures. The last IPPAS mission took place about 20 years ago; a new mission is not planned yet.

Trans-boundary impacts

For ZNPP severe accidents including containment failure and containment bypass with releases considerably higher than assumed in the EIA document cannot be excluded. 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 can be affected.

The conclusion drawn in the EIA document that there are no non-acceptable trans-boundary impacts cannot be considered sufficiently proven because worst case scenarios have not been analysed.

In the analysed scenario, the Ukrainian side provided results for possible contamination of Austrian territory below the levels for agricultural countermeasures (e. g. earlier harvesting, closing of greenhouses).

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 exceed the levels for such agricultural countermeasures Therefore, Austria could be significantly affected by a severe accident at ZNPP.

ZUSAMMENFASSUNG

Das ukrainische Kernkraftwerk Zaporoshe (ZNPP) liegt am Dnepr auf der linken Uferseite des Wasserreservoirs Kakhovka. Der KKW-Standort mit seinen sechs in Betrieb befindlichen WWER 1000 Reaktoren befindet sich in der Oblast (Verwaltungseinheit) Zaporoshe. Die Reaktoren wurden in den Jahren 1984 bis 1995 an das Netz genommen. Das KKW steht im Eigentum des Staatsunternehmens "National Nuclear Energy Generating Company Energoatom" (SE NNEGC), kurz Energoatom, SE ZNPP wiederum ist eine eigene Einheit von Energoatom.

Die ukrainische Seite führt eine Umweltverträglichkeitsprüfung im Rahmen der Espoo-Konvention für die Lebensdauerverlängerung des KKW Zaporoshe durch. Österreich wurde von der Ukraine notifiziert und entschloss sich zur Beteiligung an dieser UVP.

Das Bundesministerium für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie beauftragte das Umweltbundesamt mit der Koordination zur Erstellung eines Fachgutachtens zu den übermittelten UVP-Dokumenten (UMWELTBUNDESAMT 2021). In diesem Fachgutachten wurden die Fragen und vorläufigen Empfehlungen formuliert.

Im September 2021 übermittelte die ukrainische Seite schriftliche Antworten auf die gestellten Fragen. (ZNPP ANSWERS 2021) Dieses vorliegende Fachgutachten evaluiert die Antworten und formuliert abschließende Empfehlungen.

Das Ziel der Beteiligung Österreichs am UVP-Verfahren ist die Minimierung oder sogar Eliminierung möglicher signifikanter nachteiliger Auswirkungen auf Österreich, die von diesem Projekt ausgehen könnten.

Verfahren und Alternativen

Während Österreich zunächst für eine UVP zur Lebensdauerverlängerung für die ZNPP Blöcke 3-6 notifiziert wurde, wurde nun geklärt, dass diese UVP für alle 6 Blöcke des ZNPP durchgeführt wurde.

In den UVP-Dokumenten wurde eine Lebensdauerverlängerung von 15 Jahren für die ZNPP definiert. Doch in den ZNPP ANSWERS (2021) wurde eine Lebensdauerverlängerung von *„nicht weniger als 20 Jahren"* angekündigt. Dies ist eine signifikante Änderung gegenüber der ursprünglich übermittelten Information. Auch wurde die maximale Dauer der Lebensdauerverlängerungen bis heute nicht geklärt.

Die UVP-Dokumente, die Österreich übermittelt wurden, sind aus dem Jahr 2015 und reflektieren daher nicht die Entwicklung der letzten Jahre und erfordern eine Aktualisierung. Laut der Espoo-Konvention ist sicherzustellen, dass die der Öffentlichkeit der betroffenen Vertragspartei gebotene Möglichkeit zur Beteiligung gleichwertig zu derjenigen der Öffentlichkeit der Ursprungspartei ist. (ESPOO KONVENTION 1991, Art. 2.6). Das war hier nicht der Fall, da nicht alle UVP-Unterlagen zur Verfügung gestellt wurden und die ukrainische Öffentlichkeit mehr Unterlagen zur Einsicht erhalten hat, darunter auch Dokumente neueren Datums. Zur Konsultation wurden keine aktualisierten oder zusätzlichen UVP-Dokumente übermittelt.

Die Genehmigungen für die Lebensdauerverlängerungen von ZNPP 1-5 wurden bereits vor Abschluss der grenzüberschreitenden UVP erteilt. Laut der Espoo-Konvention muss eine UVP vor der Erteilung der Genehmigung für eine geplante Aktivität durchgeführt werden. (ESPOO KONVENTION 1991, Art. 2.3) Die Antworten aus der Konsultation klärten nicht, ob die angestrebte Bewertung der Ergebnisse aus der grenzüberschreitenden UVP durch das zuständige Umweltministerium der Ukraine auch die bereits erteilten Genehmigungen betreffen wird.

Eine Bewertung von vernünftigerweise durchführbaren Alternativen und der Null-Variante fehlt.

Abgebrannte Brennelemente und radioaktiver Abfall

Information über die Mengen des radioaktiven Abfalls, der während der Lebensdauerverlängerung des ZNPP erzeugt werden wird, wurde zur Verfügung gestellt, doch ermöglicht diese aufgrund fehlender Daten keine Gegenüberstellung zu den verfügbaren Kapazitäten von Zwischenlagern und Endlagern.

Abgebrannte Brennelemente werden im Trocken-Zwischenlager DSFSF am Standort gelagert, die Kapazitäten sind für die Lebensdauerverlängerung ausreichend. Als mögliche Entsorgungsstrategie wird der langfristige Betrieb über 50 Jahre Zwischenlagerung hinweg evaluiert.

Die Behälter im DSFSF sind nicht in einem Gebäude aufgestellt, sondern nur von einer Mauer umgeben. Es ist der Nachweis zu erbringen, dass diese Art von Trockenlager auch gegen externe Gefahren und Flugzeugabstürze, die nicht nur Ereignisse mit hoher Wahrscheinlichkeit, sondern solche mit maximaler Einwirkung erfassen, ausgelegt ist.

Abgebrannte Brennelemente und radioaktiver Abfall können negative Umweltauswirkungen haben, daher wäre es zu begrüßen, wenn die ukrainische Seite weitere Informationen über das nationale Entsorgungsprogramm und dessen Umsetzung zur Verfügung stellen würde.

Langzeitbetrieb des Reaktortyps

Obwohl die bis zu 38 Jahre alten Strukturen, Systeme und Komponenten ein Sicherheitsproblem für die Blöcke des ZNPP darstellen, wird die Frage der Alterung in den übermittelten UVP-Unterlagen nicht angesprochen. Ein umfassendes Programm für das Alterungsmanagement (AMP) ist nötig, um das alterungsbedingte Versagen zumindest in einem gewissen Umfang zu beschränken. Auch über das Alterungsmanagementprogramm wird in den UVP-Unterlagen nicht informiert. Im Dokument ZNNP ANSWERS (2021) findet sich allgemeine Information über das Programm zum Alterungsmanagement.

ZNNP ANSWERS (2021) zufolge zeigte die Evaluierung der Alterungsfolgen bei Strukturen, Systemen und Komponenten (Safety Factor (SF) 4), die im Rahmen der jüngsten Periodischen Sicherheitsüberprüfung (PSÜ) durchgeführt wurde, dass ein sicherer Betrieb bis 5. März 2027 (Block 3), bis 4. April 2028 (Block 4) und bis 27. Mai 2030 (Block 5) möglich ist. Die Neubewertung für Block 6 ist noch nicht abgeschlossen.

Auch die Topical Peer Review (TPR) zum Thema "Alterungsmanagement", die im Rahmen der Nuklearen Sicherheitsrichtlinie 2014/87/EURATOM im Jahr 2017/18 durchgeführt wurde, identifizierte jedoch einige Abweichungen zum erwarteten Leistungsniveau, das erreicht werden sollte, um ein akzeptables Alterungsmanagement in ganz Europa sicherzustellen. Die Resultate der TPR und die vorgeschlagenen Maßnahmen zur Behebung der Schwachstellen wurden in den UVP-Unterlagen nicht dargestellt, insbesondere betreffend die Versprödung des Reaktordruckbehälters (RDB). Laut SNRIU (2021a) wird die Umsetzung der im Nationalen Aktionsplan beim RDB identifizierten Schwachstellen im Dezember 2024 abgeschlossen sein.

Obwohl die konzeptuelle Alterung für ZNPP auch ein Problem darstellt, befassen sich die UVP-Unterlagen nicht mit den Sicherheitsdefiziten der WWER-1000 Reaktoren. KKW-Designs, die in den 80er-Jahren entwickelt wurden, wie die WWER-1000, entsprechen bei Redundanz, Diversität, physischer Trennung und Bevorzugung passiver Sicherheitssysteme nur teilweise modernen Auslegungsprinzipien. Dieser alte WWER-Reaktortyp weist einige Designdefizite auf, die durch Nachrüstmaßnahmen nicht behoben werden können. Der untere Bereich des Containments befindet sich im Reaktorgebäude auf einer höheren Ebene. Im Falle eines schweren Unfalls kann ein Durchschmelzen innerhalb von etwa 48 Stunden eintreten. Die Atmosphäre im Containment wird dann teilweise in die nicht dichten Bereiche des Reaktorgebäudes gelangen und somit hohe Freisetzungen verursachen. Eine andere Schwachstelle ist der Schutz gegen externe Risiken, denn das Reaktorgebäude ist nur gegen den Absturz kleiner Flugzeuge ausgelegt.

Bereits 2011 zeigten jedoch die EU Stresstests, dass die ukrainischen KKW nur 172 der 194 Anforderungen der IAEO Design Safety Standards von 2000 erfüllen. Die Umsetzung der notwendigen Sicherheitsverbesserungen wird im Rahmen des laufenden Comprehensive (Integrated) Safety Improvement Program (C(I)SIP) vorgenommen. Der Abschluss des Programms wurde wiederholt verschoben. Mit Stand 31. März 2021 war noch eine große Zahl an Maßnahmen nicht umgesetzt. Trotz einiger Fortschritte ist das Programm in deutlichem Verzug. Unter dem Aspekt der Sicherheit ist nicht nachvollziehbar, wieso der Abschluss der Maßnahmen keine Voraussetzung für die Lebensdauerverlängerung darstellte, denn die Lebensdauerverlängerung wurde bereits für die Blöcke 1-5 des KKW ZNPP genehmigt.

Die Aufsichtsbehörde SNRIU ist Mitglied bei WENRA, der Western European Regulators Association. Im Jahre 2014 veröffentlichte die WENRA eine revidierte Version der Sicherheitsreferenzlevels (RL) für bestehende Reaktoren, die die Erfahrungen aus dem Unfall in Fukushima Daiichi berücksichtigen sollten. Die Ukraine hatte am 1. Jänner 2021 88 der 342 Referenzlevel noch nicht implementiert. Ein wesentliches Update der RL war die Revision des Issue F "Design Extension of Existing Reactors" durch die Einführung des Auslegungskonzepts der Design Extension Conditions (DEC), der Erweiterten Auslegungsbedingungen. Dieses Konzept wird für ZNPP nicht angewandt. In Summe bleibt eine signifikante Kluft zwischen dem erforderlichen Sicherheitsniveau und dem tatsächlichen Sicherheitsniveau der Blöcke des ZNPP bestehen. ZNPP ANWERS (2021) lässt darauf schließen, dass bei der Lebensdauerverlängerung IAEA-Dokumente, aber nicht WENRA-Dokumente zur Anwendung kamen. Die Umsetzung der WENRA RL in ukrainisches Recht hat noch nicht stattgefunden.

Unfallanalyse

Die zur Verfügung gestellten UVP-Unterlagen enthalten Angaben zu Auslegungsstörfällen einschließlich Szenarien, Freisetzungen und deren Konsequenzen. Zu den auslegungsüberschreitenden Unfällen (BDBA) sind die Informationen jedoch eingeschränkt, weder mögliche Unfallszenarien oder Quellterme werden angeführt.

Laut ZNPP ANSWERS (2021) werden gemäß den ukrainischen Vorgaben der Aufsichtsbehörde die BDBA und schweren Unfälle im Rahmen der UVP nicht untersucht. Ebenso wird darauf verwiesen, dass die radiologischen Auswirkungen auf die Kontrollzone (30 km) bewertet wurden. Allerdings wird der Quellterm für diese Berechnung nicht angeführt.

Für die Unfallanalyse in der UVP-Dokumentation sollte ein möglicher Quellterm von der Berechnung der aktuellen Probabilistischen Sicherheitsanalyse (PSA) Level 2 abgeleitet werden. Wenn auch die berechneten Wahrscheinlichkeiten für schwere Unfälle mit großen Freisetzungen sehr gering sind, so sind die Konsequenzen dieser Unfälle potenziell sehr groß. Obwohl in den ZNPP ANSWERS (2021) viel Information zu finden ist, so fehlt doch die wichtigste Angabe für die Bewertung der möglichen Auswirkungen auf Österreich: mögliche Freisetzungen (Quellterme) im Falle eines schweren Unfalls.

Um die Folgen eines BDBA abzuschätzen ist es nötig eine Reihe von schweren Unfälle zu analysieren, einschließlich Unfällen mit Containmentversagen und Containmentbypass, die bei WWER-1000 Reaktoren möglich sind. ZNPP ANSWERS (2021) bestätigte, dass einige schweren Unfallszenarien den Verlust der Containmentintegrität verursachen können: Unfälle mit frühzeitigem Verlust der Containmentintegrität, Unfälle mit Containmentbypass sowie Unfälle mit Verlust der Containmentintegrität zu einem späten Zeitpunkt (verursacht durch Wasserstoffbrand und Überdruck oder Kernschmelzreaktion mit Beton).

Der Schlussfolgerung von SNRIU, wonach die Blöcke sicher und mit einem akzeptablen Risiko betrieben werden, kann auf der Grundlage der zur Verfügung gestellten Informationen nicht zugestimmt werden. Es besteht auch weiterhin eine hohe Wahrscheinlichkeit, dass Unfallszenarien zu schweren Unfällen werden, die die Integrität des Containments gefährden und zu hohen Freisetzungen führen.

Die Kernschadenshäufigkeit (CDF) und die Häufigkeit für große Freisetzungen (LRF) zeigen, dass der Großteil der Kernschmelzunfälle zu hohen Freisetzungen an radioaktiven Stoffen führen: etwa 53 % (Block 1), 58 % (Block 2), 87 % (Block 3) 84 % (Block 4), 63 % (Block 5) und 83 % (Block 6). Von externen Ereignissen verursachte Beschädigungen in den Abklingbecken führen nahezu immer zu hohen und frühen Freisetzungen. Aufgrund des veralteten Designs der WWER-1000 stehen keine effektiven Maßnahmen zur Verhinderung großer Freisetzungen nach einem Kernschmelzunfall zur Verfügung.

Dem Dokument ENSREG (2015) zufolge ist der Erhalt der Containmentintegrität bei schweren Unfällen ein wichtiger Faktor im Unfallmanagement. Eine anerkannte Maßnahme gegen Versagen durch Containment-Überdruck ist die gefilterte Containmentdruckentlastung (Filtered Containment Venting), die allerdings noch in keinem Block von ZNPP installiert wurde. Darüber hinaus verfügt ZNPP über kein System zur Kühlung und Stabilisierung des geschmolzenen Reaktorkerns. Im Rahmen der Stresstests sollte bis 2023 eine Strategie für einen möglichen Rückhalt der Kernschmelze innerhalb des Reaktordruckbehälters erarbeitet werden. Diese Deadline wurde bereits 2015 verlängert.

Das Ergebnis der EU Stresstests zeigte zahlreiche Defizite in der Vermeidung von schweren Unfällen und der Abmilderung ihrer Konsequenzen auf. Weitreichende Nachrüstungen werden von der Aufsichtsbehörde verlangt, allerdings empfiehlt das ENSREG Peer Review Team noch weitere Verbesserungen. Das ist eines der Beispiele für die Kluft zwischen den Sicherheitsstandards und Anforderungen der Ukraine und der EU. Die Umsetzung der Nachrüstmaßnahmen befindet sich in anhaltendem Verzug.

Außerdem, und das ist noch wichtiger, sind Sicherheitsstandards nach dem Stand der Technik wie die Berücksichtigung der erweiterten Auslegungsbedingungen (DEC) noch nicht vorgesehen. Daher wird auch nach der Umsetzung aller Maßnahmen eine signifikante Kluft zwischen dem Sicherheitsniveau, auf welches sich Europa geeinigt hat, und dem Sicherheitsniveau von ZNPP bestehen bleiben.

Ebenso unter Stand der Technik fällt die Verwendung der WENRA „Sicherheitsziele für neue Leistungsreaktoren" als Referenz zur Identifikation von vernünftigerweise durchführbaren Sicherheitsverbesserungen. Die UVP-Unterlagen erwähnen jedoch diese WENRA Sicherheitsziele nicht. Diese WENRA Sicherheitsziele sehen vor, dass Kernschmelzunfälle mit frühen oder großen Freisetzungen praktisch ausgeschlossen sein müssen. Selbst wenn die WENRA Sicherheitsziele nicht in die ukrainischen Vorschriften aufgenommen wurden, so könnten sie genutzt werden, um vernünftigerweise machbare Designmerkmale, Betriebsmaßnahmen oder Unfallmanagement im ZNPP umzusetzen und damit das Risiko zu reduzieren.

Unfälle durch externe Gefahren

Die schriftlichen Antworten der ukrainischen Seite brachten zusätzliche Informationen darüber, wie natürliche Gefährdungen in den Sicherheitsanalysen für ZNPP berücksichtigt wurden. Das Expertenteam kam zu der Schlussfolgerung, dass die externen Gefährdungen in den PSA (Probabilistische Sicherheitsanalyse) analysiert wurden, die für alle Blöcke des ZNPP ausgearbeitet wurden. Die Kernschadenshäufigkeiten (CDF), die aus den PSA für die Blöcke 1,3 und 4 abgeleitet wurden, ließen den Annahme zu, dass die Reaktoren gegen diese natürlichen Gefährdungen, die in den PSA betrachtet wurden, ausreichend geschützt sind. Für diese Blöcke wurden CDF Werte zwischen 5.00×10^{-6} und 9.72×10^{-6} identifiziert. Für die Blöcke 2,4 und 6 wurden keine Werte angegeben. Die PSA haben anscheinend keine seismischen Gefährdungen berücksichtigt. Von den Gefährdungsanalysen ausgehend, wurden unabhängig seismische PSA entwickelt. Diese PSA basieren auf Gefährdungsbewertungen, die eine seismische Auslegung von PGA=0,17g aufzeigten. Die Ergebnisse der seismischen PSA wurden nicht mitgeteilt. Die externen Flutungsgefährdungen durch die Dnjepr und/oder Dammbrüche wurden untersucht und ausgeschlossen, da es unwahrscheinlich ist, dass die Flutungen den erhöhten Standort des KKW erreichen würden.

Die zur Verfügung stehenden Informationen ermöglichen keine Abschätzung, ob alle Naturgefahren mit Relevanz für den Standort in den jüngsten Bewertungen einbezogen wurden, d.h. alle extremen Wetterphänomenen einschließlich des Klimawandels.

Das gilt auch für die Gefahrenkombinationen. Daher empfiehlt das Expertenteam sicherzustellen, dass alle relevanten Gefährdungen und deren Kombinationen in Betracht gezogen werden.

Es ist unklar, ob im LTO Projekt eine Analyse der Design Extension Conditions (DEC) für natürliche Gefährdungen durchgeführt wurde. WENRA (2021) und IAEA (2012; 2016) sehen vor, dass eine DEC Analyse durchgeführt wird, sodass die Sicherheit bestehender Anlagen weiter erhöht wird, sowie auch deren Widerstandsfähigkeit gegen Ereignisse und Bedingungen, die die der Auslegung überschreiten. Das ExpertInnenteam empfahl den LTO Prozess für komplexe DEC-Analysen in Bezug auf externe Gefährdungen zu nutzen und somit in diesem Bereich ein höheres Sicherheitsniveau zu erreichen. Da Österreich durch die Folgen von Unfällen, die aus Naturgefahren entstehen können, betroffen sein kann, ist diese Tatsache von Bedeutung.

Unfälle mit Beteiligung Dritter

Terrorangriffe und Sabotageakte können schwere Folgen für Nuklearanlagen haben und schwere Unfälle auslösen – auch beim ZNPP. Dennoch werden diese in den UVP-Unterlagen nicht erwähnt, während solche Ereignisse in vergleichbaren UVP-Berichten in einem gewissen Umfang angesprochen werden.

Terrorangriffe und Sabotageakte können nicht ausgeschlossen werden, auch wenn die nun bestehenden physischen Schutzsysteme deutlich verstärkt wurden und die Wahrscheinlichkeit dafür als gering eingeschätzt wird. Selbstverständlich können Vorkehrungen gegen Sabotage und Terror während eines UVP-Verfahrens aufgrund der Vertraulichkeit nicht im Detail diskutiert werden, die notwendigen rechtlichen Anforderungen sollten in den UVP-Unterlagen allerdings angeführt werden.

Angesichts der enormen Folgen potenzieller Terrorangriffe wären Informationen zu diesem Thema von höchstem Interesse. Insbesondere sollten die UVP-Unterlagen detaillierte Informationen über die Anforderungen an das Design gegen gezielte Abstürze von Verkehrsflugzeugen anführen. Dieses Thema ist vor allem für alle Reaktorgebäude von ZNPP wichtig, da diese gegenüber Flugzeugabstürzen vulnerabel sind. Das Dokument ZNPP ANSWERS (2021) bestätigt, dass die Blöcke nur gegen den Absturz eines Militärflugzeugs (10 t, 215 m/s) ausgelegt sind.

Eine jüngste Untersuchung zur nuklearen Sicherung in der Ukraine zeigte Defizite in den notwendigen Anforderungen auf: Der 2020 Nuclear Threat Initiative (NTI) Index bewertet die Bedingungen der nuklearen Sicherung in Bezug auf den Schutz von Nuklearanlagen gegen Sabotageakte. Mit einer Gesamtzahl von 65 von 100 Punkten lag die Ukraine auf Platz 29 von 47 Ländern, woraus auf ein geringes Schutzniveau geschlossen werden kann. Die geringe Punkteanzahl bei "Schutz gegen Insiderangriffe" und "Cybersecurity" verweisen auf Defizite in diesen Bereichen. Es wird empfohlen das International Physical Protection Advisory Service (IPPAS) der IAEO einzuladen, das Staaten bei der Stärkung ihrer nationalen Sicherungsregime, Systeme und Maßnahmen unterstützt. Die letzte IPPAS-Mission fand vor über 20 Jahren statt, auch ist noch keine weitere vorgesehen.

Grenzüberschreitende Auswirkungen

Für ZNPP können schwere Unfälle mit Containmentversagen und Containment-Bypass mit deutlich höheren Freisetzungen als in den UVP-Unterlagen angenommen nicht ausgeschlossen werden. Solche Wort-Case Unfälle sollten in die Bewertung eingeschlossen werden, da ihre Auswirkungen weitreichend und lange anhaltend sein können und sogar Länder betroffen sein können, die nicht direkt an die Ukraine angrenzen.

Die Schlussfolgerung des UVP-Berichts, wonach keine inakzeptablen grenzüberschreitenden Auswirkungen eintreten können, kann nicht als ausreichend belegt angesehen werden, da die Worst-Case Szenarien nicht analysiert wurden.

In dem untersuchten Szenario lieferte die ukrainische Seite Ergebnisse für eine mögliche Kontamination des österreichischen Staatsgebiets unterhalb der Grenzwerte für landwirtschaftliche Gegenmaßnahmen (z. B. frühere Ernte, Schließung von Gewächshäusern).

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

1 INTRODUCTION

The Ukrainian nuclear power plant Zaporizhzhya (ZNPP) is located at the Dnepr River on the left bank of the Kakhovka water reservoir. The site is located in the Zaporizhzhya oblast near the NPP satellite city Energodar, about 200 km west of Donezk and Mariupul, and 400 km south-east of Kiev. At the Zaporizhzhya site, six VVER-1000 reactors are in operation. The six reactors were connected to the grid between 1984 and 1995.

The NPP is owned by the State Enterprise "National Nuclear Energy Generating Company Energoatom" (SE NNEGC), in short Energoatom. SE ZNPP is a separate entity of Energoatom. Energoatom is subordinated to the Ministry of Energy and Coal Industry of Ukraine.

For the lifetime extension of Zaporizhzhya, 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.

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 coordinate the assessment of the submitted EIA Documents in the framework of an expert statement (UMWELTBUNDESAMT 2021). In this expert statement, questions and preliminary recommendations were formulated.

In September 2021, the Ukrainian side provided answers to these questions in written form. (ZNPP ANSWERS 2021) The final expert statement at hand assessed these answers and made final recommendations.

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 PROCEDURE AND ALTERNATIVES

2.1 Short summary of the expert statement

While Austria had been notified for an Environmental Impact Assessment (EIA) for lifetime extension of ZNPP units 3-6, the provided EIA documents gave information mainly on units 1 and 2, and on ZNPP as a whole. It had to be clarified for which ZNPP units the EIA is conducted.

According to the Espoo Convention it shall be ensured that the opportunity to participate provided to the public of the affected Party is equivalent to that provided to the public of the Party of origin. (ESPOO CONVENTION 1991, Art. 2.6) This has not been the case in this EIA because not all documents were provided. The public of Ukraine received more documents, among those also newer documents (e.g.: the non-technical Summary for ZNPP-5 is from 2020).

The EIA documents that were submitted to Austria are from 2015 and therefore did not reflect the development of the last years and they needed to be updated.

The licenses for the lifetime extensions for ZNPP 1-5 have already been issued before the trans-boundary EIA has been finished. According to the Espoo Convention an EIA has to be conducted prior to a decision to authorize the proposed activity. (ESPOO CONVENTION 1991, Art. 2.3) It must therefore be clarified if the results of this trans-boundary EIA will be taken into account at all, and how this will be done.

Also lacking was the assessment of reasonable alternatives and the no-action alternative – both should be assessed in an EIA. (ESPOO CONVENTION 1991, Appendix II)

2.2 Questions & preliminary recommendations, answers and assessment of the answers

Question Q1

Which ZNPP units are subject to the ongoing EIA?

Written answer by the Ukrainian side

Activities of the whole ZNPP complex have been considered for the EIA development.

Assessment of the answer

The question has been answered. In this case, the notification of Austria has been incomplete because it referred to units 3-6 but not all six units. This is not in line with the Espoo Convention because the description of the proposed activity that has to be included in the EIA documentation was incomplete. (ESPOO Convention 1991, Appendix II (a)).

Question Q2

How long is the maximal foreseen lifetime extension of all ZNPP units?

Written answer by the Ukrainian side

The foreseen extension of the ZNPP units' lifetime, with the consideration of the world's best practices, is estimated as not less than 20 years.

Assessment of the answer

The answer raises new questions: In the EIA documents, the original design operation period was given with 30 years, and the expected period of extension 15 years. (ZNPP EIA BOOK VOL 7 2015, p. 7) But according to the answer, a life-time extension of 20 years could also be possible. And, furthermore, if the life-time extensions of all ZNPP reactors are *"estimated as not less than 20 years"*, this could mean that the life-time extension could even be longer. Further clarification is needed.

Question Q3

What are the further steps in the EIA procedure and in the licensing procedure?

Written answer by the Ukrainian side

In accordance with the requirements of national legislation, the results of transboundary consultations with all affected states are considered at a meeting of the Interdepartmental Coordinating Council for the Implementation of the Espoo Convention (ICR) in Ukraine, which decides to take into account the comments / suggestions. Following the meeting, the relevant Protocol is drawn up, which is approved by the Chairman - the Minister of Environment and Natural Resources of Ukraine. The Protocol will establish the conditions that are mandatory for the implementation by NNEGC Energoatom and the implementation of which will be monitored by the authorized body - the Ministry of Environment and Natural Resources of Ukraine. A copy of the Protocol shall also be sent to the Cabinet of Ministers of Ukraine.

Assessment of the answer

The question has been answered concerning the further steps in the EIA procedure. Ukraine should also provide the Protocol, an English translation would be welcomed.

Further steps in the licensing procedure have not been explained sufficiently as units 1-5 have already received their decision on operation extension before the trans-boundary EIA has been completed. It is not clear if the mentioned implementations to reach the necessary conditions will also be monitored for the ZNPP units 1-5 which have already received their operation extension licenses; this should be clarified.

Question Q4

How will the results of the EIA be taken into account? Will the decisions on lifetime extension of ZNPP 1-5 be revised according to the EIA results? How will the EIA results be taken into account in the decision on lifetime extension of ZNPP 6?

Written answer by the Ukrainian side

All provided EIA documentation, comments and responses will be reviewed by the Ministry of Ecology and Natural Resources of Ukraine in accordance with legislation in force and Espoo Convention. Lifetime of Units 1-5 has been already extended. As for Unit 6, the decision will be made beginning from 2023.

- Unit 3 – until 05.03.2027
- Unit 4 – until 04.04.2028
- Unit 5 – until 27.05.2030
- Unit 6 – re-assessment has not been completed yet.

Assessment of the answer

The question has been answered partially by describing the reviewing authority and confirming that the review will be in accordance with legislation in force and the Espoo Convention. It is not clear, though, if the review will also include the already issued operation extension licenses for units 1-5.

It has to be noted that as of today, Ukraine is still not in compliance with the Espoo Convention. The final decisions on life-time extension of units 1-5 have already been taken before the transboundary consultations have been finished. The Espoo Compliance Committee wrote in its 51st session's minutes from October 2021:

"86. The Committee asked its Chair to write to Ukraine to:

a. Draw to the attention of Ukraine the fact that a situation where a final decision regarding the activity was made while transboundary consultations with and public participation in the affected Parties were ongoing constituted non-compliance with the Convention;

b. Request Ukraine to ensure that the transboundary procedure concerning the lifetime extension of the South Ukrainian and Zaporizhzhya nuclear power plants was completed with all the affected Parties in full compliance with the Convention" (UNECE 2021, 86)

A timetable for completing the EIA procedure and undertaking the review should be given.

To clarify how the EIA results will be taken into account and if the review has also included the recently issued operation extension licenses of units 1-5, Ukraine should provide the results of the mentioned review by the Ministry of Ecology and Natural Resources of Ukraine; an English translation would be welcomed.

Preliminary recommendation PR1

Ukraine should provide adequate information on the EIA procedure and the further licensing procedure.

Written answer by the Ukrainian side

In accordance with the requirements of national legislation, the results of transboundary consultations with all affected states are considered at a meeting of the Interdepartmental Coordinating Council for the Implementation of the Espoo Convention (ICR) in Ukraine, which decides to take into account the comments / suggestions. Following the meeting, the relevant Protocol is drawn up, which is approved by the Chairman - the Minister of Environment and Natural Resources of Ukraine. The Protocol will establish the conditions that are mandatory for the implementation by NNEGC Energoatom and the implementation of which will be monitored by the authorized body - the Ministry of Environment and Natural Resources of Ukraine. A copy of the Protocol shall also be sent to the Cabinet of Ministers of Ukraine.

Assessment of the answer

The Ukrainian side provided more information on the EIA procedure, but not enough on the further licensing procedure, especially not on how Ukraine intends to reach compliance with the Espoo Convention as the final decisions for the life-time extension of ZNPP units 1-5 has already been made before the trans-boundary EIA has been completed.

The Protocol of the EIA and the results of the review/monitoring should be provided, an English translation would be appreciated.

Preliminary recommendation PR2

Alternatives of the lifetime extensions and the no-action alternative should be assessed in the EIA documents.

Written answer by the Ukrainian side

The EIA was carried out for the NPP as an operating facility licensed by the state regulatory body for nuclear and radiation safety for a separate stage of the life cycle of the nuclear operation "Operation". Therefore, consideration of alternatives in this case was not envisaged.

Preliminary recommendation PR3

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, that is before a decision is taken.

Written answer by the Ukrainian side

Agree. The recommendation is justified.

Preliminary recommendation PR4

It is recommended not to issue the EIA decision until the deficiencies of the EIA have been solved.

Written answer by the Ukrainian side

The issue of providing a decision on the EIA results is the exclusive competence of the Ministry of Environmental Protection and Natural Resources of Ukraine.

2.3 Conclusions and final recommendations

While Ukraine initially notified Austria an Environmental Impact Assessment (EIA) for lifetime extension of ZNPP units 3-6, it has now been clarified that this EIA is conducted for all 6 ZNPP units.

In the EIA documents, a life-time extension of 15 years was defined for the ZNPP units. But in ZNPP ANSWERS (2021) a life-time extension of *"no less than 20 years"* was announced. This is a significant change of the information submitted initially. Furthermore, the maximum lifetime extension has not been clarified to date.

The EIA documents that were submitted to Austria are from 2015 and therefore did not reflect the development of the last years and need to be updated. According to the Espoo Convention it shall be ensured that the opportunity to participate provided to the public of the affected Party is equivalent to that provided to the public of the Party of origin. (ESPOO CONVENTION 1991, Art. 2.6) This was not the case in this EIA because only an incomplete set of documents was provided. The Ukrainian public received more documents, among those also newer documents (e.g.: the non-technical Summary for ZNPP-5 is from 2020). No updated EIA documents or additional EIA documents have been delivered during consultations.

The licenses for the lifetime extensions for ZNPP 1-5 have been issued before the trans-boundary EIA has been finished. According to the Espoo Convention an EIA has to be conducted prior to a decision to authorize the proposed activity. (ESPOO CONVENTION 1991, Art. 2.3) The provided answers during consultations did not clarify if the envisaged review of the results of the trans-boundary EIA undertaken by the responsible Ukrainian Ministry of Environment and Natural Resources will also concern the licenses issued earlier.

Moreover, a timetable for completing the EIA procedure and undertaking the review should be provided.

Furthermore, the assessment of reasonable alternatives and the no-action alternative is lacking.

Final recommendation FR1

The review of the Minister of Environment and Natural Resources of Ukraine should include the already issued operation extension licensed for ZNPP units 1-5 to ensure that the EIA results are taken into due account also for these earlier decisions. A timetable for this review should be provided.

Final recommendation FR2

Both the final EIA Protocol and the results of the following review of the Minister of Environment and Natural Resources of Ukraine should be made available; an English translation would be welcomed.

3 SPENT FUEL AND RADIOACTIVE WASTE

3.1 Short summary of the expert statement

The EIA documents did not provide information on volumes and activities of radioactive wastes generated during the ZNPP lifetime extension or complete information on the status of conditioning facilities, interim and final storages for the radioactive waste. This needed further clarification.

Spent fuel is stored at the interim dry storage DSFES on the site, capacities are sufficient for the lifetime extension. It has to be verified for how long the interim storage can be prolongated if no final repository or reprocessing possibilities will be available after the 50 years of interim storage.

In the DSFSF, the containers are not placed inside a building but outside and surrounded by a wall. It should be proved that this type of dry storage is designed to withstand external hazards and airplane crashes.

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.

3.2 Questions & preliminary recommendations, answers and assessment of the answers

Question Q5

In the Non-technical summary it is mentioned that reprocessing of spent fuel could also be done locally. Does Ukraine plan the construction of a reprocessing plant?

Written answer by the Ukrainian side

Currently there are no technologies for spent fuel reprocessing in Ukraine.

The option of returning of the fertile uranium and breed plutonium residual from spent fuel to fresh fuel by extracting them from spent fuel and separating high-level radwaste with subsequent long-term storage of high-level radwaste has been chosen by France, Great Britain, India, Japan and Russia, where a part of their spent fuel is reprocessed.

The “deferred decision” option – long-term safe storage of spent fuel in the interim storage facilities without disposal or reprocessing – has been chosen by the majority of the countries with nuclear industry, e.g. USA, Switzerland, Czech Republic, Bulgaria and Hungary. Ukraine has also chosen the “deferred decision” option.

Assessment of the answer

The question has been answered.

Question Q6

What is the status of the final disposal for spent fuel?

Written answer by the Ukrainian side

To date, the issue of disposal of spent fuel is not raised. Ukraine is considering only the issue of long-term storage of spent nuclear fuel in a centralized storage facility located in the Chernobyl Exclusion Zone.

Assessment of the answer

The question has been answered.

Question Q7

Is it planned to use copper for the spent fuel canisters for a future final repository, and if yes, how will the copper corrosion problem be solved?

Written answer by the Ukrainian side

Currently there are no technologies for spent fuel reprocessing in Ukraine.

The "deferred decision" option – long-term safe storage of spent fuel in the interim storage facilities without disposal or reprocessing – has been chosen by the majority of the countries with nuclear industry, e.g. USA, Switzerland, Czech Republic, Bulgaria and Hungary. Ukraine has also chosen the "deferred decision" option.

Copper or copper alloy are not used in the spent fuel canisters for long-term storage in the future Centralized spent fuel storage facility constructed under "Holtec International" technology.

Assessment of the answer

The question has been answered.

Question Q8

What amounts and activities of LILW are expected to arise from lifetime extension of ZNPP?

Written answer by the Ukrainian side

Based on the operation experience, average annual amount of solid radwaste delivered for temporary storage at the solid radwaste storage facilities for the last 5 years is as follows:

- 280-300 m^3 of low-level radwaste;
- 25-35 m^3 of middle-level radwaste (130-150 m^3 of salt melt).

As a result of extension of ZNPP operation lifetime, it is expected to generate low-level radwaste (thermal insulation, metal, construction, spent personal protective equipment, various sealing elements of the equipment and pipelines) and middle-level radwaste (metal, ion-exchange resins, salt melt, etc.).

During the ZNPP lifetime extension period, it is planned to store spent fuel in the cooling ponds and at the DSFSF.

Assessment of the answer

The questions has been answered partially. Information on the volume of LILW was provided, but not on activities.

Question Q9

Are there enough capacities in interim and final storages for the LILW from ZNPP lifetime extension?

Written answer by the Ukrainian side

To ensure sufficient capacity for temporary storage of waste, additional light-duty storage facility for storage of the conditioned radwaste in the reinforced-concrete containers. Commissioning of this storage for commercial operation is scheduled for 2023.

Subsequently it is planned to hand over the reinforced-concrete containers with solid radwaste to the State Specialized Enterprise 'Centralized Radwaste Management Plant' (SSE CRWMP) for disposal.

Currently ZNPP and SSE CRWMP work together to specify the criteria of solid radwaste acceptance for disposal. In 2022-2023 it is scheduled to characterize all streams of ZNPP solid radwaste, to perform safety re-assessment, to revise criteria for solid radwaste acceptance to the storage facilities of the SSE CRWMP and to develop an updated safety analysis report for the storage facilities.

Assessment of the answer

The answer confirmed that an additional facility will be needed for storing LILW. Whether this facility will be constructed at the ZNPP site or at the Vektor site in the exclusion zone remains unclear; the additional facility's interim storage capacity was not given.

Also information on final storage of radioactive waste is still incomplete. It has to be verified if all conditioned radioactive waste from the lifetime extension will be stored in the new[1] centralized storage facility complex at the Vektor site in Chernobyl.

Therefore, it cannot be assessed if enough capacities will be available for interim storage and final disposal of radioactive waste from the lifetime extension.

Question Q10

What is the status of the treatment facilities, interim and final storages for radioactive waste?

Written answer by the Ukrainian side

Operation of the DSFSF does not produce radiologically contaminated water (the level of waste water contamination is continuously monitored), which normally requires purification facilities. Atmospheric precipitation (rains) is discharged to the conventional sewage facilities.

Assessment of the answer

The question has not been answered, probably due to misunderstanding. By asking about the status, we wanted to receive information on the progress of planning and/or constructing the respective facilities.

An answer on the additional interim storage for LILW was given in Q9, the operation start is scheduled for 2023.

Final storage of LILW will be conducted by the SSE CRWMP according to Q9. According to an Energoatom press release dated 25 Nov 2021[2], the Vektor complex has started operation and in the next step the radioactive waste from ZNPP will be transferred.

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[1] The first transport of radioactive waste from Rivne NPP arrived in Nov 2021 at the Vektor complex. Transfer of the radioactive waste from ZNPP shall start soon. http://www.energoatom.com.ua/en/press_center-19/company-20/p/energoatom_dispatched_the_first_batch_of_radioactive_waste_from_npp_to_vector_production_complex_for_disposal-48524, seen 2021-11-26

[2] see footnote above

Question Q11

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?

Written answer by the Ukrainian side

ZNPP participate in the research efforts, which envisage determination of spent fuel state after storage under the conditions of the DSFSF for 50 years, and evaluation of the possibility to extend the storage period (e.g. up to 100 years, as it is foreseen at the Centralized Spent Fuel Storage Facility).

Assessment of the answer

For spent fuel, the question has been answered: long-term storage of the DSFSF (located on the ZNPP site) is being evaluated.

For radioactive waste, the new Vektor complex for long-term and final storage has recently started operation.

Question Q12

Do the containers in the dry interim storage DSFSF withstand an air-plane crash and external hazards?

Written answer by the Ukrainian side

The DSFSF site is surrounded with the radiation-protective structure. The main purpose of this structure is to protect the environment against the impact of radiation factors of the DSFSF. This is not a protection against external impact.

The site houses reinforced-concrete containers with the relevant sealed vessels with spent fuel inside in accordance with the design. The reinforced-concrete containers protect these vessels against external impact and protect the environment against negative impact of the vessels.

To meet the requirements of IAEA, the "DSFSF Safety Analysis Report" contains such initiating event, as drop of the aircraft engine turbine shaft onto the containers (being the most probable cause of damage of the containers). According to the completed analysis, in case of drop of the aircraft engine turbine shaft, the container could have minor (local) damages of the reinforced-concrete shell.

Taking into consideration the calculations of the reinforced-concrete casing and cover of the container (the strength of the cover significantly exceeds the calculated depth of damage), it has been justified that the container ensures reliable protection against its significant damage resulted from drop of the aircraft engine turbine shaft.

Thus, the event of the aircraft engine turbine shaft drop will not result in damage of the sealed vessels with spent nuclear fuel, and there will be no any release of radioactive substances to the environment.

In case of the aircraft engine turbine shaft drop onto the container, in accordance with the procedures, it is required to check for damages on its outer surface and, if necessary, to carry out the corresponding repairs.

Assessment of the answer

The question has been answered partially. Even if a crash of an aircraft's engine turbine shaft onto the containers is the most probable cause of damage of the containers, it might not be the most harmful initiating event. Furthermore, it should be clarified if the sealing of the containers could be damaged by a fire resulting from an aircraft's crash.

Preliminary recommendation PR5

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.

Written answer by the Ukrainian side

At the present time Ukraine have no spent fuel processing technologies.

"Deferred decision" alternative, that means long term storage of the spent fuel at interim storage facilities without disposal or reprocessing has been chosen by greater part of countries having nuclear power industry, like the USA, Switzerland, Czech Republic, Bulgaria and Hungary. Ukraine chose the same "deferred decision" alternative.

Since 2001, ZNPP has used dry storage (DSSNF[3]) for spent nuclear fuel. DSSNF is designed to store 380 containers (9120 fuel assemblies), which is enough to store the entire volume of spent fuel from 6 power units, taking into account their lifetime extension. The project lifetime of the DSSNF is 50 years. DSSNF project passed all the necessary expertise provided by Ukraine regulatory requirements, including environmental. Violations of the safe operation rules during the entire operation of the storage were not detected.

SE ZNPP participates in scientific and research activities, which are aimed to determine spent fuel condition after storage at Spent Fuel Dry Storage Facility conditions during 50 years and to define possibility of prolonged storage (for example up to 100 years, as it is foreseen by the Centralized SFDSF design).

Assessment of the answer

The answer clarified that the alternative solution for the backend management of spent fuel is long-term disposal.

[3] = DSFSF

3.3 Conclusions and final recommendations

Information on the volumes of radioactive waste generated during the life-time extension was provided but does not allow a comparison with the available capacities for interim and final storage because of lack of data.

Spent fuel is stored at the on-site interim dry storage DSFSF, capacities are sufficient for the lifetime extension. Long-term operation after the 50 years of interim storage period is being evaluated as a possible back-end management strategy.

The containers in the DSFSF are not placed in a building but simply surrounded by a wall. Proof needs to be provided showing that this type of dry storage is designed to withstand external hazards and airplane crashes, covering not only events with the highest probability but also with maximum impact. Furthermore, it should be clarified if the sealing of the containers could be damaged by a fire resulting from an aircraft's crash.

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

Final recommendation FR3

It would be welcomed if the Ukrainian side provides information about the progress made with the interim storage and final disposal facilities for spent fuel and radioactive waste.

Final recommendation FR4

For the DSFSF, it is recommended to assess not only impacts of the most probable initiating event but also events which have a maximum negative impact regardless of their probability of occurrence. Furthermore, it should be clarified if the sealing of the containers could be damaged by a fire resulting from an aircraft's crash.

4 LONG-TERM OPERATION OF REACTOR TYPE

4.1 Short summary of the expert statement

Although ageing of the up to 38 years old structures, systems and components (SSCs) is a safety issue for the ZNPP, it was not addressed in the provided EIA documents. 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 given in the provided EIA documents.

Ukraine participated in the Topical Peer Review (TPR) "Ageing Management" in the framework 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 documents, in particular the very important safety issue of the embrittlement of the RPVs should be discussed. The standard surveillance program for some of the Ukrainian reactors (including unit 6 of the ZNPP) is good but it is not sufficient. Comprehensive inspections of all RPVs are necessary.

Although conceptual ageing is also an issue for the ZNPP, the EIA documentation does not deal with any of the known safety issues of the VVER-1000 reactors. NPP design developed in the 1980s, like the VVER-1000, only partly meet modern design principles concerning redundancy, diversity and physical separation of redundant subsystems or the preference of passive safety systems. The EIA documents do not provide a description of the safety-relevant systems or information about the capacities, redundancies and physical separation.

The old reactor types VVER-1000 has several design weaknesses, which cannot be resolved by performing back-fitting measures. The lower containment boundary (containment basement) is not in contact with the ground but is located at a higher level in-side the reactor building. In case of a severe accident, melt-through can occur within approx. 48 hours. The containment atmosphere will then blow down in-to parts of the reactor building that are not leak-tight resulting in high releases. Another weakness is the protection against external hazard. The reactor buildings are only designed against accidents of small aircrafts.

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. 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. As of March 31, 2021 still a lot of measures have to be implemented (96 out of 466 measures).

A significant gap remains between the required safety standard and the actual safety level of the ZNPP units. In spite of some progress, the programs ran into a long delay and this situation has not changed since the last century. From a safety point of view, it is incomprehensible that the completion of the measure was not a prerequisite for the lifetime extension. But lifetime extension is already granted for units 1-5 of the ZNPP.

SNRIU is a member of the Western European Nuclear Regulators Association (WENRA). In 2014, WENRA the 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 out of the 342 until the 1 January of 2019. (UMWELTBUNDESAMT 2021)

4.2 Questions & preliminary recommendations, answers and assessment of the answers

Question Q13

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 Directive 2014/87/EURATOM?

Written answer by the Ukrainian side

In accordance with the signed Association Agreement between the European Union and Ukraine, since 2014 the Action Plan has been introduced for implementation of the Association Agreement between the European Union and the European Atomic Energy Community and their member states, of the one part, and Ukraine, of the other part.

For the first Topical Peer Review by the European Commission, based on the proposals of the Western European Nuclear Regulators' Association (WENRA), approved by the European Nuclear Safety Regulators Group (ENSREG), the "Ageing Management" area was selected.

As assigned by ENSREG, the review had to cover the NPP units and research reactors with capacity of more than 1 MW, being in operation as of 31.12.2017 or under construction as of 31.12.2016.

Ukraine joined this initiative, and in 2017 the State Nuclear Regulatory Inspectorate developed the «National Report for the First Topical Peer Review in the 'Ageing Management' Area". The EU member states reviewed the Report and admitted the high level of Ukraine with regard to the issues related to ageing. At the same time, a number of aspects were identified, which require improvement and must be addressed.

For implementation of measures for improvement of the ageing management practices, in 2019 the State Nuclear Regulatory Inspectorate, with the participation of the Operator and expert and scientific organizations developed the National Action Plan for Ageing Management. This Plan is a result of joint efforts of all concerned parties aimed at improvement of the ageing management process at the Ukrainian nuclear installations.

Assessment of the answer

The question was not answered. According to SNRIU (2021a), the National Action Plan to address the deficiencies identified in the TPR will be completed in December 2024.

Question Q14

What are the specific findings of the ageing management programme for ZNPP 3-6? Are there any differences between the units?

Written answer by the Ukrainian side

Ageing Management Program (AMP) has been developed with the consideration of the actual technical conditions of each power unit and defines administrative and technical measures for ageing management aimed at provision of the required safety level in accordance with the nuclear safety regulations and standards, as well as measures aimed at estimation and maintaining of the accepted limits of the components and structures degradation.

The result of the ageing management activities is the confirmation of compliance with the criteria specified in the nuclear and radiation safety regulations and standards and in the design documentation, which will not be exceeded during the total operation period of a specific component or structure.

In accordance with the requirements of the valid regulations, effectiveness of the AMP is checked against the criteria specified by the State Nuclear Regulatory Inspectorate.

Assessment of the answer

The question was not fully answered, only general information about the AMP was provided.

Question Q15

What are the results of Safety Factors (SF) 4 (structures, systems and components ageing) of the last periodic safety review for ZNPP 3-6? Are there any differences between the units?

Written answer by the Ukrainian side

Conclusions based on the results of ZNPP Units 3-6 periodic safety review, Safety Factors 4, 'Ageing', are as follows:

ZNPP have developed the Ageing Management Program for the power unit components.

Stipulations of the AMP are based on the requirements of the valid ZNPP production documentation and are in full compliance with them. ZNPP ANP is the basic guideline for extension of operation lifetime of the ZNPP units.

The AMP data are used for optimization of the components maintenance and repair, for implementation of their upgrade and reconstruction programs, for development of operation procedures, test and measurement programs.

Efficiency of the applied methods and equipment for monitoring of technical conditions of the power unit components is sufficient for identification and timely detection of their degradation.

Ageing management measures have been developed so that the data, obtained in the course of maintenance and repair, operation, equipment qualification, as well as implementation of special programs for specific systems (components) at ZNPP, is applied to the maximum. At the same time, the data, obtained in the process of ageing management for specific power unit components, are applied for optimization of their maintenance and monitoring procedures during operation, as well as for safety justification for extension of the unit lifetime.

ZNPP perform continuous analysis of the ageing management actions with assessment of their efficiency. Based on the analysis results, adequate measures are taken for correction of weak points and enhancement of the ageing management system for the power unit components.

Ageing processes and technical conditions are continuously monitored and periodically assessed at ZNPP units, to define effectiveness of ageing management and to re-assign lifetime of the power unit elements. Cable ageing processes are continuously monitored.

Based on the analysis completed, it has been concluded that the actual state of the ZNPP ageing management system is compliant with the regulatory requirements for the Operator's policy regarding ageing management, set-up of ageing management and resources for it.

ZNPP have implemented the computer-aided information system for ageing management. The module has been developed as an individual application integrated with the lists, reference books and classifiers of the Ukrainian NPP equipment reliability data base. The module of the computer-aided information system for ageing management and equipment reliability data base uses a unified classification system. This system ensures compatibility of the equipment data of different NPPs and, thus, provides the possibility of its joint use.

Based on the completed analysis, it may be concluded that the Ageing Management Program for ZNPP unit elements contains all required components for ageing management.

Lifetime characteristics of the critical components confirm the possibility of safe operation of a power unit during the re-assigned operation period.

In the period of the extended lifetime, it is required to perform regular safety reviews to control the ageing management system and to obtain new information on ageing of the power unit elements.

The valid AMP for the elements, as well the current state of their lifetime characteristics confirm the possibility of safe operation of a power unit during the re-assigned operation period, with the consideration of the scheduled administrative and technical measures.

Taking into account

- the obtained results of the technical condition estimation with the consideration of the elements' ageing, which limit the power unit operation lifetime;
- availability of the effective ageing management system for ZNPP unit elements;
- implementation of the measures developed based on the safety review results;

Safe operation of the power unit equipment and structures during the re-assigned period is feasible.

As the AMP is similar for all power units and is thoroughly monitored and effectively implemented in fill scope, the differences between Safety Factors 4 for different power units consist in the deadline for operation extension:

- Unit 3 – until 05.03.2027
- Unit 4 – until 04.04.2028
- Unit 5 – until 27.05.2030
- Unit 6 – re-assessment is not completed.

Assessment of the answer

The question was answered. According to the answer, the evaluation of the aging of structures, systems and components (safety factor (SF) 4) within the framework of the last periodic safety review proved that safe operation is possible until 05.03.2027 (Unit 3), until 04.04.2028 (Unit 4), until 27.05.2030 (Unit 5) respectively. The re-assessment for Unit 6 has not been completed yet.

Question Q16

What are the results of the embrittlement of the reactor pressure vessels (RPVs) for ZNPP 3-6? Are there any differences between the units?

Written answer by the Ukrainian side

Based on the results of the surveillance specimens of ZNPP Units 3-6 reactor pressure vessels, embrittlement temperature of the metal does not exceed the value set forth in the valid regulations.

Beside this, based on the results of periodic safety review of ZNPP Units 3-6, operation lifetime of the reactor pressure vessels has been extended for more 30 years, provided the ageing management measures are implemented.

Are there any differences between the units? Certainly. The design is the same, but there are differences, beginning with the start of the power units operation, their history, operation conditions, chemical composition and mechanical properties of the equipment, which influence the possibility of safe long-term operation in one way or another.

Assessment of the answer

The question was answered, but only general information was given.

Question Q17

Is there a systematic evaluation of the ZNPP design deviations from the current international safety standards and requirements envisaged?

Written answer by the Ukrainian side

In the frames of the periodic safety review, each power unit is analyzed for the compliance of its design with the valid international safety standards as a part of Safety Factor 1, 'Unit Design'. Requirements of the IAEA Safety Series, 'Safety of Nuclear Power Plants: Design. Specific Safety Requirements', No. SSR 2/1.

Assessment of the answer

The question was answered. But as mentioned earlier, the retrofit programs are delayed. In addition, the IAEA document quoted is out of date. A review of safety requirements was conducted in 2011 after the accident at Japan's Fukushima Daiichi nuclear power plant. Therefore, a revision of the IAEA document was published in 2016. (IAEA 2021a)

Question Q18

When will the WENRA RL be fully implemented in the Ukrainian regulations? Is the application of the RL binding?

Written answer by the Ukrainian side

Implementation of the international safe requirements into national legislation is the competence of the authorized state body - State Nuclear Regulatory Inspectorate of Ukraine (SNRIU).

Question Q19

When will a review be conducted if the RL will be met for the ZNPP?

Written answer by the Ukrainian side

After the implementation of the requirements of WENRA RL at the regulatory framework at national level.

Assessment of the answer

The question was answered, but no date was provided for the implementation of the WENRA RL into Ukrainian legislation will take place.

Question Q20

Which WENRA Documents are mandatory for the lifetime extension?

Written answer by the Ukrainian side

In organization of works on lifetime extension and long-term operation SS ZNPP follows the national codes and standards as well as the branch documents of the SS NNEGC "Energoatom" that were developed with account for recommendations of the following IAEA documents:

1. IAEA. Ageing Management for Nuclear Power Plants: International Generic Ageing Lessons Learned (IGALL), IAEA Safety Reports Series No. 82, Vienna 2015
2. INTERNATIONAL ATOMIC ENERGY AGENCY, Ageing Management and Development of a Programme for Long Term Operation of Nuclear Power Plants, Specific Safety Guide No. SSG-48, IAEA, Vienna 2018
3. IAEA-TECDOC-1557 Assessment and Management of Ageing of Major NPP Components Important to Safety - PWR Pressure Vessel Internals, IAEA, Vienna 2007
4. IAEA-TECDOC-1556 Assessment and Management of Ageing of Major NPP Components Important to Safety - PWR Vessels, IAEA, Vienna 2008

5. Unified Procedure for Lifetime Assessment of Components and Piping in WWER NPPs "VERLIFE", version, 2008
6. IGALL Database (/gnssn.iaea.org/) - AMR tables, a collection of AMPs, a collection of TLAAs

Definition of mandatory of WENRA documents is the competence of the authorized state body - State Nuclear Regulatory Inspectorate of Ukraine (SNRIU).

Assessment of the answer

The question was not answered directly; however, it became clear that only IAEA Documents are used.

Preliminary recommendation PR6

It is recommended to implement all available design improvements of VVER-1000 reactor for the ZNPP.

Written answer by the Ukrainian side

Implementation of all the modernization activities targeted to improve SE ZNPP safety is performed in accordance with "Complex (consolidated) safety upgrade program of nuclear power plants units" put into effect by the Cabinet of Ministers of Ukraine dated 07.12.2011 №1270.

Assessment of the answer

The safety level achieved after implementation of all measures of the C(I)SIP does not correspond to the state of the art, therefore the recommendation remains valid. Furthermore, the improvement programs are delayed. All in all, the recommendation remains valid and will be modified.

Preliminary recommendation PR7

It is recommended to undertake a comparison of the design and measures of the ZNPP with all requirements of SRL F. In case of deviations will be found and accepted the reasons for this decision should be explained.

Written answer by the Ukrainian side

There is no such the requirement in the current Ukrainian legislation, thus the question was not considered during the development of the SE ZNPP EIA.

Assessment of the answer

Even though the WENRA RL have not yet been transposed into Ukrainian nuclear legislation, the WENRA RL could be taken into account in the context of the lifetime extension; especially as Ukraine is a member of WENRA. Therefore the recommendation remains valid.

Preliminary recommendation PR8

It is recommended provide the following further information:

a. a detailed description 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 in 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 dealing of uncertainties and non-knowledge and its effects on risk
    - Deviations from the state of the art in science and technology with regard to the detection methods used, the technical estimates and calculation procedures.
    - The safety margins available for the individual safety-relevant components and their respective ageing related changes compared to the original condition.
d. Information to the ageing management program, the following issues should be presented in the EIA documents:
    - 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.
    - Evaluation of the conditions of the RPV internals and head penetrations including trends of events, and envisaged exchange measures.
    - Evaluation of the conditions of components of the primary circuit components and of the electrical installations including trends of events, and envisaged exchange measures.
e. Regarding operation experience, the EIA documents should present an evaluation of safety relevant events including the lessons learned.

Written answer by the Ukrainian side

a) The information is presented in the SE ZNPP power units design documentation, safety analysis reports, which are developed in accordance with national safety requirements and are approved by the State Nuclear Regulation Inspectorate of Ukraine.

b,c) SE ZNPP power units' safety analysis reports and SE ZNPP periodical safety assessment reports are considers national and international safety requirements.

These reports are approved by the State Nuclear Regulation Inspectorate of Ukraine.

The EIA is performed in accordance with the "Recommendations concerning content of materials on operational facilities environmental impact" and DBN A.2.2-1-2003 "Composition and content of environmental impact assessment (EIA) materials during design and construction of enterprises, building and constructions" and considering requirements of legislative, regulative and methodical documents.

Assessment of the answer

Some of the requested information was provided by the Ukrainian side. While the requested information would help to evaluate the potential impacts on Austria, its complete submission is not required in the EIA process. Thus, the recommendation can be omitted.

4.3 Conclusions and final recommendations

Although ageing of the up to 38 years old structures, systems and components (SSCs) is a safety issue for the ZNPP, the EIA documents did not address it. 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. Information of an ageing management programme (AMP) is also not given in the EIA documents. In the ZNPP ANSWERS (2021) some general information about the AMP was provided.

According to the ZNPP ANSWERS (2021), the evaluation of the aging of structures, systems and components (safety factor (SF) 4) within the framework of the last periodic safety review proved that safe operation is possible until 05.03.2027 (Unit 3), until 04.04.2028 (Unit 4), until 27.05.2030 (Unit 5) respectively. The re-assessment for Unit 6 is not completed yet.

However, the Topical Peer Review (TPR) "Ageing Management" under the Nuclear Safety Directive 2014/87/EURATOM, carried out in 2017/18 found deviation of the TPR expected level of performance that should be reached to ensure an acceptable ageing management throughout Europe. The results of the TPR and the activities to remedy the weaknesses were not presented in the EIA documents. According to SNRIU (2021a), the National Action Plan to address the deficiencies identified in the TPR will be completed in December 2024.

Although conceptual ageing is also an issue for the ZNPP, the EIA documentation does not deal with any of the known safety issues of the VVER-1000 reactors. NPP design developed in the 1980s, like the VVER-1000, only partly meet modern design principles concerning redundancy, diversity and physical separation of redundant subsystems or the preference of passive safety systems. The old reactor types VVER has several design weaknesses, which cannot be resolved by performing back-fitting measures. The lower containment boundary (containment basement) is not in contact with the ground but is located at a higher level in-side the reactor building. In case of a severe accident, melt-through can occur within approx. 48 hours. The containment atmosphere will then blow down in-to parts of the reactor building that are not leak-tight resulting in high releases. Another weakness is the protection against external hazard. The reactor buildings are only designed to withstand accidents with small aircrafts.

In 2011, 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. 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. As of March 31, 2021, still a range of measures have yet to be implemented (96 out of 466 measures).

In spite of some progress, the programmes ran into a long delay and this situation has not changed since the last century. From a safety point of view, it is incomprehensible that the completion of the measure was not a prerequisite for the lifetime extension. Instead, the lifetime extension permit has already been granted for units 1-5 of the ZNPP.

SNRIU is a member of the Western European Nuclear Regulators' Association (WENRA). In 2014, WENRA the 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 out of the 342 until the 1 January of 2021. (WENRA 2021a) The implementation of the WENRA RL into Ukrainian legislation has not taken place yet.

Summing up, between the required safety level and the safety level of the ZNNP a gap remains. Firstly, vulnerabilities exist that cannot be removed; secondly, the improvement program is considerably delayed; and thirdly, the safety requirements in Ukraine's regulatory framework do not comply with the WENRA safety requirements.

Final recommendation FR5

It is recommended to implement all available design improvements of VVER-1000 reactor for the ZNPP in a timely manner.

Final recommendation FR6

It is recommended to undertake a comparison of the design and measures of the ZNPP with all requirements of WENRA RL F to identify further measures to improve the safety level.

5 ACCIDENT ANALYSIS

5.1 Short summary of the expert statement

The provided EIA documents gave information about Design Basis Accidents (DBA) including the scenarios, the releases and the consequences. The information about Beyond Design Basis Accidents (BDBA), however, was very limited. Neither the accident scenarios nor the possible source terms were provided.

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-1000 reactor type. A systematic analysis of BDBAs is missing in the provided EIA documents.

The accident analyses in the EIA documents should use a possible source term derived from the calculation of the current probabilistic safety analyses (PSA) 2. Even though the calculated probability of severe accidents with a large release is very low, the consequences caused by these accidents are potentially enormous.

The conclusion of State Nuclear Regulatory Inspectorate of Ukraine (SNRIU) that the units are operating safely with an acceptable level of risk cannot be agreed on the basis of the available information. The Core Damage Frequency (CDF) and Large Release Frequency (LRF) values show that almost every core melt accident will result in an accident with a large release of radioactive substances. Because of the outdated design of the VVER-1000, there are not effective measure to avoid a large release after a core melt accident.

According to ENSREG (2015), maintaining containment integrity under severe accident conditions remains an important issue for severe accident management. Filtered containment venting is a well-known approach to prevent containment overpressure failure, but it is not implemented at any unit of the ZNPP yet. Furthermore, there is no system for cooling and stabilizing molten core for the ZNPP available. In the framework of the EU Stress Tests a strategy for possible corium confinement within the reactor pressure vessel has to be analyzed by 2023. The deadline was postponed from 2015. It is not known whether there will be any result, which would lead to the implementation of an appropriate measure.

The conclusion to be drawn is clear: the next years will be the prolongation of the status quo: An accident, for example triggered by an external event, can result in a severe accident, but at the same time the plant and the staff will not be able to cope with these accidents. This might result in very serious consequences: Large radioactive releases.

The EIA documents should explain how the safety issues that endangered the containment integrity will be solved. As far as can be seen from the documents provided and available, there is still a high probability that accident scenarios will develop into a severe accident that threatens the integrity of the containment and results in a large release.

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 EU Stress Tests showed that after decades of implementing safety programs, Ukrainian reactors continue posing exceptionally high risk. One characteristic of nuclear safety in the Ukraine: the constant severe delay of the implementation of upgrading measures.

Furthermore, and even more importantly, state of the art safety standards like consideration of "design extension condition" (DEC) are still not envisaged. Thus, even after the implementation of all measures there will remain a considerable gap between the safety level agreed in Europe and the safety level of the ZNPP.

It is also state of the art to use the WENRA "Safety Objectives for New Power Reactors" as a reference for identifying reasonably practicable safety improvements. However, the EIA documents do not mention this WENRA safety objectives. According to the WENRA safety objective core melt accidents which would lead to early or large releases would 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 for ZNPP. (UMWELTBUNDESAMT 2021)

5.2 Questions & preliminary recommendations, answers and assessment of the answers

Question Q21

What are the source terms of the possible BDBAs calculated in the probabilistic safety analyses (PSA) 2 including releases from the spent fuel pools?

Written answer by the Ukrainian side

PSA 2 covers the following sources of radioactivity:

- Reactor installation;
- Cooling pond.

Assessment of the answer

The question was not answered. Only the sources of release but not the amount of release (source term) were listed.

Question Q22

What is the currently valid time schedule for the implementation of all required SAM features for ZNPP? When will the implementation of all C(I)SIP measures be finished?

Written answer by the Ukrainian side

The Complex (Consolidated) Safety Upgrade Program includes more than 1200 measures to be implemented at the Ukrainian nuclear power plants (about 70% of them have been implemented as of today). Implementation of the C(C)SUP measures is focused only on improvement of safety of the NPPs in operation and is not relevant to construction or increase of capacity.

Assessment of the answer

The question was not properly answered but stated that 70% of the measures have been implemented-. Considering the start of the program in 2011 or in some parts in 2005, the program is very long.

Question Q23

What are the parameters of the maximum aircraft crash (plane mass and speed) the buildings of ZNPP can withstand?

Written answer by the Ukrainian side

Design of the reactor building at Unit 1 was developed without consideration of the impacts of the air crash. However, checking calculations for the aircraft crash, completed for the containment of the unified VVER-1000 NPP, confirmed that the civil structures of the dome and cylinder would withstand the impact of the 10 tons aircraft, dropping at the angle of 10° to 45° to horizontal with the speed of 215 m/s.

Assessment of the answer

The question was answered.

Question Q24

What is the source term and the accident scenario of the BDBA that is chosen to calculate possible trans-boundary consequences? What is the technical justification for the use of this BDBA?

Written answer by the Ukrainian side

In accordance with the valid Ukrainian regulatory and industrial documents related to safety analysis of the NPP power units, calculation of the possible transboundary consequences is not foreseen. On the other hand, in accordance with the requirements of the above referenced documents, radiation impact on the territory of the so-called surveillance zone has been evaluated. This zone is specified with the NPP design and, for ZNPP, it is equal to 30 km.

Technical justification of the completed radiation impact evaluation is included into the report, "Zaporizhzhia NPP. Refinement of Area of ZNPP Surveillance Zone in Frames of Periodic Safety Review. Final Report", 00.ТН.ЗП.ОТ.368, 2014, approved by State Nuclear Regulatory Inspectorate of Ukraine.

Assessment of the answer

The question was not answered. It is stated that in accordance with Ukraine regulatory documents the BDBA and Severe Accident scenarios were not analysed as part of the EIA procedure. It is also pointed out that the radiation impact on the surveillance zone has been evaluated.

Question Q25

Which design basis accidents can develop into a beyond design basis accident?

Written answer by the Ukrainian side

Theoretically almost any of DBAs, provided additional failures occur beside a single failure on the safety systems in comparison to the design basis accidents, or in case of wrong decisions made by the personnel.

Assessment of the answer

The question was answered.

Question Q26

Which accidents scenarios with the loss of containment integrity or containment bypass are physical possible for the units of the ZNPP?

Written answer by the Ukrainian side

The following scenario groups are possible:

1. For design-based accidents

   Leakage from primary to secondary circuit (for example, steam generator collector cap break-away).

2. For beyond-the-design accidents

   Leakage from primary circuit out of containment or into secondary circuit assuming failure of different safety functions.

3. For severe accidents
   - accident with containment integrity loss at early stage;
   - accidents with containment bypassing;
   - accident with containment integrity loss at late stage.

   Note. Accident with containment integrity loss at late stage can be caused by the following phenomena:
   - *containment damage due to hydrogen burning;*
   - *containment damage due to overpressure;*
   - *containment damage due to core melt reaction with concrete*

Assessment of the answer

The question was answered. It is confirmed that there are several accident scenarios which can cause a loss of the containment integrity.

Preliminary recommendation PR9

It is recommended to use the WENRA Safety Objectives for new NPP to identify reasonably practicable safety improvements for the ZNPP. It is recommended to use the concept of practical elimination for this approach.

Written answer by the Ukrainian side

WENRA requirements are not incorporated into the Ukrainian codes and standards.

Assessment of the answer

The recommendation remains valid. Even though the WENRA Safety objectives are not implemented in the Ukraine regulations, they could be used to identify reasonably practicable improvements.

Preliminary recommendation PR10

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 all possible 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.

Written answer by the Ukrainian side

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

Power unit 1:

- Core damage frequency (CDF) – 5,00E-06
- Large (early) release frequency (L(E)RF) of reactor facility (RF) – 2,66E-06
- Fuel damage frequency (FDF) - 5,62E-06
- Large (early) release frequency (L(E)RF) of spent fuel pond (SFP) - 5,58E-06

Power unit 2:

- CDF – 5,91E-06
- LERF RF – 3,41E-06
- FDF - 5,29E-06
- LERF SFP - 5,24E-06

Power unit 3:

- CDF – 9,72E-06
- LERF RF – 8,45E-06
- FDF - 4,75E-07
- LERF SFP - 4,43E-07

Power unit 4:

- CDF – 9,20E-06
- LERF RF – 7,75E-06
- FDF - 4,79E-07

Power unit 5:

- CDF – 6,38E-06
- LERF RF – 4,02E-06
- FDF – 5,38E-06
- LERF SFP – 5,25E-06

Power unit 6:

- CDF – 9,01E-06
- LERF RF – 7,51E-06
- FDF - 4,79E-07
- LERF SFP - 4,41E-07

b) Contribution of internal events as well as internal and external hazards to CDF and L(E)RF is provided below, under the table[4].

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

1. Complete blackout and loss of external and internal power sources, including reserve diesel generators.

[4] The tables are in the ANNEX

2. Small break including high pressure (HP) emergency core cooling system (ECCS) failure.
3. Small break including HP ECCS and low pressure (LP) ECCS failure.
4. Small break including complete blackout.
5. Medium break including HP ECCS failure.
6. Medium break including HP ECCS and LP ECCS failure.
7. Large break including HP ECCS failure.
8. Large break including HP ECCS and LP ECCS failure.
9. Large break including sprinkler systems failure.
10. Anticipated transient without scram (ATWS).
11. Make-up water loss including SG emergency feedwater supply failure.
12. Leakage from primary to secondary circuit (steam generator collector cap break-away) including steam relief valves nonclosure.
13. Steamline ruptures (in parts which can be isolated, and which cannot be isolated).
14. Accidents with primary circuit leakages including bubbling condenser system failures (for VVER-440 reactors).

d) The 2-level PSA considers the following radiation sources:

- reactor facility;
- spent fuel pond.

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

The answer to this question depends on the scenario being considered. There is a very large set of initial events of accidents, ways of their progress and the corresponding final conditions.

These scenarios are considered in the safety analysis reports, which are developed by the nuclear power plant operator and approved by the national regulatory authority.

Assessment of the answer

Almost all information required by this recommendation was provided. However, the most important information for the evaluation of the possible impact on Austria is missing: releases (source terms) in case of a severe accident. These values show that the calculated frequencies for large early releases are relatively high. The values also show that most of the core melt accidents cause large early releases; about 53 % (unit 1), 58 % (unit 2), 87 % (unit 3) 84 % (unit 4), 63 % (unit 5) and 83 % (unit 6). Fuel damages in the spent fuel pools caused by an external event almost always result in a large and early release.

5.3 Conclusions and final recommendations

The provided EIA documents give information about Design Basis Accidents (DBA) including the scenarios, the releases and the consequences. The information about Beyond Design Basis Accidents (BDBA), however is very limited. Neither the accident scenarios nor the possible source terms are provided.

It is stated in the ZNPP ANSWERS (2021) that in accordance with Ukraine regulatory documents the BDBA and Severe Accident scenarios were not analysed as part of the EIA procedure. It is also pointed out that the radiation impact on the surveillance zone (30 km) has been evaluated. However, the source term for this calculation is not given.

The accident analyses in the EIA documents, however, should use a possible source term derived from the calculation of the current probabilistic safety analyses level 2 (PSA 2). Even though the calculated probability of severe accidents with a large release is very low, the consequences caused by these accidents are potentially enormous. While much information was provided in ZNPP ANSWERS (2021), the most important information for the evaluation of the possible impact on Austria was not provided: possible releases (source terms) in case of a severe accident.

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 types of severe accidents are possible for the VVER-1000 reactor type.

It is confirmed by the ZNPP ANSWERS (2021) that there are several accident scenarios which can cause a loss of the containment integrity: accident with containment integrity loss at early stage; accidents with containment bypass; and accident with containment integrity loss at late stage (due to hydrogen burning; overpressure or core melt reaction with concrete).

According to ENSREG (2015), maintaining containment integrity under severe accident conditions remains an important issue for severe accident management. Filtered containment venting is a well-known approach to prevent containment overpressure failure, but it is not implemented at any unit of the ZNPP. Only 70 % of the backfitting program have been implemented as of today. Furthermore, there is no system for cooling and stabilizing molten core for the ZNPP available. In the framework of the stress tests a strategy for possible corium confinement within the reactor pressure vessel has to be analysed by 2023. The deadline was postponed from 2015. It is not yet known whether there will be an outcome leading to the implementation of an appropriate measure.

The conclusion of SNRIU that the units are operating safely with an acceptable level of risk cannot be agreed on the basis of the available information. There is still a high probability that accident scenarios will develop into a severe accident that threatens the integrity of the containment and result in a large release.

The values for the core damage frequency and the large early release frequency also show that most of the core melt accidents cause large early releases: about 53 % (unit 1), 58 % (unit 2), 87 % (unit 3) 84 % (unit 4), 63 % (unit 5) and 83 % (unit 6). Fuel damages in the spent fuel pools caused by an external event almost always result in a large and early release.

The results of the EU Stress Tests 2011 have revealed a high number of shortcomings in 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, even further improvements were recommended by the ENSREG peer review team. This is one example for the gap between the Ukraine and the EU safety standards and requirements. There is a constant delay in the implementation of safety upgrades in Ukraine.

Furthermore, and even more importantly, state of the art safety standards like consideration of "design extension condition" are still not envisaged. Thus, even after the implementation of all measures a considerable gap between the safety level agreed in Europe and the safety level of the ZNPP will remain.

It is state of the art to use the WENRA "Safety Objectives for New Power Reactors" as a reference for identifying reasonably practicable safety improvements. However, the EIA documents do not mention this WENRA safety objectives. According to the WENRA safety objective core melt accidents which would lead to early or large releases would have to be practically eliminated. Even as the WENRA Safety objective are not implemented in the Ukraine regulations, they could be used to identify reasonably practicable design features, operational measures or accident management procedures to lower the risk further should be implemented for ZNPP.

Final recommendation FR7

It is recommended to use the WENRA Safety Objectives for new NPP to identify reasonably practicable safety improvements for the SUNPP. It is recommended to use the concept of practical elimination for this approach.

Final recommendation FR8

It is recommended to provide the source terms (radioactive releases) of all possible BDBAs including releases from the spent fuel pools calculated in the PSA 2.

6 ACCIDENTS DUE TO EXTERNAL HAZARDS

6.1 Short summary of the expert statement

Information on natural hazards that have potentially negative impacts on the safety of the ZNPP was insufficient in the EIA. The EIA documents did not contain information as to whether all natural hazards relevant to the site were taken into account in the site assessment in the most recent periodic safety review (PSR) or in the LTO project. It could not be concluded from the EIA documents that the 6 units of ZNPP are adequately protected from the effects of natural hazards. Since Austria can be potentially affected by the consequences of accidents caused by natural hazards, this fact is relevant in the ongoing EIA.

WENRA (2015, Chapter 7; 2021, Issue P, Reference Level P2.2 (g)) calls for a review of the risk analysis for the NPP site for the PSR. It is unclear whether a comprehensive assessment including the steps as requested by WENRA (2015, 2021, Issues E, F, TU) has been performed:

- identification of site-specific natural hazards including combinations of hazards,
- hazard assessment,
- definition of the design basis for the identified natural hazards and combinations of hazards on the basis of events with an average recurrence interval of 10,000 years,
- development of a protection concept,
- analysis of the conditions for beyond design basis accidents.

For these steps, the team of experts recommends the use of a generic list of natural hazards (e.g., WENRA 2015, Appendix 1) as a starting point for the identification of site-specific natural hazards and the identification of relevant combinations of hazards (DECKER & BRINKMAN 2017) in order to ensure that all relevant hazards and combinations of hazards are taken into account.

6.2 Questions & preliminary recommendations, answers and assessment of the answers

Question Q27

Were the original design bases with regard to natural hazards and the protection systems against the effects of natural hazards systematically reassessed as part of the EIA process and / or as part of the extension of the operating license (LTO) for ZNPP?

Written answer by the Ukrainian side

During the development of the PSA and integral models for determination of quantitative indices of Core damage frequency (CDF), Fuel damage frequency (FDF), Large (early) releases frequency (L(E)RF) of reactor facility (RF) and Large (early) releases frequency (L(E)RF) of spent fuel pond (SFP) values, there was a PSA for external extremal impacts performed. The analysis considered natural and technogenic impacts. Contribution of the PSA for external extremal impacts to the integral values of the CDF, FDF, L(E)RF RF and L(E)RF SFP is provided below the table (see p.2).

Assessment of the answer

The expert team appreciated the efforts the Ukrainian side undertook when providing detailed information on PSA results.

With respect to external hazards the PSA results refer to "external (natural and technogenic) impacts" in general. It remains unclear if a targeted identification and reassessment of all hazards that apply to the site has been performed in the framework of the PSA analyses. Also, the reply does not provide information on the types of natural hazards that were considered in the PSA. Such information, however, is partly included in the answer to question Q36.

Question Q28

Do all of the design bases with regard to natural hazards conform to the WENRA requirements to define design basis events for occurrence probabilities of 10^{-4} per year?

Written answer by the Ukrainian side

SE ZNPP power units safety assessment reports considers national and international safety requirements. These reports are approved by the State Nuclear Regulation Inspectorate of Ukraine.

Assessment of the answer

The Ukrainian reply leaves open if design bases with regard to natural hazards conform to the WENRA requirement to define design basis events for occurrence probabilities of 10^{-4} per year.

Question Q29

Is adequate protection in place to conservatively ensure that all SSCs relevant to safety withstand design basis events of natural hazards with occurrence probabilities of 10^{-4} per year?

Written answer by the Ukrainian side

SE ZNPP power units safety assessment reports considers national and international safety requirements and confirms safe operation of the SE ZNPP power units. These reports are approved by the State Nuclear Regulation Inspectorate of Ukraine.

Assessment of the answer

The Ukrainian reply confirmed an adequate protection level with respect to national and international safety requirements. It is, however, not stated as to whether this also applies to the requirement to protect SSCs relevant to safety define design basis events for occurrence probabilities of 10^{-4} per year (WENRA 2021).

Question Q30

Have new hazard analyses for natural hazards other than seismic been carried out for ZNPP as part of the EIA process and / or as part of the extension of the operating license (LTO) and / or other projects?

Written answer by the Ukrainian side

During the development of the PSA and integral models for determination of quantitative indices of CDF, FDF, L(E)RF RF and L(E)RF SFP values, there was a PSA for external extremal impacts performed. The analysis considered natural and technogenic impacts. Contribution of the PSA for external extremal impacts to the integral values of the CDF, FDF, L(E)RF RF and L(E)RF SFP is provided below the table (see p.2).

Assessment of the answer

The Ukrainian reply clarified that “external impacts” were considered in the development of PSA.

No information is provided on the types of natural hazards that were considered in the PSA (such information is partly given in the answer to question Q36).

It also remains open if targeted hazard re-assessments for natural hazards other than seismic were performed in the course of the LTO process.

Question Q31

If new hazard analyses were carried out: did they confirm the original design bases, or do the new analyses require retrofitting SSCs relevant to safety?

Written answer by the Ukrainian side

Based on the PSA for external extremal impacts results there was a recommendation on safety level improvement issued concerning installation of Mobile Pump Station for Sprinkler Basins. At the present time the recommendation is fulfilled.

Assessment of the answer

The Ukrainian reply indicates that PSA results led to safety upgrades. The answer, however, left open whether the original design bases for all types of natural hazards were confirmed, or new hazard analyses performed in the PSA indicated the need for new design basis values.

Question Q32

Has the upgrading of the seismic resistance of all SSCs important to safety to the new DBE of PGA=0.1g as announced in the Stress Tests been completed for ZNPP?

Written answer by the Ukrainian side

Acceleration on the soil surface at the level of 0.1g is not the level of the design earthquake for SE ZNPP. Based on national regulations NP 306.2.208-2016, for nuclear power plant power units the peak value of acceleration of the soil movement horizontal component during an earthquake, which corresponds to the maximum calculated earthquake, is taken not less than 0.1g regardless of the NPP site seismicity.

In fact, according to the agreement with the SNRIU, for assessment of seismic resistance of structures, equipment, pipelines and plant-shared facilities of SE Zaporizhzhia NPP power units 1-6 located on the ground surface of the site, in order to take into account all possible seismic impacts, in the form of qualification requirements there is the envelope curve of spectral accelerations obtained for the Maximum Calculated Earthquake (MCE or DBE) and for the Design Earthquake (DE) on the free surface of the soil, according to the results of deterministic and probabilistic (PSHA) approaches to analysis, and equal to (PGA, MCE) = 0.17g (PGA (DE) = 0.085g) is used.

Considering the levels, within the framework of action 1810 of "Complex (consolidated) safety upgrade program of nuclear power plants units" and depending on the seismic category established in the SAR, there was an assessment of the seismic resistance of all safety important SSCs performed. According to the results of such assessment of structures, systems and pipelines, all power units have performed compensatory actions necessary to ensure the required level of seismic resistance. The only thing that remains in the process now is to complete the implementation of compensatory measures for individual pipelines at the power unit № 6 during 2022.

Assessment of the answer

According to the reply, the seismic design basis for ZNPP was updated to PGA=0.17g. The DBE resulted from deterministic and probabilistic (PSHA) analyses. It is said that, with the exception of some SSCs of power unit 6, upgrades of the seismic resistance of SSCs important to safety have been performed.

Question Q33

What are the results of the latest seismic hazard assessment (PSHA 2013-2014) in terms of the design basis earthquake? Are the new design basis values enveloped by the seismic resistance of all SSCs relevant to safety?

Written answer by the Ukrainian side

Equipment and constructions seismic stability assessment was performed in the framework of action 18101 of "Complex (consolidated) safety upgrade program of nuclear power plants units". Based on the results of the assessment there were appropriate compensating actions performed to increase the seismic stability level up to the requested level.

Assessment of the answer

The written answer did not clarify the issue.

The Ukrainian reply to question Q32 stated that deterministic and probabilistic (PSHA) analyses have resulted in an update of the seismic design basis for ZNPP which is PGA=0.17g.

Question Q34

Please provide information on the results of seismic margin assessments that were carried out to assure the robustness of equipment, piping, buildings and structures important to safety.

Written answer by the Ukrainian side

In the framework of implementation of the p.1 of SE NNEGC "Energoatom" organizational and technical actions concerning implementation of NP 306.2.208-2016 "Requirements to earthquake-proof designing and assessment of nuclear power plant power units seismic safety", SE Zaporizhzhia NPP power unit components seismic margins are determined in the additional materials for the safety analysis, which are harmonized with the NP 306.2.208-2016.

Assessment of the answer

The Ukrainian side confirmed that seismic margin assessments were carried out. Details of the results are not provided. The answer to question Q32 confirmed that SSCs resist the seismic design basis of PGA=0.17g (with exception of some SSCs in unit 6).

Question Q35

Is the hazard of external flooding, in particular river floods and floods by the possible break or mismanagement of Dniepr dams upstream of ZNPP, appropriately taken into account in the definition of the design basis flood, i.e., by referring to occurrence probabilities of 10^{-4} per year (average recurrence period of 10,000 years)?

Written answer by the Ukrainian side

During the development of the PSA and integral models for determination of quantitative indices of CDF, FDF, L(E)RF RF and L(E)RF SFP values, there was a PSA for external extremal impacts performed. The analysis considered natural and technogenic impacts.

In part of the natural impacts here were also analyzed river floods and possible failure or wrong control on dams located on river Dnipro over the SE ZNPP site.

For quantify the impact caused by external flooding, the dam failure frequencies listed in Flood Hazard for Nuclear Power Plants on Coastal and River Sites Safety Standards Series No. NS-G-3.5, IAEA, VIENNA, 2003 were analyzed. According to these estimates, for some dams the frequency may be 1E-03 1/h, the database for all dams gives the range 1E-04 - 1E-05 1/h.

All dams of the Dnieper cascade are referred to the first class in terms of capital and are designed for a flood of 0.01% security. Thus, the frequency of dam failure does not exceed 1E-04 1/h. For further analysis, the most conservative value of the dam failure rate is 1E-03 1/h.

The calculation of the NPV, the value of which is less than 1% (0.1%) of the NPP of internal initial events, was performed. The value obtained is below the screening criterion. There is no danger of external flooding.

Assessment of the answer

The Ukrainian reply clarified that the hazard of external flooding, in particular river floods and floods by the possible break or mismanagement of dams, were considered in the safety analysis of ZNPP.

Question Q36

The EIA document REPORT CONSULTATIONS (2018, Annex 2, p. 13) states the following CDF and LRF values for units 1 and 2 of ZNPP: unit1 – CDF=6.37E-06 1/year, LRF=4.92E-06 1/year; unit 2 - CDF=5.97E-06 1/year, LRF=4.96E-06 1/year.

- Are the values derived from an **extended** Level 2 PSA?
- Which types of initiating events (internal hazards, internal fire, seismic, flooding etc.) are considered in the PSA?
- Does the analysis consider potential releases from the spent fuel pool?
- Why is the LRF value larger than the CDF?
- What are the CDF and LRF values of the units 3 to 6 of ZNPP, should such data be available?

Written answer by the Ukrainian side

At the present time there are other (actual) values of the CDF, FDF, L(E)RF RF and L(E)RF SFP for all SE ZNPP power units.

Quantitative indices account complete range of initiating events, like:

- Internal initiating events;
- Internal fires;
- Internal floods;
- External extremal impacts;

Seismic PSA is performed separately. At the present time the following Seismic PSA values for power unit 1 are approved:

CDF - 3.69E-06

FDF - 2.29E-06

L(E)RF RF - 2.27E-06

L(E)RF SFP - 2.06E-06.

Seismic PSA for power units 2-4 is now passing approval, seismic PSA for power units 5-6 is in development process. The performed analyses consider emissions from the spent fuel pond.

Value of large (early) release frequency is lower than the core damage frequency.

CDF, FDF, L(E)RF RF and L(E)RF SFP values are provided for all SE ZNPP power units (see. p.1).

Assessment of the answer

The reply clarified that, with the exception of seismic events, all types of initiating events were considered in the PSA. The hazard types summarized under "extreme external events" are not further specified.

The Ukrainian side confirmed that seismic PSAs were developed for all power units of ZNPP.

Preliminary recommendation PR11

It remains unclear whether all natural hazards relevant to the site were taken into account in the site safety analysis, as required by WENRA (2021) and further explained by WENRA (2015). The team of experts recommends using the "Non-Exhaustive List of Natural Hazards" (WENRA 2015) as a starting point to ensure that all site-specific hazards affecting ZNPP are taken into account.

Written answer by the Ukrainian side

WENRA requirements are not incorporated into the Ukrainian codes and standards.

Assessment of the answer

WENRA Reference Levels for Existing Reactors (WENRA 2021) are an acknowledged basis for safety evaluations of existing NPPs. They are generally in line with other safety standards and safety guidelines such as the ones issued by IAEA.

The identification and analysis of all natural hazards that apply to a site are standard procedures for the safety demonstration of a nuclear installation.

The recommendation remains valid.

Preliminary recommendation PR12

It seems uncertain whether all hazard combinations were taken into account in the assessment of the site, as required by WENRA (2021) and further explained by WENRA (2015). The team of experts recommends using a hazard correlation diagram (e. g. DECKER & BRINKMAN 2017) as a starting point to ensure that all relevant combinations are taken into account.

Written answer by the Ukrainian side

WENRA requirements are not incorporated into the Ukrainian codes and standards.

Assessment of the answer

WENRA Reference Levels for Existing Reactors (WENRA 2021) are an acknowledged basis for safety evaluations of existing NPPs. They are generally in line with other safety standards and safety guidelines such as the ones issued by IAEA. IAEA provides extensive guidelines on the analysis of hazard combinations (e.g., IAEA 2021, Appendix 1).

The identification and analysis of all natural hazards that apply to a site, as well as relevant combinations of hazards such as for example earthquake-induced fire or earthquake-induced internal flooding, are standard procedure for the safety demonstration of a nuclear installation.

The recommendation therefore remains valid.

Preliminary recommendation PR13

The team of experts recommends taking into account all combinations of relevant processes that determine the height of river floods, such as mismanagement of dams, dam break and waves when assessing the risk of river flooding (WENRA 2016).

Written answer by the Ukrainian side

WENRA requirements are not incorporated into the Ukrainian codes and standards.

Assessment of the answer

The Ukrainian reply to question Q35 clarified that river floods and floods associated with dam breaks or mismanagement of dams were considered in safety analyses. The recommendation is therefore obsolete.

Preliminary recommendation PR14

The 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 identified for the site and use the derived parameters to develop adequate protection concepts.

Written answer by the Ukrainian side

WENRA requirements are not incorporated into the Ukrainian codes and standards.

Assessment of the answer

WENRA Reference Levels for Existing Reactors (WENRA 2021) are an acknowledged basis for safety evaluations of existing NPPs. The requirement of defining design basis values is in line with other safety standards and safety guidelines addressing natural hazards such as the ones issued by IAEA.

The definition of design bases parameters for all types of natural hazards and providing adequate protection for all SSCs important to safety to conservatively ensure their functionality under design basis accident conditions constitutes a standard procedure for the safety demonstration of a nuclear installation.

The recommendation therefore remains valid.

Preliminary recommendation PR15

The 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.

Written answer by the Ukrainian side

WENRA requirements are not incorporated into the Ukrainian codes and standards.

Assessment of the answer

The analysis of Design Extension Conditions (DEC) is common practice in the safety assessment of existing NPPs and, besides WENRA, also included in the IAEA Specific Safety Requirements (IAEA 2012, p. 23; IAEA 2016, p. 24; Requirement 20: Design extension conditions[5]).

The recommendation remains valid.

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5 "A set of design extension conditions shall be derived … for the purpose of further improving the safety of the nuclear power plant by enhancing the plant's capabilities to withstand, without unacceptable radiological consequences, accidents that are either more severe than design basis accidents or that involve additional failures. These design extension conditions shall be used to identify the additional accident scenarios to be addressed in the design and to plan practicable provisions for the prevention of such accidents or mitigation of their consequences if they do occur."

6.3 Conclusions and final recommendations

The Ukrainian side's written replies added important information on how natural hazards that have potentially negative impacts on the safety of the ZNPP were considered in safety analyses.

The expert team concluded that the impacts of external hazards were analysed in Level 1 PSA studies performed for all 6 power units of ZNPP. CDF and LERF derived from PSA for the units 1, 3 and 4 of ZNPP suggest that the reactors are adequately protected from the effects of those natural hazards that were considered in the PSA. For these units "integrated core damage frequencies" between 5.00×10^{-6} and 9.72×10^{-6} are stated. No values are provided for units 2, 4 and 6. The values apparently do not consider seismic hazards. Seismic PSAs were developed independently and based on updated hazard assessments that revealed a seismic design basis of PGA=0,17g for the site. The expert team was not informed about the results of the seismic PSA. External flooding hazards by river floods of the Dnepr and/or dam breaks were analysed and screened out, apparently due to the unlikeliness of floods reaching up to the elevation of the NPP site.

The EIA documents and the written replies did not contain information as to whether all natural hazards relevant to the site were taken into account in the recent PSAs or in the LTO project, e.g., all types of extreme meteorological phenomena including climate change effects. The same is true for hazard combinations. The team of experts therefore recommends identifying relevant hazards and hazard combinations of hazards based on WENRA (2020a) and DECKER & BRINKMAN (2017) to ensure that all relevant hazards and hazard combinations are taken into account.

Whether the LTO project included an analysis of the Design Extension Conditions (DEC) for natural hazards remained unclear. WENRA (2021) and IAEA (2012; 2016) require that DEC analysis shall be undertaken, e.g., in the framework of Periodic Safety Reviews (PSR; WENRA 2021, Issue F, Reference Level F5.1; Issue A, Reference Level A2.3) with the purpose of further improving the safety of existing nuclear power plants and enhancing their capability to withstand events or conditions more challenging than those considered in the design basis. The expert team recommended using the LTO process for comprehensive DEC analyses with respect to external hazards to achieve higher levels of safety with respect to natural hazards. It is of relevance, since Austria can be affected by the consequences of accidents caused by natural hazards.

Final recommendation FR9

It remains unclear whether all natural hazards relevant to the site were taken into account in the site safety analysis, as required by WENRA (2014; 2021) and further explained by WENRA (2015; 2020a). The team of experts recommends using the "Non-Exhaustive List of Natural Hazards" (WENRA 2015; 2020a) as a starting point to ensure that all site-specific hazards affecting ZNPP are taken into account.

Final recommendation FR10

It seems uncertain whether all hazard combinations were taken into account in the assessment of the site, as required by WENRA (2014; 2021) and IAEA (2021), and further explained by WENRA (2015; 2020a). The team of experts recommends using a hazard correlation diagram (e. g. DECKER & BRINKMAN 2017) as a starting point to ensure that all relevant combinations are taken into account.

Final recommendation FR11

The 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 identified for the site and use the derived parameters to develop adequate protection concepts.

Final recommendation FR12

The expert team recommends applying 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. According to WENRA requirements (WENRA 2014; 2021) and IAEA Safety Requirements (IAEA 2012; 2016), DEC analysis shall be undertaken with the purpose of further improving the safety of existing nuclear power plants and enhancing their capability to withstand events or conditions more challenging than those considered in the design basis.

7 ACCIDENTS WITH THIRD PARTIES' INVOLVEMENT

7.1 Short summary of the expert statement

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

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

Information regarding the issue of terror attacks would be of great interest, considering the large consequences of potential attacks. In particular, the EIA documents should include detailed information on the requirements for the design against the targeted crash of a commercial aircraft. This topic is in particular important, because reactor building of all units of the ZNPP are vulnerable against airplane crashes.

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 29th 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. In UMWELTBUNDESAMT (2021), it was recommended to invite the International Physical Protection Advisory Service (IPPAS) of the IAEA that assisted states, in strengthening their national nuclear security regimes, systems and measures.

7.2 Questions & preliminary recommendations, answers and assessment of the answers

Question Q37

What are the requirements with respect to the NPP design against the deliberate crash of a commercial aircraft?

Written answer by the Ukrainian side

Power unit 1 reactor compartment design was developed without consideration of impact from falling aircraft, because there were no specific requirements from the Customer to consider an aircraft fall on to the NPP (see p.1.8.6 PiN AE-5,6 "Construction design norms for NPPs with reactors of different types"). But the checking calculations were performed for case of aircraft fall impact on to protective enclosure of unified type NPP with VVER-1000 reactor. The calculations showed that the building constructions of the enclosure dome and cylinder can endure and stay integral in case of hit of aircraft having weight 10 tons, and falling down at angle to horizon in range from 10 to 45 degrees with a speed up to 215 m/s (archived values from calculations performed by the "Atomenergoproject" institute, Moscow, №6343, Kuibyshev Engineering and Construction Institute reports 1982-1987). The calculations also confirmed correspondence to requirements concerning enclosure construction strength on local penetration, and were performed in accordance with the program "HOLE" (Scientific and Research Institute of Concrete and Reinforced Concrete) and considering the SRICRC recommendations in 1983.

Commercial aircraft crash on to power unit was also excluded from the following consideration as soon as there are no large civil airports and no air route near the NPP site. The appropriate request was sent to the Ministry of transport.

Based on results of consultations with representatives of the Ministry of Emergency Situations it was found, that in the 30 kilometer area around SE ZNPP site there are no military factories and airports. The nearest military airport is situated in Melitopol (160 km from SE ZNPP) and there is 4 km area around SE ZNPP that is free from military aircraft air routes. Based on the obtained information and based on PSA for External Extremal Impacts, all extremal impacts related to aircraft fall on to the power unit were excluded from the following consideration.

Assessment of the answer

The question was answered. It is explained that the crash of a commercial aircraft was excluded because of the distance to airports. However, this fact does not matter in the case of deliberate aircraft crashes. It is also explained that the units can only withstand a crash of a military aircraft (10 tons, 215 m/s).

Question Q38

Against which external attacks must the reactor building, and other safety relevant buildings be designed? Is this protection still guaranteed despite adverse ageing effects?

Written answer by the Ukrainian side

Checking calculations were performed, which showed that in case of aircraft crash impact on to protective enclosure of unified type NPP with VVER-1000, the building constructions of the enclosure dome and cylinder can endure and stay integral in case of hit of aircraft having weight 10 tons, and falling down at angle to horizon in range from 10 to 45 degrees with a speed up to 215 m/s (archived values from calculations performed by the "Atomenergoproject" institute, Moscow, №6343, Kuibyshev Engineering and Construction Institute reports

1982÷1987). The calculations also confirmed correspondence to requirements concerning enclosure construction strength on local penetration, and were performed in accordance with the program "HOLE" (Scientific and Research Institute of Concrete and Reinforced Concrete) and considering the SRICRC recommendations in 1983.

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Assessment of the answer

The question is only partly answered. It is stated that the reactor building can withstand a crash with a military aircraft. Nothing was said concerning the protection against other attacks or the decrease of the protection due to adverse aging effects.

Question Q39

Is a peer-review mission of the IAEA International Physical Protection Advisory Service (IPPAS) planned?

Written answer by the Ukrainian side

The last IPPAS missions were conducted in Ukraine during 2000-2002. At present, such missions are not planned.

Assessment of the answer

The question was answered.

Preliminary recommendation PR16

The EIA documents 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.

Written answer by the Ukrainian side

The EIA is performed in accordance with the "Recommendations concerning content of materials on operational facilities environmental impact" and DBN A.2.2-1-2003 "Composition and content of environmental impact assessment (EIA) materials during design and construction of enterprises, building and constructions" and considering requirements of legislative, regulative and methodical documents. There are no such requirements in the DBN for the EIA development.

Assessment of the answer

According to the answer, the Ukrainian legislation regulating EIA procedures does not ask for this information. Furthermore, information on this topic was provided in the answer to question Q38. All in all, this recommendation can be omitted.

Preliminary recommendation PR17

In the light of the special situation in Ukraine, the effects of third parties (terrorist attacks or acts of sabotage of the plant) should be given high priority. Protection against cyber-attacks and the treat of insiders should be improved. The IAEA's International Physical Protection Advisory Service (IPPAS) should be used to improve the security.

Written answer by the Ukrainian side

The following organizational and technical measures are used to ensure the cybersecurity:

Regarding internal threats (insiders):

- restriction of physical access to premises with Informational and Control Systems (ICS) equipment and to ICS equipment itself;
- control of access to critically important ICS units by regular operational personnel;
- impossibility of additional physical connections to technological networks;

Regarding external threats:

- application of controlling software and hardware means, filtering and restriction of network traffic between ICS networks and corporate networks;
- absence of ICS connection to the Internet and other public networks;

- protection of workstations by means of authentication and authorization.

Assessment of the answer

The answer listed several cybersecurity protection measures. According to the NTI Index deficits in this area remain. The Ukrainian side also provide information concerning IPPAS in the answer to question Q39. All in all, the recommendation remains valid.

7.3 Conclusions and final recommendations

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

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

Information regarding the issue of terror attacks would be of great interest, considering the large consequences of potential attacks. This topic is of particular importance, because the reactor buildings of all units of the ZNPP are vulnerable against a deliberate crash of an airplane. The ZNPP ANSWERS (2021) confirmed that the units can only withstand a crash of a military aircraft (10 tons, 215 m/s).

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 29th out of 47 countries, which indicates a low protection level. It is recommended to invite the International Physical Protection Advisory Service (IPPAS) of the IAEA that assisted states, in strengthening their national nuclear security regimes, systems and measures. The last IPPAS mission took place 20 years ago; a new mission is not planned yet.

Final recommendation FR13

In the light of the special situation in Ukraine, the effects of third parties (terrorist attacks or acts of sabotage of the plant) should be given high priority. Protection against cyber-attacks and the treat of 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 Short summary of the expert statement

For ZNPP severe accidents scenarios including containment failure and containment bypass with releases considerably higher than assumed in the EIA documents were not analysed but cannot be excluded. 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.

The project flexRISK conducted an assessment of source terms and identified for ZNPP a possible source term for Cs-137 (51.05 PBq). This source term was determined in relation to the plant behaviour during a severe accident and the possible release.

The conclusion drawn in the EIA documents that there are no non-acceptable trans-boundary impacts cannot be considered sufficiently proven because such worst case scenarios have not been analysed. 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 exceed the threshold for agricultural intervention measures (e. g. earlier harvesting, closing of greenhouses). Therefore, Austria could be significantly affected by a severe accident at ZNPP.

8.2 Questions & preliminary recommendations, answers and assessment of the answers

Question Q40

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

Written answer by the Ukrainian side

Calculation of the radionuclides surface concentration is performed using the JRodos software. Input data are taken in accordance with the "Typical methodology on calculation of emission into containment and environment in case of accident at VVER-1000 reactor facility" MT-T.0.41.450-19.

According to the calculation the ground depositions shall amount:

- Cs-137 nuclide 10-100 Bq/m2.
- I-131 nuclide 1-10 Bq/m2.

Assessment of the answer

Results for Cs-137 and I-131 contamination data (Bq/m^2) for Austrian territory are given, they are below the levels triggering agricultural countermeasures in Austria. Nevertheless, as discussed above, the assessed accident is not necessarily the accident with maximum consequences.

Preliminary recommendation PR18

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

Written answer by the Ukrainian side

No comment was given by the Ukrainian side.

Assessment of the answer

The recommendation remains valid.

8.3 Conclusions and final recommendations

For ZNPP severe accidents scenarios including containment failure and containment bypass with releases considerably higher than assumed in the EIA documents were not analysed but cannot be excluded. 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 can be affected.

The project flexRISK conducted an assessment of source terms and identified for ZNPP a possible source term for Cs-137 (51.05 PBq). This source term was determined in relation to the plant behaviour during a severe accident and the possible release.

The conclusion drawn in the EIA documents that there are no non-acceptable trans-boundary impacts cannot be considered sufficiently proven because such worst case scenarios have not been analysed.

In the analysed scenario, the Ukrainian side provided results for possible contamination of Austrian territory below the levels for agricultural countermeasures (e. g. earlier harvesting, closing of greenhouses).

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 exceed the levels for such agricultural countermeasures Therefore, Austria could be significantly affected by a severe accident at ZNPP.

Final recommendation FR14

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

9 SUMMARY OF FINAL RECOMMENDATIONS

9.1 Procedure and alternatives

9.1.1 Final Recommendations:

Final recommendation FR1

The review of the Minister of Environment and Natural Resources of Ukraine should include the already issued operation extension licensed for ZNPP units 1-5 to ensure that the EIA results are taken into due account also for these earlier decisions. A timetable for this review should be provided.

Final recommendation FR2

Both the final EIA Protocol and the results of the following review of the Minister of Environment and Natural Resources of Ukraine should be made available; an English translation would be welcomed.

9.2 Spent fuel and radioactive waste

9.2.1 Final Recommendations:

Final recommendation FR3

It would be welcomed if the Ukrainian side provides information about the progress made with the interim storage and final disposal facilities for spent fuel and radioactive waste.

Final recommendation FR4

For the DSFSF, it is recommended to assess not only impacts of the most probable initiating event but also events which have a maximum negative impact regardless of their probability of occurrence. Furthermore, it should be clarified if the sealing of the containers could be damaged by a fire resulting from an aircraft's crash.

9.3 Long-term operation of reactor type

9.3.1 Final Recommendations:

Final recommendation FR5

It is recommended to implement all available design improvements of VVER-1000 reactor for the ZNPP in a timely manner.

Final recommendation FR6

It is recommended to undertake a comparison of the design and measures of the ZNPP with all requirements of WENRA RL F to identify further measures to improve the safety level.

9.4 Accident analysis

9.4.1 Final Recommendations:

Final recommendation FR7

It is recommended to use the WENRA Safety Objectives for new NPP to identify reasonably practicable safety improvements for the SUNPP. It is recommended to use the concept of practical elimination for this approach.

Final recommendation FR8

It is recommended to provide the source terms (radioactive releases) of all possible BDBAs including releases from the spent fuel pools calculated in the PSA 2.

9.5 Accidents due to external hazards

9.5.1 Final Recommendations:

Final recommendation FR9

It remains unclear whether all natural hazards relevant to the site were taken into account in the site safety analysis, as required by WENRA (2014; 2021) and further explained by WENRA (2015; 2020a). The team of experts recommends using the "Non-Exhaustive List of Natural Hazards" (WENRA 2015; 2020a) as a starting point to ensure that all site-specific hazards affecting ZNPP are taken into account.

Final recommendation FR10

It seems uncertain whether all hazard combinations were taken into account in the assessment of the site, as required by WENRA (2014; 2021) and IAEA (2021), and further explained by WENRA (2015; 2020a). The team of experts recommends using a hazard correlation diagram (e. g. DECKER & BRINKMAN 2017) as a starting point to ensure that all relevant combinations are taken into account.

Final recommendation FR11

The 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 identified for the site and use the derived parameters to develop adequate protection concepts.

Final recommendation FR12

The expert team recommends applying 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. According to WENRA requirements (WENRA 2014; 2021) and IAEA Safety Requirements (IAEA 2012; 2016), DEC analysis shall be undertaken with the purpose of further improving the safety of existing nuclear power plants and enhancing their capability to withstand events or conditions more challenging than those considered in the design basis.

9.6 Accidents with third parties' involvement

9.6.1 Final Recommendations:

Final recommendation FR13

In the light of the special situation in Ukraine, the effects of third parties (terrorist attacks or acts of sabotage of the plant) should be given high priority. Protection against cyber-attacks and the treat of 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

9.7.1 Final Recommendations:

Final recommendation FR14

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

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11 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
CERAWM	see CRME
CRME	State Specialized Enterprise Centralized Radioactive Waste Management Enterprise (also called CERAWM or CRWMP)
CRWMP	see CRME
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
DSFSF	Dry Spent Fuel Storage Facility
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 of the Earth (9.82ms^{-2})

I .... Earthquake intensity

HLW.................................... High level radioactive waste

I&C..................................... Instrumentation and Control

I-131 .... Iodine-131

IAEA .... International Atomic Energy Agency

ILW..................................... Intermediate level radioactive waste

INSC................................... Instrument for Nuclear Safety Cooperation

IPPAS .... International Physical Protection Advisory Service

IVMR .... In-Vessel Melt Retention

IVR .... In-Vessel Retention

LLW.................................... Low level radioactive waste

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

MSK .... Medvedev-Sponheur-Karnik scale of earthquake intensity

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)

PBq .... PetaBecquerel

PGA.................................... Peak Ground Acceleration

PSA .... Probabilistic Safety Assessment

PSHA .... Probabilistic Seismic Hazard Assessment

PSR .... Preliminary Safety Report

PSR .... Periodic Safety Review

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)

SSC .... Structure, Systems and Components

SSE.................................... Safe Shutdown Event

SSE “CERAWM” .... State specialized enterprise “Central enterprise on radioactive waste handling”

SUNPP............................... South Ukraine NPP

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

ZNPP .... Zaphorishshya NPP

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