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NPP South Ukraine

Lifetime Extension EIA

Final Expert Statement

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

pulswerk
Das Beratungsunternehmen des
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NPP SOUTH UKRAINE LIFETIME-EXTENSION ENVIRONMENTAL IMPACT ASSESSMENT

Final Expert Statement

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SUMMARY

The Ukrainian nuclear power plant South Ukraine (SUNPP) is located at the Southern Bug River in the Mykolaiv province. At the South Ukraine site, three VVER-1000 reactors are in operation. The reactors were connected to the grid between 1982 and 1989.

The NPP is owned by the State Enterprise "National Nuclear Energy Generating Company Energoatom" (SE NNEGC), in short Energoatom. SE SUNPP is a separate entity of Energoatom.

For the lifetime extension of SUNPP, 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. (SUNPP 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

The EIA documents that were submitted to Austria were from 2015 and therefore did not reflect the development of the last years and they 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 has not been the case here because not all EIA documents were provided; the public of Ukraine received more documents. No updated EIA documents or additional EIA documents have been delivered during consultations.

The licenses for the lifetime extensions for SUNPP 1-3 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). The answers provided during consultations did not clarify if the envisaged review of the results of the trans-boundary EIA undertaken by the responsible Ukrainian Ministry of Envi-

ronment and Natural Resources will also be reflected in the already issued licenses. Moreover, a timetable for completing the EIA procedure and undertaking the review should be provided.

The maximum lifetime extension planned for the SUNPP units has not been given.

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

Spent fuel and radioactive waste

Information on the volumes of radioactive waste that results from the life-time extension was not provided in sufficient detail, furthermore it cannot be compared to the available interim and final storage capacities due to missing information.

Starting from 2021, spent fuel is no longer shipped to Russia for temporary storage and reprocessing, because the dry interim storage CSFSF in Chernobyl has started operation. It has to be verified if the capacity of the CSFSF is sufficient for the spent fuel from SUNPP's lifetime extension, taking into account that it will be used for all Ukrainian NPP except ZNPP and its units' lifetime extensions.

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 32-, 35- and 39-years old structures, systems and components is a safety issue for the SUNPP units 1-3, it is not addressed in the EIA documents. A comprehensive ageing management program (AMP) is necessary to limit ageing-related failures at least to a certain degree. However, no information about an AMP is provided in the EIA documents. The SUNPP ANSWERS (2021) provide some general information. This document refers to the evaluation of the ageing of structures, systems and components (safety factor (SF) 4) as part of the last Periodic Safety Review for units 1 to 3 which showed that safe operation is possible until at least the end of 2023, 2025 and February 2030, respectively.

It has to be noted that the IAEA PRE-SALTO Mission for SUNPP 3 in 2018, however, found that the current safety analysis report and the periodic safety review are not sufficiently comprehensive to demonstrate the safety for the Long Term Operation (LTO) period.

Also, 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. According to SNRIU (2021a), the National Action Plan to address the deficiencies identified in the TPR is scheduled for December 2024.

Although conceptual ageing is also an issue for the SUNPP, 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 EU Stress Tests had revealed as early as 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 under way in the framework of the ongoing Comprehensive (Integrated) Safety Improvement Program (C(I)SIP). The completion of the program was postponed several times. In 2021 still a high number of measures are awaiting implementation. 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. Although safety relevant issues were not completely solved, the State Nuclear Regulatory Inspectorate of Ukraine (SNRIU) granted the 10-year lifetime extensions permit for three units SUNPP in 2013, 2015 and 2020, respectively.

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 SUNPP.

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.

According to the SUNPP ANSWERS (2021), BDBA and Severe Accident scenarios were not analysed as part of the EIA procedure. Calculations within the implementation of emergency measures to minimize or prevent accidental releases were performed and the results used in the EIA documents. However, the assumed accident scenario and the source terms are not mentioned.

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, severe accidents which can occur at the VVER-1000 reactor type; this fact is confirmed by the SUNPP ANSWERS (2021).

Thus, 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 (PSA 2). Even though the calculated probability of severe accidents with a large release is low, the consequences caused by these accidents are potentially enormous. 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.

The document SUNPP ANSWERS (2021) mentioned that several accident scenarios can lead to a containment failure and these accident scenarios could be prevented with the post-Fukushima improvements. However, these measures already chosen in the stress tests to address the existing weaknesses are not fully implemented yet.

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 unit 3 of the SUNPP yet. Furthermore, there is no system for cooling and stabilizing a molten core for the SUNPP 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 information provided leads to the conclusion that accident scenarios can develop into a severe accident and threaten the integrity of the containment and result in large releases with a high probability. The values for the core damage frequencies and large early release frequencies show that about 39 % (unit 1), 35 % (unit 2) and 14 % (unit 3) of the core damage accidents result in large early releases.

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 another example for the gap between the Ukrainian and the EU safety standards and requirements. There is a constant delay of the implementation of safety upgrading measures in Ukraine.

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 SUNPP.

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 the SUNPP.

Accidents due to external hazards

The Ukrainian side's written answers added important information on how natural hazards were considered in safety analyses for SUNPP. The expert team concluded that hazard analysis started with a list of hazards and had included a screening process. Although it seems that all natural hazards relevant to the site were taken into account, this is apparently not the case for hazard combinations. The expert team therefore recommends identifying relevant combinations of hazards. The relatively high contribution of internal flooding to the CDF (stated with 1,25×E-05 per year) requires that special attention is given to the combinations of earthquake-induced internal flooding and earthquake-induced internal fire.

According to the written information received, updates of the assessment of the seismic safety of the SUNPP after the European Stress Tests were completed by upgrading the seismic design basis to PGA=0.12g. Further evaluation in the framework of a Seismic PSA is still pending.

Whether the LTO project included an analysis of the Design Extension Conditions (DEC) for natural hazards remained unclear. WENRA requires that DEC analysis shall be undertaken regularly 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 recommends using the LTO process for comprehensive DEC analyses with respect to external hazards to achieve higher levels of safety with respect to natural hazards.

In sum, the EIA documents and the written replies do not allow concluding that the 3 units of SUNPP are adequately protected from the effects of natural hazards. Austria can potentially 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 SUNPP. Nevertheless, they are not discussed in the EIA documents. In comparable EIA documents such events were addressed to some extent.

Even if the current physical protection system that was increased significantly and 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. This topic is of particular importance because the reactor buildings of all SUNPP units are vulnerable against airplane crashes. The SUNPP ANSWERS (2021) confirmed that the NPP is not designed to withstand the crash of a commercial airliner, but a military jet.

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 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 mission of the International Physical Protection Advisory Service (IPPAS) of the IAEA was performed about 20 years ago. A new mission is not envisaged yet.

Trans-boundary impacts

For SUNPP 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. 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 SUNPP.

ZUSAMMENFASSUNG

Das ukrainische Kernkraftwerk Südukraine (SUNPP) liegt am Südlichen Bug in der Oblast (Verwaltungseinheit) Mykolajiw. An diesem Kernkraftwerksstandort sind drei WWER-1000 Reaktoren in Betrieb. Die Reaktoren gingen zwischen 1982 und 1989 ans Netz.

Das KKW steht im Eigentum des Staatsunternehmens "National Nuclear Energy Generating Company Energoatom" (SE NNEGC), kurz Energoatom. SE SUNPP wiederum ist eine eigene Einheit von Energoatom.

Die ukrainische Seite führt eine Umweltverträglichkeitsprüfung im Rahmen der Espoo-Konvention für die Lebensdauerverlängerung des KKW Südukraine (SUNPP) 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 der Fachstellungnahme zu den übermittelten UVP-Dokumenten (UMWELTBUNDESAMT 2021). In dieser Fachstellungnahme wurden Fragen und vorläufige Empfehlungen formuliert.

Im September 2021 beantwortete die ukrainische Seite in schriftlichen Antworten diese Fragen. (SUNPP ANSWERS 2021) Das vorliegende abschließende Fachgutachten evaluiert diese 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

Die UVP-Dokumente, die Österreich übermittelt wurden, stammen aus dem Jahre 2015 und berücksichtigen daher die Entwicklungen der letzten Jahre nicht. Sie bedürfen einer 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 hatte. Während der Konsultation wurden keine zusätzlichen UVP-Dokumente übermittelt.

Die Genehmigungen für die Lebensdauerverlängerungen von SUNPP 1-3 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 CONVENTION 1991, Art. 2.3)

Die Antworten aus der Konsultation lieferten keine Klarstellung durch die ukrainische Seite, ob und auf welche Weise die Ergebnisse dieser grenzüberschreitenden UVP durch das zuständige Umweltministerium der Ukraine in Hinblick auf die bereits erteilten Genehmigungen berücksichtigt werden. Zusätzlich sollte ein Zeitplan für die Fertigstellung des UVP-Verfahrens und die Durchführung der Überprüfung zur Verfügung gestellt werden.

Die maximale geplante Lebensdauer für die Blöcke des SUNPP wurde nicht angeführt.

Darüber hinaus fehlt eine Bewertung von vernünftigerweise durchführbaren Alternativen und der Null-Variante.

Abgebrannte Brennelemente und radioaktiver Abfall

Informationen über die Mengen an radioaktivem Abfall, die während der Lebensdauerverlängerung des KKW Südukraine erzeugt werden, wurden nicht in ausreichendem Detaillierungsgrad übermittelt, und daher ist es unmöglich, diese den verfügbaren Kapazitäten für Zwischen- und Endlagerung gegenüberzustellen.

Seit 2021 werden die abgebrannten Brennelemente zur zwischenzeitlichen Lagerung und Wiederaufbereitung nicht mehr nach Russland transportiert, da der Betrieb im Trocken-Zwischenlager CSFSF in Tschernobyl aufgenommen wurde. Es ist zu überprüfen, ob die Kapazität des CSFSF ausreichend ist, um die abgebrannten Brennelemente aus der Lebensdauerverlängerung von SUNPP zu lagern, da dieses Zwischenlager für die Lagerung von abgebrannten Brennelementen aller ukrainischer Kernkraftwerke, außer Zaporoshe, und der Lebensdauerverlängerungen dieser Reaktoren verwendet werden wird.

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 Alterung der 32, 35 und 39 Jahre alten Strukturen, Systeme und Komponenten ein Sicherheitsproblem für die Blöcke 1-3 des KKW Südukraine darstellt, wird sie in den UVP-Unterlagen nicht angesprochen. Ein umfassendes Programm für das Alterungsmanagement (AMP) ist nötig, um das alterungsbedingte Versagen zumindest in einem gewissen Umfang zu beschränken. Allerdings enthalten die UVP-Unterlagen keine Informationen zum AMP. Im Dokument SUNPP ANSWERS (2021) fand sich allgemeine Information. Es erläuterte die Evaluierung der Alterung von Strukturen, Systemen und Komponenten (Safety Factor (SF) 4), die in der letzten Periodischen Sicherheitsüberprüfung (PSÜ) für die Blöcke 1 bis 3 durchgeführt wurde und zeigte, dass ein sicherer Betrieb jeweils bis mindestens Ende 2023, 2025 und Februar 2030 möglich ist.

Zu beachten ist allerdings, dass die IAEO PRE-SALTO Mission für SUNPP 3 im Jahre 2018 zu dem Schluss kam, dass die aktuellen Sicherheitsanalysen und die Periodische Sicherheitsprüfung nicht umfassend genug waren, um den Sicherheitsnachweis für den Langzeitbetrieb (LTO) zu erbringen.

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 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. Laut SNRIU (2021a) sollte der Nationale Aktionsplan die im TPR identifizierten Schwachstellen bis Dezember 2024 gelöst haben.

Obwohl die konzeptuelle Alterung für SUNPP 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.

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. Im Jahre 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. Obwohl die sicherheitsrelevanten Probleme nicht vollständig gelöst waren, erteilte die Nuklearaufsichtsbehörde (SNRIU) die Lebensdauerverlängerungen um 10 Jahre für die drei Blöcke von SUNPP jeweils in den Jahren 2013, 2015 und 2020.

SNRIU ist Mitglied in 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 2019 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 SUNPP nicht angewandt.

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 noch Quellterme werden angeführt.

Laut SUNPP ANSWERS (2021) wurden Szenarien von BDBA und schweren Unfällen nicht im Rahmen des UVP-Verfahrens analysiert. Berechnungen zur Implementierung von Notfallmaßnahmen zwecks Minimierung oder Verhinderung von unfallbedingten Freisetzungen wurden durchgeführt und die Ergebnisse dieser Berechnungen in den UVP-Unterlagen verwendet. Allerdings werden die verwendeten Unfallszenarien oder Quellterme nicht angeführt.

Für die Einschätzung von Konsequenzen der BDBA ist es notwendig, eine Reihe von schweren Unfällen zu analysieren, einschließlich solcher mit Containment-versagen und Containment-Bypass, schwere Unfälle, die beim WWER-1000 Reaktortyp auftreten können; diese Tatsache wurden von SUNPP ANSWERS (2021) bestätigt.

Daher sollte für die Unfallanalyse in der UVP-Dokumentation ein möglicher Quellterm verwendet werden, der von der Berechnung der aktuellen Probabilistischen Sicherheitsanalyse PSA Level 2 (PSA 2) abgeleitet wird. Wenn auch die berechneten Wahrscheinlichkeiten für schwere Unfälle mit großen Freisetzungen gering sind, so sind die Konsequenzen dieser Unfälle potenziell sehr groß. Der Schlussfolgerung von SNRIU, wonach die Blöcke sicher und mit einem akzeptablen Risiko betrieben werden, kann auf der Grundlage der vorliegenden Informationen nicht zugestimmt werden.

Laut SUNPP ANSWERS (2021) können einige Unfallszenarien zu Containment-versagen führen. Auch wird festgehalten, dass die Unfallszenarien durch die Umsetzung der Post-Fukushima-Sicherheitsmaßnahmen verhindert werden könnten. Dennoch wurden diese bereits während der Stresstests ausgewählten Maßnahmen zur Behebung der bestehenden Schwachpunkte noch nicht vollständig umgesetzt.

Dem Dokument ENSREG (2015) zufolge ist der Erhalt der Containment-Integrität 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 in Block 3 des SUNPP noch nicht installiert wurde. Darüber hinaus verfügt SUNPP 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 von 2015 auf später verschoben.

Aus den zur Verfügung gestellten Dokumenten ist ersichtlich, dass auch weiterhin eine hohe Wahrscheinlichkeit besteht, dass Unfallszenarien sich in schwere Unfälle weiterentwickeln werden, die die Containmentintegrität gefährden und in eine große Freisetzung münden. Die Werte für die Kernschadenshäufigkeit und hohe frühe Freisetzungen zeigen, dass etwa 39 % (Block 1), 35 % (Block 2) und 14 % (Block 3) der Kernschadensunfälle zu hohen Freisetzungen führen.

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 von Nachrüstmaßnahmen für die nukleare Sicherheit erfährt in der Ukraine eine fortdauernde Verzögerung.

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 bestehen, auf welches sich Europa geeinigt hat, und welches bei SUNPP vorliegt.

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 Wahrscheinlichkeit für einen bestimmten Unfallablauf sehr gering ist, so sollte jedes zusätzliche vernünftigerweise praktikable Auslegungsmerkmal, jede Betriebsmaßnahme oder Maßnahme im Unfallmanagement im SNUPP zur weiteren Senkung des Risikos umgesetzt werden.

Unfälle durch externe Gefahren

Die schriftlichen Antworten der ukrainischen Seite brachten wichtige Information dazu, wie Naturgefahren in den Sicherheitsanalysen für SUNPP berücksichtigt wurden. Das ExpertInnenteam geht davon aus, dass die Gefahrenanalyse mit einer Auflistung der Gefährdungen begann und einen Screening-Prozess umfasst. Es scheinen alle natürlichen Gefährdungen mit Relevanz für den Standort erfasst zu sein, jedoch nicht alle Kombinationen der Gefährdungen. Das ExpertInnenteam empfiehlt daher, auch die relevanten Kombinationen der Gefährdungen zu identifizieren. Der relativ hohe Beitrag aus der internen Flutung zur Kernschadenshäufigkeit CDF (mit 1,25×E-05 pro Jahr) erfordert, dass der Kombination aus Erdbeben-bedingter interner Flutung und Erdbeben-bedingtem internem Brand besondere Beachtung findet.

Laut den schriftlichen Antworten wurden die Aktualisierung der seismischen Sicherheit des SUNPP nach den EU Stresstests durch die Erhöhung der seismischen Auslegung auf PGA=0.12g erzielt. Weitere Auswertungen im Rahmen der seismischen PSA sind noch in Vorbereitung.

Es ist unklar, ob im LTO-Projekt die WENRA-Verfahren zur Analyse der Design Extension Conditions (DEC) für natürliche Gefährdungen angewendet wurden. WENRA sieht die regelmäßige Durchführung einer DEC-Analyse zwecks weiterer Verbesserung der Sicherheit bei bestehenden KKW vor, sowie auch zur Verbesserung deren Widerstandsfähigkeit gegenüber Ereignissen und Bedingungen, die die Auslegung überschreiten. Das ExpertInnenteam empfiehlt die Nutzung des LTO-Prozesses für eine umfassende Analyse der DEC für externe Gefährdungen, um in diesem Bereich höhere Sicherheitsniveaus zu erreichen.

Zusammenfassend ermöglichen die UVP-Dokumente und schriftlichen Antworten nicht die Schlussfolgerung, dass die drei Blöcke von SUNPP adäquat gegen Naturgefahren geschützt wären. Österreich kann durch die Folgen von Unfällen, die aus Naturgefahren entstehen können, betroffen sein.

Unfälle mit Beteiligung Dritter

Terrorangriffe und Sabotageakte können schwere Folgen für Nuklearanlagen haben und schwere Unfälle auslösen – auch beim SUNPP. Dennoch werden diese in den UVP-Dokumenten 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. Dieses Thema ist vor allem für die Reaktorgebäude von SUNPP wichtig, da diese gegenüber Flugzeugabstürzen vulnerabel sind. Die SUNPP ANSWERS (2021) bestätigen, dass das KKW nicht gegen den Absturz eines Verkehrsflugzeugs ausgelegt ist, sondern eines Militärflugzeugs.

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. Es wird empfohlen das International Physical Protection Advisory Service (IPPAS) der IAEO einzuladen, das Staaten bei der Stärkung ihrer nationalen Sicherungsregimes, Systeme und Maßnahmen unterstützt. Die letzte Mission des International Physical Protection Advisory Service (IPPAS) der IAEO fand vor etwa 20 Jahren statt. Eine neuerliche Mission ist noch nicht vorgesehen.

Grenzüberschreitende Auswirkungen

Für das KKW Südukraine 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. 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 KKW Südukraine signifikant betroffen sein.

1 INTRODUCTION

The Ukrainian nuclear power plant South Ukraine (SUNPP) is located at the Southern Bug River. The site is located near the NPP satellite city of Yuzhnoukrainsk in the Mykolaiv oblast, approximately 350 kilometres south of Kyiv. At the South Ukraine site, three VVER-1000 reactors are in operation. The reactors were connected to the grid between 1982 and 1989.

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

For the lifetime extension of SUNPP, 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. (SUNPP 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.

2 PROCEDURE AND ALTERNATIVES

2.1 Short summary of the expert statement

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 here because not all EIA documents were provided; the public of Ukraine received more documents.

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

The licenses for the lifetime extensions for SUNPP 1-3 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 is 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

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

Written answer by the Ukrainian side

According to NP 306.2.214-2017 “Requirements for Periodic Safety Review of NPP units” the lifetime is extended based on the results of PSR, which is performed in accordance with the Document 306.2.141-2008 “General Safety Provisions for NPPs” every 10 years. According to the current license the operation at power levels is allowed for Unit 1, until 02.12.2023, for Unit 2 until 31.12.2025, for Unit 3 until 10.02.2030. The decisions on further operation at power will be made based on the results of next periodic safety reviews. If justification of the NPP unit safety during LTO is impossible, the operating organization takes decision to carry out activities at the stage of the life cycle "decommissioning of the nuclear installation" in accordance with the General Provisions of NP 306.2.141-2008.

Assessment of the answer

The question has not been answered. It has been explained that further lifetime extensions will be depending on the PSA results, but no maximum extension period has been given.

Question Q2

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

Further steps in the licensing procedure have not been explained sufficiently; units 1-3 were granted the operation extension before completion of the transboundary EIA. It should be clarified whether the implementation of the identified upgrades will also be monitored for the SUNPP units 1-3 though they received their operation extension licenses earlier.

Question Q3

How will the results of the EIA be taken into account? Will the decisions on lifetime extension of SUNPP 1-3 be revised according to the EIA results?

Written answer by the Ukrainian side

The EIA underwent the state ecology expertise of the Ministry of Ecology getting the positive results. There are no comments related to the EIA materials. Therefore, there are no grounds for reviewing the decisions.

Assessment of the answer

The answer on this question is contradicting answer on Q2.

It has to be noted that as of today, Ukraine remains in non-compliance with the Espoo Convention. This concerns especially the fact that final decisions have already been made on life-time extension of units 1-3 before concluding the transboundary consultations. 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 1-3, 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

No comment was given by the Ukrainian side.

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

No comment was given by the Ukrainian side.

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

No comment was given by the Ukrainian side.

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

No comment was given by the Ukrainian side.

2.3 Conclusions and final recommendations

The maximum lifetime extension planned for the SUNPP units has not been given.

The EIA documents that were submitted to Austria were from 2015 and therefore did not reflect the development of the last years and they 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 has not been the case here because not all EIA documents were provided; the public of Ukraine received more documents. No updated EIA documents or additional EIA documents have been delivered during consultations.

The licenses for the lifetime extensions for SUNPP 1-3 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) 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.

The assessment of reasonable alternatives and the no-action alternative is also 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 SUNPP units 1-3 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 SUNPP 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 shipped to Russia for temporary storage and reprocessing. In 2021, the dry interim storage CSFSF in Chernobyl has started operation. It is not clear how much of the spent fuel from the lifetime extension of SUNPP will be shipped to Russia and how much will be stored in the CSFSF. This has to be verified. Also it has to be verified if the capacity of the CSFSF is sufficient for the spent fuel from SUNPP's lifetime extension, taking into account that it will be used for all Ukrainian NPP except ZNPP and their lifetime extensions.

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 Q4

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

At present, the strategic documents on the energy complex development in Ukraine do not provide the establishment of enterprises for the spent nuclear fuel reprocessing.

Assessment of the answer

The question has been answered.

Question Q5

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 Q6

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

Copper or copper 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 Q7

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

Written answer by the Ukrainian side

After the NPP unit's lifetime extension, the amounts and activities of LILW are expected to be at the level of average values for the previous years.

Assessment of the answer

Radioactive waste is a very important impact of NPP operation and should be described in an EIA Report. For an EIA it would be adequate to express the volume of different types of radioactive waste generated during life-time extension in specific numbers. Also data on activity would be welcomed.

Question Q8

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

Written answer by the Ukrainian side

The storage capacity is sufficient for the placement of LILW along the lifetime of South-Ukraine NPP units with account taken of their lifetime extension.

Assessment of the answer

As it is not clear how long the maximum lifetime extension might be, correct information on the available storage capacity per years of lifetime available would be welcome.

Question Q9

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

Written answer by the Ukrainian side

SUNPP treatment facilities are in satisfactory condition and serviceable.

Assessment of the answer

The question concerning the condition of existing facilities and storages is answered.

Question Q10

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

About radioactive waste (RW)

According to the radioactive waste management Strategy in Ukraine, all NPP waste must be transferred to the state operator – state specialized enterprise «Central enterprise for radioactive waste management», which has already built the first stage of the Vector complex (TRV-1, TRV-2) in the Chernobyl Exclusion Zone.

It is expected that the transfer of the first batches of radwaste to existing NPPs to the Vector complex will begin in late 2021- early 2022. By 2030, the 2nd stage storage facilities of this complex should be put into operation. The volume of storage facilities of the Vector complex will satisfy the needs of all power units of Ukrainian NPPs.

Assessment of the answer

The question has been answered for radioactive waste.

It has to be verified if the capacity of the CSFSF is sufficient for the spent fuel from SUNPP's lifetime extension, taking into account that it will be used for all Ukrainian NPP except ZNPP units and their lifetime extensions.

Question Q11

How much spent fuel from SUNPP will be sent to Russia for reprocessing in total?

Written answer by the Ukrainian side

NNEGC "Energoatom" doesn't plan to send the spent fuel to Russia starting from 2021 because of putting into operation of Centralized spent fuel storage facility.

Assessment of the answer

The question has been answered.

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

No comment was given by the Ukrainian side.

Assessment of the answer

The recommendation remains valid.

3.3 Conclusions and final recommendations

Information on the volumes of radioactive waste that results from the life-time extension was not provided in sufficient detail, furthermore it cannot be compared to the available capacities for interim and also final storage due to missing information on those.

Starting from 2021, spent fuel is no longer shipped to Russia for temporary storage and reprocessing, because the dry interim storage CSFSF in Chernobyl has started operation. It has to be verified if the capacity of the CSFSF is sufficient for the spent fuel from SUNPP’s lifetime extension, taking into account that it will be used for all Ukrainian NPP except ZNPP and its units' lifetime extensions.

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 on its interim storage and final disposal facilities for spent fuel and radioactive waste.

4 LONG-TERM OPERATION OF REACTOR TYPE

4.1 Short summary of the expert statement

Although ageing of the 32-, 35- and 39-years old structures, systems and components is a safety issue for the SUNPP unit 1-3, it was not addressed in the 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, no information about an AMP was provided in the EIA documents.

The IAEO PRE-SALTO Mission for SUNPP 3 in 2018 found that the current safety analysis report and the periodic safety review (PSR) are not sufficiently comprehensive for demonstration of safety for Long Term Operation (LTO) period.

Ukraine participated in the Topical Peer Review (TPR) "Ageing Management" under 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 that should be reached to ensure an 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 reactor pressure vessels (RPVs) should be discussed. The standard surveillance programme for some of the Ukrainian reactors is good but it is not sufficient. Comprehensive inspections of all RPVs are necessary.

Although conceptual ageing is also an issue for the SUNPP, the EIA documents does not deal with any of safety issues of the VVER-1000 reactors. NPP designs 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 neither provide a description of the safety-relevant systems nor information about the capacities, redundancies and physical separation. The old VVER reactor type 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 a melt-through can occur within approx. 48 hours. The containment atmosphere will then blow down into parts of the reactor building that are not leak-tight and resulting in high releases. Another weakness is the protection against external hazard. Concerning airplane crashes, the reactor buildings are designed to withstand accidents of small airplanes only.

Although safety relevant issues were not completely solved, the State Nuclear Regulatory Inspectorate of Ukraine (SNRIU) granted 10-year lifetime extensions for three units SUNPP in 2013, 2015 and 2020, respectively. 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. Scheduled completion is now 2023. As of 31/03/2021 still a lot of measures have to be implemented (2, 8 and 22 respectively). It is noteworthy that the total number of measures for unit 1 and 2 is significantly lower than for unit 3.

A significant gap remains between the required safety standard and the actual safety level of the SUNPP units. 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.

SNRIU is a member of the Western European Nuclear Regulators Association's (WENRA). In 2014, WENRA published a revised version of the Safety Reference Levels (RLs) for existing reactors which had been developed by the Reactor Harmonisation Working Group (RHWG). The objective of the revision was to take into account lessons learned from the TEPCO Fukushima Daiichi accident. A major update of the RLs was the revision of Issue F "Design Extension of Existing Reactors" introducing the concept of Design Extension Conditions (DEC). However, it has to be noted that Ukraine has not implemented 88 RL of the 342 until January 1, 2019. (UMWELTBUNDESAMT 2021)

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

Question Q12

What is the status of the LTO for the unit 3 of the South Ukraine NPP?

Written answer by the Ukrainian side

After the safety reassessment of Unit 3, the State Nuclear Regulatory Inspectorate of Ukraine issued a licence # 000064 for the right to operate. Validity of the licence is until the issuance of a licence to carry out activities at the stage of the life cycle “decommissioning of a nuclear installation” of SUNPP Unit 3.

Assessment of the answer

The question was answered.

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) carried out in line with Article 8e of Directive 2014/87/EURATOM?

Written answer by the Ukrainian side

In order to improve AMP, a periodic assessment of its efficiency is carried out, as evidenced by the closed cycle of a systematic approach applied to ageing management. Ageing management programmes are periodically improved in accordance with the level of science and technology development and with account taken of the operational experience and ageing management results.

The efficiency of the ageing management programmes is assessed based upon the results of meeting 9 efficiency attributes presented in Annex G of the utility standard SOU NAEK 141: 2017.

The assessment of the AMPs efficiency is performed at least once a year.

Assessment of the answer

Although interesting information was provided, the question cannot be considered 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 SUNPP unit 1 to 3? Are there any differences between the units?

Written answer by the Ukrainian side

DS SU NPP is constantly assessing ageing management activities, considering the following aspects:

- the policy of the operating organization on ageing management, arrangement of ageing management and resources for its implementation;
- methods and criteria for identifying the systems and components to be included into the list of critical components;
- lists of components to be controlled by ageing;
- information that provides support for ageing management;
- research and information on degradation mechanisms that can potentially affect the design functions of systems and components important to safety. Investigation of the dominant mechanisms of degradation as a result of ageing.

The following information is used as the indicators of ageing management efficiency:

- forced outage of the power unit due to the failures of components associated with their ageing;
- change in the cost of scheduled repairs and maintenance of components and structures, as well as their corrective maintenance;
- deviations of the operating parameters values of the components and structures of the power unit, covered by the ageing management activities from the allowable values of the operational documentation;
- change in the frequency of repairs and maintenance, adopted as a result of ageing management activities, in relation to the frequency specified initially in the operational and design documentation.

The efficiency indicator of ageing management is determined by the following formula:

$$K_{ус} = \left(1 - \frac{n_{ст}}{H_{от}}\right) \times 100$$

where nст - the number of failures due to the ageing of equipment during the last four quarters, including the reporting one (direct causes are taken);

Нот - the total number of failures during the last four quarters, including the reporting one.

Ultimately, data are presented on the failures or no failures due to the equipment ageing during each year, improvement or deterioration of the ageing management efficiency indicator at each NPP unit.

The ageing management efficiency indicator as the main indicator (the most forward-looking one) shows that for the period from 2007 to 2020, shutdowns of the power units related to the failures due to the equipment ageing were not registered. This is confirmed by the information contained in the annual reports on the assessment of the current level of the operational safety of SU NPP units #1,2,3.

Thus, one can state the fact that the number of failures due to ageing during operation of the power unit components has not increased. Forced outages of the power unit due to the failures of components associated with their ageing were not registered.

As a result of the analysis of information on the ageing management efficiency, we can conclude the following:

- no failures of the components included into AMP, due to ageing, indicates that there is efficient ageing management in place at power units №1-3;
- the existing maintenance system for ageing management of the components included into AMP is efficient as since the implementation of the ageing management programme no failures of critical components have been detected due to poor maintenance system;

- during the observation period, the efficiency of ageing management activities is currently considered satisfactory.

There are no differences between the power units in terms of specific AMP results.

Assessment of the answer

The question was answered. It is explained that the calculated efficiency indicator of ageing management did not increase between 2007 and 2020.

Question Q15

What are the results of Safety Factors (SF) 4 (structures, systems and components ageing) of the last periodic safety review for unit 1 to 3? Are there any differences between the units?

Written answer by the Ukrainian side

During the periodic safety review on SF-4 "Ageing of structures, systems and components" it was confirmed that at the time of the assessment of SU NPP units #1, #2, #3 AMPs for systems and components important to safety exist and function efficiently that ensures the equipment operability and safety functions fulfilment of the power units at the required level during operation of power units beyond the design period.

Taking into the account the obtained results on the prediction of the technical condition of the critical components of the power units, the availability of an efficient ageing management system for SU NPP units 1-3 components and the implementation of the measures developed as a result of safety reassessment, safe operation of equipment and facilities is possible:

- SU NPP unit 1 at least until the end of 2023;
- SU NPP unit 2 at least until the end of 2025;
- SU NPP unit 3 at least until February 10, 2030.

As for the results of Safety Factors (SF) 4 there are no differences between the units (except for the terms of possible safe operation of equipment and facilities).

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 for units 1 to 3 proved that safe operation is possible until at least the end of 2023, 2025 and February 2030, respectively.

Question Q16

What are the results of the embrittlement of the reactor pressure vessels (RPVs) for the units 1 to 3? Are there any differences between the units?

Written answer by the Ukrainian side

Assessment of brittle fracture resistance of the power unit's reactor vessels (RV) can be performed according to the methodology allowed for use by the State Nuclear Regulatory Inspectorate of Ukraine. SNRIU allowed to use "Methodology for the Calculation of Brittle Fracture Resistance of VVER Reactor Vessels during Operation", VERLIFE ver.2003 and domestic methodology MT-D.0.03.391-09 (that is currently replaced by the document SOU NAEK 177: 2019 "Engineering, scientific and technical support. Methodology on the assessment of brittle fracture of VVER reactor vessels").

Power Unit 1

Assessment of brittle fracture resistance of Unit 1 reactor vessel was performed in accordance with the recommendations of the VERLIFE methodology ver.2003 (Unified Procedure for Lifetime Assessment of Components and Piping in VVER NPPs "VERLIFE", ver. 2003).

Assessment of the critical brittle temperature point is performed only up to the values of the fluence accumulated by the witness samples. The lowest fluence is accumulated by the weld metal # 3 - 33.3×10^{22} neutr / m^2 (taking into account the increase in fluence by 10% - 36.6×10^{22} neutr / m^2). The critical temperature point of the weld metal # 3 does not exceed the maximum allowable value of $T^a{}_K$= 71°C, obtained on the basis of calculations for brittle fracture resistance. In view of the above, it is concluded that the safe service life of the reactor vessel is justified up to 40 years of operation (i.e. up to a fluence of 36.6×10^{22} neutrons/m^2).

For Unit 1 RV the lifetime of safe operation is justified up to 40 years of operation on the basis of the existing results of witness samples program implementation, taking into account the preservation of the existing core loading pattern. After receiving the new data (during the implementation of single-tier container assemblies upgrading program), the results will be re-assessed in order to update the critical brittle temperature point and the possible lifetime of safe operation.

Power Unit 2

Assessment of brittle fracture resistance of Unit 2 RV was performed in accordance with the recommendations of "Methodology for assessing the strength and lifetime of VVER RVs during operation" MT-D .0.03.391-09.

Critical brittle temperature point T_K of SUNPP Unit 2 RV metal:

Structural component	**T_K, °C**	**Fluence, 10^{22}, m^{-2}**	**T_K, °C**	**Fluence, 10^{22}, m^{-2}**	**T_K, °C**	**Flu-ence, 10^{22}, m^{-2}**	**T_K, °C**	**Flu-ence, 10^{22}, m^{-2}**
	30 years		**40 years**		**50 years**		**60 years**	
Lower shell	33	30.3	38	40.6	42	50.9	45	61.1
Weld # 3	64	31.6	73	42.4	80	53.2	87	64
Weld # 4	43	26.4	51	35.7	57	44.9	63	54.2

The critical unit of SUNPP #2 RV is Weld # 3. For this component the minimum value of the allowable critical brittle temperature point is identified which is 78.3 ° C.

The conditions of brittle strength of SUNPP Unit 2 are fulfilled for the service life of at least 40 years. After reaching this service life, it is possible to extend it. For this purpose, before the next reassessment of SUNPP Unit 2 safety, there will be performed calculations on brittle fracture resistance using the properties of the materials in the irradiated state, corresponding to the service life of up to 40 years.

Power Unit 3

Assessment of brittle fracture resistance of Unit 3 RV was performed in accordance with the recommendations of "Methodology for assessing the strength and lifetime of VVER RVs during operation "MT-D .0.03.391-09.

As a result of the refined calculations the following values of T_{KA} were received:

- -weld #4 - 65.17°C;
- -the main metal of the upper shell - 73.00°C;
- -weld #3 - 62.36°C.

and the margin of brittle strength ΔT_{KA} [°C] depending on the service life:

Area	**30 years**	**40 years**	**50 years**	**60 years**
Weld # 4	32.05	27.06	22.79	19.03
main metal of the upper shell	48.31	46.9	45.73	44.7
Weld # 3	42.49	37.54	33.28	29.52

Calculations of brittle strength under nonlinear fracture mechanics show that the area that limits the RV lifetime is Weld #4.

For the cylindrical and nozzle part of SUNPP Unit 3 RV the conditions of brittle fracture resistance are fulfilled for the service life of at least 40 years.

Assessment of the answer

The question was answered. For the reactor pressure vessels of units 1-3 of SUNPP, the conditions of brittle fracture resistance are met for the service life of 40 years.

Question Q17

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

Written answer by the Ukrainian side

The analysis of compliance of design technical solutions implemented at SUNPP with the requirements of normative technical documentation on safety is performed in accordance with regulatory documents on nuclear and radiation safety that are in force in Ukraine. Regulatory documents are based on the requirements of Ukrainian legislation, take into account the recommendations of the International Atomic Energy Agency and the International Atomic Energy Advisory Group for nuclear installation safety, as well as domestic and foreign safe operational experience of NPPs.

Grouping by areas and ranking of NTD deviations by categories depending on safety impact is performed in accordance with the international safety assessment practice stated in IAEA document IAEA-EBP-WWER-14 “Safety issues and their ranking for WWER-1000 "small series".

Assessment of the answer

The question was answered.

Question Q18

Why is the number of measures of the C(I)SIP for SUNPP unit 3 is higher than for SUNPP units 1 and 2?

Written answer by the Ukrainian side

In order to fulfil the provisions of the Convention on Nuclear Safety and to improve the safety of the Ukrainian NPPs units, the Concept of Safety Improvement (CSI) of Operating NPP units was developed and put into effect in 2005.

In 2010, after the expiry of the CSI, Comprehensive (Integrated) Safety Improvement Program (C(I)SIP) for Ukrainian NPP units was developed with the aim of further implementation of safety improvement activities within the framework of the implementation of the long-term state strategy for improving safety of NPP units by the State Enterprise NNEGC “Energoatom”. Activities that were not completed under the CSI were transferred to C(I)SIP.

The difference in the number of activities in C(I)SIP for SUNPP units 1& 2 of ("small" series) and SUNPP unit 3 of (series unit) is stipulated by the following:

- within CSI, first of all, actions were implemented for the power units that were put into operation earlier (power units 1&2) and, accordingly, more actions were implemented for these power units than for power unit 3;
- design difference, as the power unit were designed by different design organizations.

Assessment of the answer

The question was answered.

Question Q19

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

Written answer by the Ukrainian side

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

Question Q20

When will be reviewed whether the RL will be meet for the SUNPP?

Written answer by the Ukrainian side

After the implementation of the requirements of WENRA RL at the national legislation.

Assessment of the answer

The question was answered, however, without stating when the implementation of the WENRA RL into Ukrainian legislation will take place.

Question Q21

Which WENRA Documents will be mandatory for lifetime extensions?

Written answer by the Ukrainian side

In organization of works on lifetime extension and long-term operation SS SUNPP follows the national codes and standards as well as the branch documents of the 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 directly answered but clarified that only IAEA documents are used.

Preliminary recommendation PR6

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

Written answer by the Ukrainian side

No comment was given by the Ukrainian side.

Assessment of the answer

The recommendation remains valid but will be modified.

Preliminary recommendation PR7

It is recommended to undertake a comparison of the design and measures of the SUNPP 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

No comment was given by the Ukrainian side.

Assessment of the answer

It is clear from the answer to question Q20 that the WENRA RL has not yet been transposed into the Ukrainian nuclear legislation. Nevertheless, the WENRA RL should be used to identify possible improvement measures. 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 and a 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

No comment was given by the Ukrainian side.

Assessment of the answer

Some of the requested information is provided by the Ukrainian side in chapter 4.2. 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 32-, 35- and 39-years old structures, systems and components is a safety issue for the SUNPP unit 1-3, it is not addressed in the 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, no information about an ageing management programme (AMP) is provided in the EIA documents. The SUNPP ANSWERS (2021) provide some general information. It is explained that the evaluation of the aging of structures, systems and components (safety factor (SF) 4) within the framework of the last periodic safety review for units 1 to 3 has shown that safe operation is possible until at least the end of 2023, 2025 and February 2030, respectively.

For the reactor pressure vessels of units 1-3 of SUNPP, the conditions of brittle fracture resistance are met for the service life of at least 40 years. For prolonged lifetimes, new analyses and/or measures are necessary.

It has to be noted, that the IAEO PRE-SALTO Mission for SUNPP 3 in 2018 found that the periodic safety review and current safety analysis report are not sufficiently comprehensive for demonstration of safety for Long Term Operation (LTO) period.

Also, 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 is scheduled for December 2024.

Although conceptual ageing is also an issue for the SUNPP, the EIA documents did not deal with any of safety issues of the VVER-1000 reactors. NPP designs 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 VVER reactor type 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 inside the reactor building. In case of a severe accident a melt-through can occur within approx. 48 hours. The containment atmosphere will then blow down into parts of the reactor building that are not leak-tight and resulting in high releases. Another weakness is the protection against external hazard. Concerning airplane crashes, the reactor buildings are designed to withstand accidents of small airplanes only.

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. Scheduled completion is now 2023. As of 31/03/2021, still a range of measures has to be implemented. 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. Although safety relevant issues were not completely solved, the State Nuclear Regulatory Inspectorate of Ukraine (SNRIU) granted 10-year lifetime extensions for three units SUNPP in 2013, 2015 and 2020, respectively.

SNRIU is a member of the Western European Nuclear Regulators Association's (WENRA). In 2014, WENRA published a revised version of the Safety Reference Levels (RLs) for existing reactors which had been developed by the Reactor Harmonisation Working Group (RHWG). The objective of the revision was to take into account lessons learned from the TEPCO Fukushima Daiichi accident. A major update of the RLs was the revision of Issue F "Design Extension of Existing

Reactors" introducing the concept of Design Extension Conditions (DEC). However, it has to be noted that Ukraine has not implemented 88 RL of the 342 until January 1, 2021. (WENRA 2021a)

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

Final recommendation FR4

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

Final recommendation FR5

It is recommended to undertake a comparison of the design and measures of the SUNPP 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 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 the 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.

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 unit 3 of the SUNPP yet. Furthermore, there is no system for cooling and stabilizing a molten core for the SUNPP 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 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 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 SUNPP.

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 the SUNPP. (UMWELTBUNDESAMT 2021)

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

Question Q22

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

When ranking the radioactive release, the following factors were taken into account:

- availability or lack of conditions for the containment bypass;
- fulfilment/nonfulfillment of the isolation function of the containment;
- is the development of a severe accident accompanied by RV damage and release of the core melt in the containment;
- spray system operability;
- anticipated modes of containment failure.

The boundary for the large early release frequency (LERF) and the fuel melting frequency (FMF) in the spent fuel pool is conservatively considered the total value of the frequencies of all the categories of radioactive releases, combining emergency sequences with the severe core damage and the containment failure.

As a result of a quantitative assessment, the following values of the target safety indicators were obtained - the core damage frequency (CDF), LERF and FMF:

- Power unit 1: CDF= 1.32E-05; LERF = 5.15E-06; FMF = 2.76E-07.
- Power unit 2: CDF = 8.96E-06; LERF = 3.1E-06; FMF = 3.56E-07.
- Power unit 3: CDF = 4.70E-05; LERF = 6.51E-06; FMF = 3.58E-07.

Assessment of the answer

The question was not answered. The values for the core damage frequencies and large early release frequencies are provided, but not the source terms. These values show that the calculated frequencies for large early releases are relatively high. The values also show that about 39 % (unit 1), 35 % (unit 2) and 14 % (unit 3) of the core damage accidents result in large early releases.[1]

Question Q23

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

Written answer by the Ukrainian side

According to the C(I)SIP time schedule for 2021, the final date for the implementation of C(I)SIP measures is 31.12.2023.

Assessment of the answer

The question was answered.

[1] It has to be noted that the given values for the CDF does not add up with the values given in the answer to question Q30. The mentioned contribution of internal flooding (1,25×E-05) is higher as the total values of CDF for unit 2.

Question Q24

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

Written answer by the Ukrainian side

When assessing the consequences of aircraft crashes on the main buildings and structures, aircraft of the following groups were taken into account:

- aircraft of Categories 1-3;
  - aircraft of Class 4, AN-2 type;
  - transport, sports, general purpose aircraft of Class 4;
  - helicopters;
  - military aviation

Assessment of the answer

The question was not answered; however, the requested information is provided in the answer to question Q41.

Question Q25

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

While developing the EIA, an analysis was performed for transboundary consequences of DBA initial events. This analysis showed that there were no consequences.

The BDBA and Severe Accident scenarios have not been analyzed within the EIA. However, emergency response measures taken and actions and modernizations being implemented at the plant minimize or prevent accidental releases, that is confirmed by calculations run under the frame of these actions implementation and Units Periodic Safety Review as well.

The calculation results show that power unit life extension doesn't lead to impaired transboundary consequences.

Assessment of the answer

The question was not answered. It is stated that the BDBA and Severe Accident scenarios were not analysed as part of the EIA procedure. It is also pointed out that the calculations within the implementation of emergency measures show that these measures minimize or prevent accidental releases.

Question Q26

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

Written answer by the Ukrainian side

According to the IAEA Glossary:

Design basis accident - accident conditions against which a facility is designed according to established design criteria, and for which the damage to the fuel and the release of radioactive material are kept within authorized limits.

Beyond design basis accident - accident conditions more severe than a design basis accident.

Therefore, any design basis accident can develop into a beyond design basis accident if it is combined with additional equipment failure.

Assessment of the answer

The question was answered in general terms.

Question Q27

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

Written answer by the Ukrainian side

Under DBA, the conditions of the loss of containment integrity are not reached. As to containment bypass, within the analysis of the DBA, the scenarios were considered for the SG header lid lift-off, the RHR pipeline rupture outside containment, the pulse tube rupture outside containment.

While developing the Severe Accident Management Guideline, an analytical justification has been performed. In the frame of it, the BDBA initial events that could lead to containment failure have been defined and calculated.

The analysis showed that under BDBA (severe accidents) related to primary or secondary leakage combined with the station-blackout SBO conditions or under SBO conditions, the containment design pressure limit was reached, and theoretically, the loss of containment integrity was possible.

In addition, for accidents progressed into ex-vessel phase there was a possibility of containment floor corium melting.

However, post-Fukushima improvements introduced at South Ukraine Units (installed containment filtered venting system, passive hydrogen recombines, measures on preventing containment floor melting) make it possible to prevent containment failure that is confirmed by appropriate calculations.

Assessment of the answer

The question was answered explaining that several accident scenarios can lead to containment failure.

Question Q28

Which additional measures are envisaged to avoid large releases in case of an accident?

Written answer by the Ukrainian side

The following documents were developed and introduced under C(I)SIP) measures for severe accident management:

Severe Accident Management Guidelines, which are applied when the reactor facility is under the following states: “Power Operation”, “Minimum Controlled Reactor Power”, “Hot shutdown”, “Semi-hot shutdown”, “Shutdown for testing”, “Cold shutdown”, “Shutdown for maintenance”(with the upper unit installed on the reactor);

Severe Accident Management Guidelines which are applied for the state “Shutdown”, when the reactor facility is under the following states: “Shutdown for maintenance ”(with the dismantled upper unit of the reactor) and “Refuelling”.

The following equipment were assembled and put into operation:

- system for monitoring hydrogen concentration in the containment for beyond design basis accidents;
- emergency hydrogen removal system to ensure hydrogen explosive safety in case of beyond design basis accidents (installation of autocatalytic hydrogen recombiners);
- Filtered Containment Venting System.

Mobile pumping units were purchased and there were implemented the necessary upgrades of the systems ensuring make-up and cooling for SFPs and SGs feed in case of SBO, as well as the operability of service water consumers of group "A" in case of water loss by the spray ponds.

Measures were taken to prevent early containment bypass as a result of the release of the molten corium from the reactor vault outside the containment.

Also, works are ongoing at the industry level to analyze the feasibility of implementing a strategy for localizing the corium in the reactor vessel.

Assessment of the answer

The question was answered. The measures already chosen in the stress tests to address the existing weaknesses are mentioned. The answer mentioned the ongoing analyses of the feasibility of a strategy for corium localization in the reactor vessel.

Question Q29

How is the situation of the fuel issue at the SUNPP? Was the emergency shut down on the 27 November 2016 of unit 3 related to fuel problems? Are the units still using Westinghouse fuel? Have calculation been made to assess possible consequences for the structural degradation of the fuel? Can this degradation prevent the insertion of the control rods?

Written answer by the Ukrainian side

At Unit 1 we use fuel produced by Russian Joint-Stock Company "TVEL".

At Unit 2 and 3 we use fuel produced by "Westinghouse" company. Moreover, at Unit 3 the fuel produced by "Westinghouse" company was put into commercial operation.

Unit 3 shutdown (November 2016) was caused by cut-off of 3 of 4 reactor coolant pumps and is not related with safety of nuclear fuel operation.

We have not done calculations to evaluate possible consequences of structural degradation of the fuel since this shutdown was not related with exceeding of operational limits during the nuclear fuel operation. Moreover, in the course of every outage we perform selective inspection of fuel assemblies with "Westinghouse" company representatives. It is done using special Fuel Inspection and Repair Equipment.

Assessment of the answer

The questions were answered.

Preliminary recommendation PR9

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.

Written answer by the Ukrainian side

No comment was given by the Ukrainian side.

Assessment of the answer

The recommendation remains valid.

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):

1. Core damage frequency (CDF) and large (early) releases frequency (L(E)RF)
2. Contribution of internal events as well as internal and external hazards to CDF and L(E)RF
3. List of the beyond design basis accidents (BDBAs)
4. Source terms of all possible BDBAs including releases from the spent fuel pools
5. 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

No comment was given by the Ukrainian side.

Assessment of the answer

Some of the requested information is given in the answer to question Q22. However, the most important information to evaluate possible impacts on Austrian territory are not provided: the source terms calculated in PSA 2. Therefore, this part of the recommendation remains valid.

5.3 Conclusions and final recommendations

The provided EIA documents inform 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 scenarios nor the possible source terms are provided.

According to the SUNPP ANSWERS (2021), BDBA and Severe Accident scenarios were not analysed as part of the EIA procedure. Calculations within the implementation of emergency measures to minimize or prevent accidental releases were performed and the results used in the EIA documents. However, the assumed accident scenario and the source terms are not mentioned.

But the accident analyses in the EIA documents 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.

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; this fact is confirmed by the SUNPP ANSWERS (2021).

It is explained that several accident scenarios can lead to a containment failure. It is also stated that these accident scenarios could be prevented by the post-Fukushima improvements. However, these measures to address the existing weaknesses which were already identified with the stress tests are not fully implemented yet.

The information provided leads to the conclusion that accident scenarios can develop into a severe accident and threaten the integrity of the containment and result in large releases with a high probability. The values for the core damage frequencies and large early release frequencies show that the calculated frequencies for large early releases are relatively high. The values also show that about 39 % (unit 1), 35 % (unit 2) and 14 % (unit 3) of the core damage accidents result in large early releases.

According to ENSREG (2015), maintaining containment integrity under severe accident conditions remains an important issue for accident management. Filtered containment venting, a well-known approach to prevent containment overpressure failure, is not implemented at unit 3 of the SUNPP yet. Furthermore, no system for cooling and stabilizing a molten core is available at SUNPP. In the framework of the Stress Tests the feasibility of implementing a strategy for possible corium confinement within the reactor pressure vessel is to be analysed by 2023. The deadline was postponed from 2015.

The results of the EU Stress Tests have revealed a 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; on top 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 upgrading measures 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 SUNPP 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 the SUNPP.

Final recommendation FR6

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 FR7

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 SUNPP was insufficient. The EIA documents did not contain adequate 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 cannot be concluded from the EIA documents that the three units of SUNPP 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 required 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 Q30

Please provide access to the Periodical Safety Re-Assessment Report (PSRAR), in particular to information on internal and external hazards (chapter SF-7 Internal and external hazard analysis).

Written answer by the Ukrainian side

Within the analysis of the impact on the power unit safety of internal and external events (Safety factor SF-7 Analysis of internal and external hazards"), the following events were considered and analyzed:

1) internal:

- fires, as well as measures aimed at preventing, detecting and extinguishing fires;
- floodings, including spraying and irrigation due to spray system operation or pipeline rupture;
- emissions and deposition of toxic and /or corrosive gases and liquids;
- explosions;
- missiles impacts;
- drop of heavy objects;
- pipe whip;
- steaming;
- irrigation;
- emissions of hot and cold gases and vapours;
- vibration;
- destruction of civil structures;
- electromagnetic and radio frequency interference;
- loss of support systems (cooling water,power supply);
- lack or low capacity of air conditioning systems.

2) external:

- floodings and inundations;
- strong winds, hurricanes and tornadoes;
- seismic impacts;
- aircraft crash;
- fires and explosions;
- toxic and /or corrosive liquids and gases, other contaminants that enter the human body during breathing;
- meteorological effects (extreme temperatures, high humidity, drought, snow, icing, lightning strikes, hail);

- solar storms;
- hydrogeological and hydrological impacts (extreme groundwater levels);
- missiles impacts;
- biological pollution;
- electromagnetic and radio frequency interference;
- vibration;
- loss of support systems (cooling water, power supply).

All of the above impacts were analysed in detail, taking into account the accepted screening criterion based on the frequency of occurrence (more than 10^{-7} 1/year) or on the quality of the impact on the operation of the power unit. For further analysis, the following impacts were highlighted:

- internal fires;
- internal flooding;
- internal explosions;
- drop of heavy objects;
- pipe whip, steaming; irrigation (the impact of the spectrum of spatial interactions);
- emissions of hot and cold gases and vapours
- tornadoes;
- seismic impacts;
- aircraft crash;
- vibration (within seismic impact analysis).

Quantitative indicators of external and internal impacts on SU NPP safety

#	Description of Impact	CDF (FMF for SFP PSA), LERF, 1/year
	Extreme internal events	
1	PSA-1 of the internal event of the reactor facility for all operational states	6,62×E-06
	PSA-2 of the internal event of the reactor facility for all operational states	1,93×E-06
	PSA-1 of the internal event of SFP for all operational states	1,69×E-08
	PSA-2 of the internal event of SFP for all operational states	3,73×E-10
2	PSA-1 of the internal flooding of the reactor facility for all operational states	1,25×E-05
	PSA-2 of the internal flooding of the reactor facility for all operational states	7,85×E-07
	PSA-1 of the internal flooding of SFP for all operational states	2,92×E-10
	PSA-2 of the internal flooding of SFP for all operational states	4,19×E-12

#	Description of Impact	CDF (FMF for SFP PSA), LERF, 1/year
	Extreme internal events	
3	Drop of heavy objects (PSA-1)	1,65×E-07
	Drop of heavy objects (PSA-2)	4,89×E-08
	Extreme external event (EEE)	
4	PSA-1 of EEE of the reactor facility for all operational states, including:	4,04×E-07
	• tornadoes,	1,33×E-07
	• aircraft crash	2,71×E-07
	PSA-2 of EEE of the reactor facility for all operational states, including:	2,89×E-07
	• tornadoes,	1,78×E-08
	• aircraft crash	2,71×E-07
	PSA-1 of EEE of SFP for all operational states, including:	3,16×E-07
	• tornadoes,	2,87×E-08
	• aircraft crash	2,87×E-07
	PSA-2 of EEE of SFP for all operational states, including:	2,08×E-08
	• tornadoes,	1,88×E-09
	• aircraft crash	1,89×E-08
5	Seismic impacts	have not been assessed

Based on the results of the analysis of internal and external impacts, as well as the reduced quantitative indicators, it was concluded that the power unit design, technical equipment and administrative measures for the protection of structures, systems and components ensure reliable protection of the power unit from the impact of extreme natural and man-made hazards.

These conclusions do not relate to the analysis of seismic impacts on the safety of SUNPP units, which is planned to be carried out separately within the relevant activities "Development of Seismic PSA".

Assessment of the answer

Information provided by the Ukrainian side partly clarified part of the question by listing the hazard types addressed in the analysis and the screening of hazards which was based on the frequency of occurrence of 10^{-7}/year.

The expert team appreciated the detail of the information provided for core damage frequencies (CDF) and large early release frequencies (LERF). The listed analyses, however, only describe part of the total risk by being restricted to selected hazard types such as internal flooding, tornado and airplane crash. Main contributors such as internal fire and seismic hazards, which typically contribute most to the CDF/LERF values, are not mentioned.

The CDF/LERF frequencies resulting from extreme external events for *"all operational states"* are only provided as the sum of the contribution of tornado and airplane crash to the "total" CDF/LERF. It appears that other external initiating events (e.g., external flooding, extreme weather) were screened out because of their unlikeness (below 10^{-7} 1/year). The contribution of seismic hazards is not considered in the values listed in the Ukrainian reply.

With respect to internal hazards, the expert team particularly noted the high contribution of internal flooding which contributes 1,25×E-05 to the CDF value. The data suggests that the total CDF for the reactor may be much higher when considering all types of internal initiating events listed in the reply, i.e., including internal fires, explosions, pipe whip etc..

Question Q31

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 SUNPP?

Written answer by the Ukrainian side

Within the Safety Analysis Report, a PSA was produced for external hazards that defined the rates of external hazards for SU NPP vulnerabilities having an impact upon the Power Unit safety; the probabilistic modelling of the external hazards was also performed; an assessment of a core damage frequency resulted from the external hazards was performed; significance, uncertainty sensitivity analyses of the obtained results were performed.

"Stress-tests" are defined as a targeted re-assessment of the relevant safety margins in light of the events which occurred at Fukushima Daiichi: extreme natural events challenging the plant main safety functions and, as a result, leading to a severe accident. Their objective is: to perform an extra targeted safety review of South Ukraine Power Units in terms of extreme natural hazards and their combinations that could result into safety function degradation and severe accidents; to develop suggestions on relevant preventive and compensatory measures. Within performed stress-tests, in 2012 the Operators of Nuclear Power Plants thoroughly analyzed the extreme natural hazards (earthquake/seismic event, flooding, fires, tornadoes, extreme high/low temperatures, extreme rainfall, strong winds, event combinations).

While extending the current power units lifetime, in the frame of the Periodic Safety Review Report, Safety Factor No 6 was produced that refereed to impacts of the extreme hazards upon Power Unit safety considering the introduced modifications.

Assessment of the answer

Information provided in the replies to the questions Q31 and Q32 indicates that natural hazards and protection against the effects of natural hazards were reassessed in the framework of a PSA. The PSA is said to cover all relevant external hazards with the exception of seismic hazards. According to Q31, analyses of seismic hazards are *"planned to be carried out separately within the relevant activities "Development of Seismic PSA""*.

Question Q32

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

When performing a probabilistic analysis of the impact of extreme external impacts on safety, all the events with a frequency of 10-7 years and higher are analyzed, i.e. these events happen 3 orders of magnitude rarer than the events mentioned in WENRA recommendations.

Assessment of the answer

The Ukrainian reply does not clarify the question. It is left open if the analysis of *"events with a frequency of 10^{-7} years and higher"* led to the definition of design basis loads for the considered hazards as required by WENRA.

Question Q33

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

For extreme external impacts (EEI), the frequency of occurrence of which exceeds 10-4years (for example, lightning strikes) at SUNPP units, there are technical factors that exclude the impact of EEI on the safety of the power unit. For example: for lightning, the severity of the consequences of a lightning strike depends, first of all, on the explosion or fire hazards of buildings or structures during the thermal effects of lightning on these facilities. Organizationally and technically, buildings and structures of explosion and fire hazards are located at the NPP site in such a way that the occurrence of extreme situations at these facilities (explosions and fires) do not pose a threat to the power unit, since these facilities are located at safe distances from it.

Assessment of the answer

The reply does not clarify if all SSCs important to safety are conservatively protected against the loads of design basis events for all types of external hazards. The answer only refers to the example of lightning. It remains open whether design basis loads have been defined for other hazards such as meteorological hazards (storm, heavy rain, snow, extreme temperature etc.; see Q32), and if protection is adequate to conservatively ensure the functionality of SSCs relevant to safety in the case of design basis events.

Question Q34

Have new hazard analyses for natural hazards other than seismic been carried out for SUNPP 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

When performing PSR of the power unit, each time a list of analyzed impacts is substantiated, which is regularly supplemented with new items in accordance with the enacted regulatory legal acts). For example, during the last PSR of SU NPP Unit 3, the list of analyzed impacts was supplemented by the impact of solar storms.

Assessment of the answer

The Ukrainian reply and the answers to questions Q30-Q31 clarify that assessments of natural hazards were updated.

Question Q35

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

In cases where safety deficiencies are identified based on the results of the safety analysis of the power unit, compensatory actions aimed at improving safety (including technical activities) are developed and implemented.

Assessment of the answer

The answer clarifies question Q35 sufficiently by stating that identified safety deficiencies were addressed.

Question Q36

Has the upgrading of the seismic resistance of all SSCs important to safe-ty to the new DBE of PGA=0.12g as announced in the Stress Tests been completed for SUNPP?

Written answer by the Ukrainian side

The seismic resistance of equipment has been revised with the account taken of new requirements. All the equipment being evaluated has confirmed its operability for PGA=0.12g.

Assessment of the answer

The Ukrainian side confirmed that all SSCs important to safety withstand the updated design basis earthquake load of PGA=0.12g.

Question Q37

Which faults in the region around SUNPP have been analysed with respect to active faulting, and what are the results of these investigations?

Written answer by the Ukrainian side

The South-Ukraine NPP is located at a complex intersection of at least three large systems of Early Proterozoic faults: the Pervomaisk submeridional strike, lineament "B" of northwest strike, lineament "G", traced to the northeast from the Vrancea area. In addition to the listed zones of the ancient faults, there is a latitudinal fracture system, which is associated with the crook of the Southern Bug channel and which manifests itself in the dynamics of the modern magnetic field.

The ascending neotectonic movements of the earth's crust correspond to Kirovograd and Podolsk blocks. The alternating ones correspond to Odesa-Yadlovsk proto-orogenic. The South Ukraine NPP is located at the junction of zones of alternating and, mainly, ascending movements.

A number of large tectonic disturbances of mantle and crustal-mantle formations are identified in the area of the South Ukraine NPP: Pervomaisk, Odesa, Talne, Petrivka, Vradievka, Central, Kirovograd.

The Vradievka and Bratske (Central) faults and, especially, the Pervomaisk fault zone located near SU NPP site are most represented in the physical fields and contrastingly manifested geologically.

The NPP site is located in Pervomaisk fault zone between Akmechetski and Voznesensk faults, which are part of the Pervomaisky fault zone.

In practice, none of the above faults can be attributed to tectonically active faults (faults with which the relative movements of the sides in the Quaternary period are associated over (1-2) x10^6 years).

Discontinuous faults are divided into: regional mantle ones, faults limiting large blocks of the earth's crust, geostructures of the first order, regional intracrustal and local ones. The first two types of faults are deep-seated. Local faults are often derived from regional mantle and crustal faults or they complicate local structures.

Deep-seated faults are intricately constructed zones (5-30 km wide) that penetrate the earth's crust and are peculiarly manifested in its individual layers. The tracing of deep faults is shown on tectonic maps conventionally by lines, since the width and often the inclined position of the faults are variable in space and are not always specified along the entire fault trace.

Regional mantle (deep-seated) blocks that limit large blocks of the basement include: Odesa, Odesa-Talne, Kryvyi Rih-Kremenchuh.

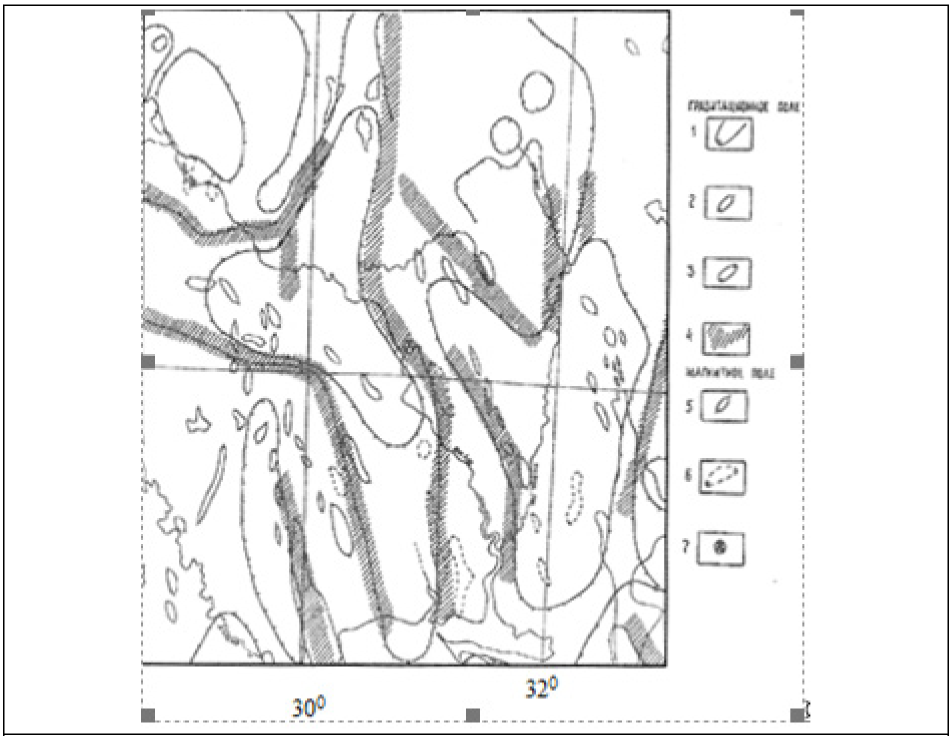
To assess the geological-tectonic, geomorphological conditions and seismic hazard of South-Ukraine NPP, it is necessary to identify tectonically active faults within a radius of 150-200 km, assess their seismic activity and possible tectonic and seismic hazard.

Therefore, more attention was paid to the study of large discontinuous faults located in the area and the location of the South-Ukraine power complex.

Discontinuous faults of the first order include: Pervomaisk (which is of the greatest interest, since South-Ukraine power complex is located in its zone) and Talne faults. In the immediate vicinity of the South Ukraine nuclear power plant, there is a northwest Central Fault strike. In addition, in the region, smaller discontinuous faults of the orthogonal (submeridional and sublatitudinal) and diagonal systems have been identified.

The Pervomaisk deep fault is manifested in the form of a system of closely adjacent faults of the earth's crust (Akmechetski, Voznesensk, Mykolaiv, etc.), concentrated in a zone up to 10 kilometers or more wide. In the area of the power complex, it has a northwest strike and a northeast dip of fault planes. According to preliminary data obtained in the course of seismic studies carried out by the Institute of Geophysics of the National Academy of Sciences of Ukraine and the Central Geophysical Expedition, displacements along the Moho surface are associated with the Pervomaisk fault zone. In the gravitational field, a sharp gravity step corresponds to it which separates the Golovanivsk maximum and the Kirovograd gravity minimum (Figure 1.3).

Figure 1.3: Fragment of the map of a geological structure of Ukrainian SSR and Moldavian SSR (elements of the structure of geophysical fields)



Legend: Gravitational field:

1 – boundaries of lowered areas of positive values of gravity (and relative gravi-tational maxima);

2 – areas of relatively increased values of gravity;

3 – areas of relatively low values of gravity;

4 – gravity steps. Magnetic field:

5 – the most typical magnetic maxima;

6 – the most typical magnetic minima;

7 – South-Ukraine power complex

The fault can be traced both in the crystalline basement and in the lower part of the sedimentary cover, since along the southeastern extension (within the Black Sea depression) there is an abrupt change in the thickness and facies of Cretaceous and Paleogene rocks. The morpho-kinematic characteristics of the Pervomaisk fault zone are ambiguous.

Some researchers interpret the Pervomaisk fault as a thrust fault with a significant right-lateral strike-slip displacement; others describe it as a right-lateral strike slip.

Pervomaisk fault zone has a complex structure: in the section from Pervomaisk to Voznesensk, it is traced by a series of subparallel faults; the western branch is assosiated with the valley of the Southern Bug River. In the lower reaches of the Southern Bug, the zone is traced by two single-order faults. The northeastern side of the Pervomaisk fault in the Pervomaisk area is uplifted by about 10-15 km. According to the maps of neotectonics of the southwestern USSR and the latest tectonics, fragments of which are shown, the Pervomaisk fault zone is mapped according to the deformations of the pontic surface. The severity of the

Pervomaisk fault in the relief and structure of the Neogene-Quaternary strata is manifested in the following: to the north of the NPP site - in local changes in the thickness of the newest deposits, deformation of terraces and peneplains; to the south - only in the deformation of terraces and peneplains.

Near the site of the South Ukraine NPP, a number of local discontinuous faults are identified, which manifested themselves at the neotectonic stage with different manifestation morphology, but none of them passes through the NPP site. The answer about the position of the Pervomaisk fault and its feathering discontinuous faults, the degree of their neotectonic activity was obtained in the course of field research, after the implementation of the program of works by the Black Sea Exploration Survey Company, the Central Geophysical Expedition and other organizations.

The central fault extends in a northwestern direction and is quite distinctly traced from the southeastern to northwestern edge of the Ukrainian craton. It separates the Bratske syncline and the Novoukrainsk geo-anticline, has a northeastern dip of the fault plane surface and is defined as a thrust fault, with some strike-slip displacements of blocks along it. On the neotectonic map, it does not appear in the form of discontinuous faults.

The Talne fault of submeridional strike is a thrust fault or reverse fault, with a right-lateral strike-slip component, along which the Golovanivsk zone experienced upward movements with respect to the Podolsk block. It manifests itself on the surface of "Moho", in the field of gravity it is expressed by a gravity step. On the map of neotectonics, a zone of increased fracture density of rocks and deposits is highlighted by satellite images. It manifests itself in the deformation of terraces and peneplains. The analysis of geological materials showed that many of the faults of the Ukrainian craton were repeatedly rejuvenated in the Late Precambrian and Phanerozoic, up to the neotectonic stage.

In recent times, almost all submeridional discontinuous faults of the southern slope of the Ukrainian craton and the South Ukraine monocline have become active: Odesa, Odesa-Talne (Talne), Mykolaiv, Pervomaisk, Ochakiv, etc. In some areas of these zones of discontinuous faults, activation is represented fragmentarily. There are few data on direct confirmation of neotectonic activation, although there are many indirect confirmations. On land, all submeridional faults are well traced along the deformations of the pontic surface. Based on the materials of geodetic levelling, modern movements are noted along Kryvyi Rih-Kremenchuh and Talne faults.

Of great interest are discontinuous faults of the II and III orders, included in the zones of northeastern strike: Kyshyniv and Odesa, which form a "transcontinental" zone of disjunctive dislocations.

Kyshyniv zone, about 35-40 km wide, is traced by fragments of faults, often close to 150-5000 m. Discontinuous faults are well traced in the deformations of the initial peneplain. In a number of wells, closer to the southwestern end of the platform, zones of discontinuities in Pliocene and Quaternary deposits were identified.

The Odesa fault zone with a width of about 15-20 km (within the land) is well represented in the deformations of the pontic surface. They are associated with straightened relief elements, local changes in the thickness of the newest deposits, zones of increased fracture density, well mapped using satellite images. They are associated with the zones of discontinuities in Pliocene and Quaternary sediments.

Thus, the most potentially tectonically active zones near the site of the South Ukraine NPP are: Talne, Pervomaisk faults. Tectonically, weakened zones can be the places of intersection of the above-named faults with Kyshyniv and Odesa zones of faults in the northeastern direction. Kyshyniv and Odesa discontinuous fault zones are located at a distance of 80-100 km from the NPP site and, even in the event of an earthquake of Mmax = 4.0-4.5 at depths Hmin = 5-7 km, the calculated intensity of the seismic impact will be below 4 points according to MSK scale -64 for soils of category II and may not be taken into account. We exclude these zones from the consideration as potential source zones.

Assessment of the answer

Ukrainian experts' answer confirmed that the Thalne fault and the Pervomaisk fault were investigated in detail.

The expert team appreciates the considerable efforts the Ukrainian side devoted to the exhaustive reply.

Question Q38

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. In particular:

- What is the robustness of the containment (in PGA)?
- What is the robustness of the piping of the primary cooling circuit and the pressurizer surge line (in PGA)?

Written answer by the Ukrainian side

Seismic margin of the containment is 0,3g on ground level;

Seismic margin of the piping of the primary cooling circuit is 0,3g on ground level;

Seismic margin of the piping of the pressurizer is within the range of 0,15 - 0,3g on ground level.

Assessment of the answer

The answer provides comprehensive information on the seismic resistance of buildings and SSCs in question.

Question Q39

Is the hazard of external flooding, in particular river floods 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

Taking into account the specifics of SUNPP location with relation to the Southern Bug, as well as the impact of floods on the Tashlyk brook, the events associated with river flooding do not lead to the violation of the current safe operation standards. In addition, all the reporting documentation on the safety analysis of SUNPP power units, including PSR documentation, contains an analysis of flooding. The mentioned documentation obligatory undergoes the state expert review by SSTC NRS and it is approved by the regulatory body of Ukraine-SNRIU.

Assessment of the answer

The answer confirmed that external flooding hazards have been adequately addressed.

Question Q40

EIA documents mention an increase of average temperatures for about 2°C over the last about 30 years. Has this finding been analysed further in the context of climate change and with respect potentially hazardous effects of extreme temperatures of air and cooling water?

Written answer by the Ukrainian side

Global climate change is one of the most important ecological issues solving of which is the overriding priority for the world. Adaptation to global climate change is the adjustment process to reduce the harmful effects of climate change upon human life, infrastructure functioning, and it is an issue of national security, and it requires a long-term well-coordinated policy on all management levels.

An activity to reduce the negative effects of increased annual average temperatures of air and cooling water is being carried out by the NNEGC "Energoatom" and SUNPP on a regular basis through:

- optimization of projects on recycling water supply systems of South Ukraine Power Complex comprising South Ukraine NPP, Olexandrivka Hydroelectric Plant, Tashlyk Pumped-Storage Plant;
- modernization (upgrading) of a South Ukraine Power Unit service water system (operation of Power Units - 1,2,3 on the Tashlyk reservoir and spray cooling ponds);

- construction of the Tashlyk PSP to supply peak power demands of the Ukraine's Power Grid and to increase high speed highly maneuverable capacities;
- upgrading of a chemical water treatment system;
- elaboration and implementation of projects related to a step-by-step increase of the normal impounded water level in the Olexandrivka water reservoir up to + 20,7 m elevation to enable the operation of the highly maneuverable Tashlyk PSP comprising 6 storage pumps, to ensure hydroeconomic needs in Mykolaiv Region and residual flow maintaining in the Olexandrivka HEP lower pond, to improve hydrological and hydrobiological regimes of the Olexandrivka water reservoir, to remedy sanitary and epidemiological situation in the Lower Southern Buh;
- implementation of a plan of actions to reach maximum permissible discharges of substances in SU NPP discharged waters, to exclude the exceedance of the maximum permissible discharges, to monitor water bodies within South Ukraine facilities monitoring coverage.

The objective of these actions is to ensure improved efficiency of water supply systems, water reservoirs, sustainable use of surface water resources and to reduce water losses as well as to maintain the quality of water bodies.

Thus, improved efficiency and safety of the Nuclear Power Plant, the Olexandrivka hydropower units, increased scope of peak and high speed highly maneuverable capacities of the Tashlyk PSP, where the electricity generated by the NPP, HEP, PSP does not result into increased CO_2 emissions but ensures power supply without failures, are one of the most effective mechanism to adapt power facilities to climate changes.

Assessment of the answer

The experts appreciated the detailed information. The answer confirmed that the effects of global warming have been taken into account.

Preliminary recommendation PR11

Whether all natural hazards relevant to the site were taken into account remains unclear 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 SUNPP are taken into account.

Written answer by the Ukrainian side

No comment was given by the Ukrainian side.

Assessment of the answer

The Ukrainian answer to question Q30 includes a list of hazards that were considered in the safety analysis. Based on this list, the recommendation can be regarded obsolete.

Preliminary recommendation PR12

Whether all hazard combinations were taken into account in the assessment of the site, as required by WENRA (2021) and further explained by WENRA (2020a) remains unclear. 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

No comment was given by the Ukrainian side.

Assessment of the answer

None of the answers of the Ukrainian side addressed the issue of hazard combinations. The recommendation is 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 2020b).

Written answer by the Ukrainian side

No comment was given by the Ukrainian side.

Assessment of the answer

The answer to question Q39 clarified that river flooding has been adequately addressed. 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 that apply to the site and use the derived parameters to develop adequate protection concepts.

Written answer by the Ukrainian side

No comment was given by the Ukrainian side.

Assessment of the answer

The Ukrainian side's replies have so not unequivocally confirmed that design bases for all types of external hazards relevant to the site have been developed. The recommendation therefore remains valid.

Preliminary recommendation PR15

The expert team recommends the application of the WENRA approach of analysing Design Extension Conditions (DEC) for natural hazards and up-dates 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

No comment was given by the Ukrainian side.

Assessment of the answer

The Ukrainian side's written answers have not addressed the issue of Design Extension Conditions (DEC). The recommendation therefore remains valid.

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 SUNPP were considered in safety analyses. The expert team concluded that hazard analysis had started with a list of hazards and had included a screening process. Some hazards were screened out based on the frequency of occurrence (less than 10^{-7} 1/year) or the *"impossibility of impact on the operation of the power unit".*

Although it seems that all natural hazards relevant to the site were taken into account, this is apparently not the case for hazard combinations. The expert team therefore recommends identifying relevant combinations of hazards based on WENRA (2020a) and DECKER & BRINKMAN (2017) in order to ensure that all relevant combinations of hazards are taken into account. The relatively high contribution of internal flooding to the CDF (stated with 1,25×E-05 per year) requires devoting special attention to the combinations of earthquake-induced internal flooding and earthquake-induced internal fire.

According to the written information received, updates of the assessment of the seismic safety of the SUNPP after the European Stress Tests were completed by upgrading the seismic design basis to PGA=0.12g. Further evaluation is still pending. The Ukrainian side informed the expert team that the development of a Seismic PSA is *"planned".* Information on how this planning is related to the LTO project is not available to the expert team.

Whether the LTO project included an analysis of the Design Extension Conditions (DEC) for natural hazards remained unclear. DEC are neither analysed in the available EIA document nor mentioned in written replies. WENRA requires undertaking DEC analyses regularly, 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 more challenging events or conditions than those considered in the design basis. In its recommendation the expert team stresses to utilize the LTO process for comprehensive DEC analyses with respect to external hazards to achieve higher levels of safety with respect to natural hazards.

Final recommendation FR8

Whether all hazard combinations were taken into account in the assessment of the site, as required by WENRA (2021) and further explained by WENRA (2020a) remains unclear. 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.

In view of the relatively high contribution of internal flooding to the CDF (stated with 1,25×E-05 per year) special attention should be given to the combinations of earthquake-induced internal flooding and earthquake-induced internal fire.

Final recommendation FR9

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 that apply to the site and use the derived parameters to develop adequate protection concepts.

Final recommendation FR10

The expert team recommends the application of the WENRA approach of analysing Design Extension Conditions (DEC) for natural hazards and up-dates 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.

Final recommendation FR11

The expert team took particular note of the relatively high contribution of internal flooding to the CDF (stated with 1,25×E-05 per year). It suggested to analyze the respective PSA results in order to identify reasonably practical upgrading measures to reduce the risk contribution of internal flooding.

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 South Ukraine NPP. Nevertheless, they were not discussed in the EIA documents for the SUNPP. In comparable EIA Reports such events were addressed to some extent.

Even if the current physical protection system that was increased significantly after Russia's aggressive actions in eastern Ukraine and the probability of terror acts and sabotage is considered being low, this kind of attacks are 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 South Ukraine units 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 Q41

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

Written answer by the Ukrainian side

The NPP was designed without taking into account the aircraft impact, as the Customer did not put forward specific requirements to consider the aircraft impact on NPPs.

The performed verification calculations of the containment of the standard NPP with VVER-1000 reactor type for the aircraft impact showed that the civil structures of the containment dome and cylinder withstand the strength of the aircraft impact weighing 10 tons, falling at an angle to the horizon in the range from 10 to 45 degrees at a speed of 215 m/s.

Assessment of the answer

The question was answered and confirmed that the NPP is not designed to withstand the crash of a commercial airliner, but only a military jet.

Question Q42

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

The civil structures prevent the radiation exposure and the spread of radioactive materials, also they allow to differentiate NPP premises according to different categories, to create the required climatic and temperature conditions in the premises, to arrange ventilation, to implement controlled leakage collection and letdown system, to unfasten pipelines and equipment against the effects of emergency and seismic loads and etc.

The space-planning structure of the reactor compartment is based on the principle of safety systems zoning and production categories.

The building is designed as an independent cubic content and meets both the requirements of a free-standing structure and a single-unit solution.

When assembling the building, the possibility of counter deformations of different mass parts of the building from seismic and dynamic impacts was taken into account. At the same time, the possibility of their collision was excluded by arranging design isolation joints with a width exceeding by at least 20 mm the sum of the absolute values of the calculated displacements of the parts of the building shared by them.

All the civil structures of the reactor compartment are load-bearing. However, some of them (walls and floors of compartments) combine the functions of load-bearing and enclosing structures.

When designing the structures of the reactor compartment, the principle of ensuring the minimum difference in deformations of the components of different rigidity of the structure was observed. In this regard, the calculations were carried out on the limit states of the components, which, provided that their strength and load-bearing capacity are ensured by all means, also ensured the minimum difference in deformations of the neighbouring components. At the same time, the dynamic characteristics of the structures were optimized, namely, limiting the propagation of oscillations from the resonance zones with the sources of mechanical oscillations dominating in the reactor compartment (MCP and other units). As a result of these design measures, the lack of cracking and other deviations in the materials of the structures and their failure-free operation from the moment of start-up to the present time was ensured.

Seismic design

The structures of the reactor compartment are designed for two levels of seismic impact:

- design basis earthquake - 6 points, based on a recurrence rate -once every 100 years
- maximum credible earthquake -7 points, based on the recurrence rate - once every 10,000 years.

Explosion resistance

When checking the reactor compartment for the effect of an external shock wave, the calculations were based on the pressure 30 kPa in the shock wave front from external sources of an explosive hazard.

The enclosing structures of the reactor compartment were designed for an external shock air wave with an equivalent static load on the frontal surface of the nuclear auxiliary building, equal to 11.4 tf /m^2.

Extreme climatic impacts in the area of the NPP site

The design calculation for the shock wave, covers all types of meteorological extreme impacts and therefore the strength and stability of the reactor compartment against these impacts is ensured by the components.

Aviation hazard

The performed verification calculations of the containment of the standard NPP with VVER-1000 reactor type for the aircraft impact showed that the civil structures of the containment dome and cylinder withstand the strength of the aircraft impact weighing 10 tons, falling at an angle to the horizon in the range from 10 to 45 degrees at a speed of 215 m /s.

Fire resistance of structures

In accordance with the industry-specific building codes VBN V1.1-034-3.307-2003, the grade of fire resistance of the reactor compartment structures, namely: the nuclear auxiliary building, the foundation part, the internal structures of the containment and under containment area is Grade I.

Assessment of the answer

The question was partially answered. It is not explained against which external (terror) attacks the units are designed but against which natural external events they are designed. The possible effects of ageing effects are not mentioned.

Question Q43

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 Report 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 Ukrainian side provide most of this information in the answers to the questions Q41 and Q42.

Assessment of the answer

The recommendation was complied with to a sufficient extent; therefore, it can be omitted.

Preliminary recommendation PR17

In 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 threat 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 Ukrainian side provide some information in the answer to question Q43.

Assessment of the answer

Because the last IPPAS mission took place about 20 years ago, 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 South Ukraine NPP. Nevertheless, they are not discussed in the EIA documents for the SUNPP. In comparable EIA Reports such events were addressed to some extent.

Even if the current physical protection system that was increased significantly and the probability of terror acts and sabotage is considered being low, this kind of attacks are 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. This topic is of particular importance because the reactor buildings of all South Ukraine units are vulnerable against airplane crashes. The SUNPP ANSWERS (2021) confirmed that the NPP is not designed to withstand the crash of a commercial airliner, but only a military jet.

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 has to be pointed out that the low scores for "Insider Threat Prevention" and "Cybersecurity" indicate deficiencies in these issues.

The last mission of the International Physical Protection Advisory Service (IPPAS) of the IAEA that assists states in strengthening their national nuclear security regimes, systems and measures took place about 20 years ago. A new mission is not envisaged yet.

Final recommendation FR12

In 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 threat 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 SUNPP 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 for such types of severe accidents and identified for SUNPP a possible source term for Cs-137 (204.22 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 no non-acceptable negative trans-boundary impacts could be identified 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 SUNPP.

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

Question Q44

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

SUNPP has no quantitative results of the calculated ground deposition of I-131 and Cs-137 for the distance to Austria.

Assessment of the answer

This answer confirms the recommendation to perform a dispersion calculation using a source term that is based on specific severe accident analyses of the SUNPP.

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 SUNPP.

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 SUNPP 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.

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Final recommendation FR13

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

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 SUNPP units 1-3 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 on its interim storage and final disposal facilities for spent fuel and radioactive waste.

9.3 Long-term operation of reactor type

9.3.1 Final Recommendations:

Final recommendation FR4

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

Final recommendation FR5

It is recommended to undertake a comparison of the design and measures of the SUNPP 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 FR6

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 FR7

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 FR8

Whether all hazard combinations were taken into account in the assessment of the site, as required by WENRA (2021) and further explained by WENRA (2020a) remains unclear. 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.

In view of the relatively high contribution of internal flooding to the CDF (stated with 1,25×E-05 per year) special attention should be given to the combinations of earthquake-induced internal flooding and earthquake-induced internal fire.

Final recommendation FR9

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 that apply to the site and use the derived parameters to develop adequate protection concepts.

Final recommendation FR10

The expert team recommends the application of the WENRA approach of analysing Design Extension Conditions (DEC) for natural hazards and up-dates 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.

Final recommendation FR11

The expert team took particular note of the relatively high contribution of internal flooding to the CDF (stated with 1,25×E-05 per year). It suggested to analyze the respective PSA results in order to identify reasonably practical upgrading measures to reduce the risk contribution of internal flooding.

9.6 Accidents with third parties' involvement

9.6.1 Final Recommendations:

Final recommendation FR12

In 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 threat 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 FR13

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

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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 ($9.82 ms^{-2}$)

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 .... Zaphorizhzhya NPP

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