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NPP South Ukraine

Lifetime Extension EIA

Expert Statement

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

pulswerk
Das Beratungsunternehmen des
Österreichischen Ökologie-Instituts

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NPP SOUTH UKRAINE LIFETIME-EXTENSION ENVIRONMENTAL IMPACT ASSESSMENT

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. In Austria, the public can comment on the EIA document from 21 June until 30 July, 2021.

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

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. 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 are dated 2015 and therefore do 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 completion of the trans-boundary EIA. This is not in line with the Espoo Convention, which requires an EIA to be conducted prior to a decision to authorize the proposed activity. Whether the results of this trans-boundary EIA will be taken into account and in which manner needs clarification.

Also lacking is the assessment of reasonable alternatives and the no-action alternative – both should be assessed in an EIA.

Spent fuel and radioactive waste

The EIA documents do 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 needs 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. It also 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 Zaporizhzhya NPP and all units which undergo lifetime extension.

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

Long-term operation of 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. But no information about an AMP is provided in the EIA documents. 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" carried out in 2017 under the Nuclear Safety Directive 2014/87/EURATOM 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 should be presented in the EIA documents, in particular the very important safety issue of the embrittlement of the reactor pressure vessels (RPVs).

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 and 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 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.

Although safety relevant issues were not completely solved, the State Nuclear Regulatory Inspectorate of Ukraine (SNRIU) granted 10-year lifetime extensions for the three SUNPP units in 2013, 2015 and 2020, respectively. 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. As of March 31, 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.

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, 2019. 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. All in all, a significant gap remains between the required safety standard and the actual safety level of the SUNPP units.

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.

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.

The accident analyses in the EIA documents should use a possible source term derived from the calculation of the current probabilistic safety analyses PSA level 2. Even though the calculated probability of severe accidents with a large release is very 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.

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. It is not known whether there will be any result, which would lead to the implementation of an appropriate measure.

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 many shortcomings in the prevention of severe accidents and the mitigation of its consequences. One characteristic of nuclear safety in the Ukraine is the constant severe delay of the implementation of upgrading measures.

Furthermore, and even more important, state of the art safety standards like consideration of "design extension condition" are still not envisaged. Thus, even after the implementation of all measures there will remain a considerable gap between the safety level agreed in Europe and the safety level of the 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 documents available to the experts do not contain a systematic assessment of natural hazards. The EIA documents do not encompass 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. Documents do not provide information on the types of hazards or hazard combinations that apply to the SUNPP site, the severity of hazards, the definition of adequate design basis events with occurrence probabilities of 10^{-4} per year, and the protection of SUNPP against natural hazards. On seismic hazards the EIA provided only sparse information. In addition to more detailed data on seismic hazards, information on external flooding caused by rivers, all types of extreme meteorological phenomena including climate change and possible hazard combinations should be provided in an EIA process.

Information on natural hazards that have potentially negative impacts on the safety of the SUNPP is therefore insufficient. It cannot be concluded from the EIA documents that the 3 units of SUNPP are adequately protected from the effects of natural hazards. Since Austria can potentially be affected by the consequences of accidents caused by natural hazards, this fact is relevant in the ongoing EIA.

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

Information regarding the issue of terror attacks would be of great interest, considering the large consequences of potential attacks. In particular, the EIA documents should include detailed information on the requirements for the design against the targeted crash of a commercial aircraft. This topic is of particular importance because the reactor buildings of all SUNPP 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 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 only 29 out of 47 countries, which indicates a low protection level. It has to be pointed out that the low scores for "Insider Threat Prevention" and "Cybersecurity" indicate deficiencies in these issues. It is recommended to invite the International Physical Protection Advisory Service (IPPAS) of the IAEA that assisted states in strengthening their national nuclear security regimes, systems and measures.

Trans-boundary impacts

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, like Austria, 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. In Österreich ist es der Öffentlichkeit möglich, den UVP-Bericht von 21. Juni bis 30. Juli 2021 einzusehen und Stellungnahmen abzugeben.

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

Verfahren und Alternativen

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. Das war hier nicht der Fall, da nicht alle UVP-Unterlagen zur Verfügung gestellt wurden und die ukrainische Öffentlichkeit mehr Unterlagen zur Einsicht erhalten hat.

Die UVP-Dokumente, die Österreich übermittelt wurden, sind mit 2015 datiert und spiegeln daher die Entwicklungen der letzten Jahre nicht wider und bedürfen einer Aktualisierung.

Die Genehmigungen für die Lebensdauerverlängerungen von SUNPP 1-3 wurden bereits vor Abschluss der grenzüberschreitenden UVP erteilt. Das widerspricht den Vorgaben der Espoo-Konvention, die die Durchführung einer UVP vor Erteilung der Genehmigung für eine geplante Aktivität vorsieht. Daher erfordert es nun eine Klarstellung durch die ukrainische Seite, ob und auf welche Weise die Ergebnisse dieser grenzüberschreitenden UVP berücksichtigt werden.

Darüber hinaus fehlt eine Bewertung von vernünftigerweise durchführbaren Alternativen und der Null-Variante, die beide in einer UVP zu prüfen sind.

Abgebrannte Brennelemente und radioaktiver Abfall

Die UVP-Unterlagen enthalten keine Information über die Mengen und Aktivitäten des radioaktiven Abfalls, der während der Lebensdauerverlängerung des KKW Südukraine erzeugt wird, ebenso fehlen umfassende Angaben zum Status der Konditionierungsanlagen, Zwischenlager und Endlager für radioaktive Abfälle. Dazu sind weitere Information zur Verfügung zu stellen.

Zurzeit werden die abgebrannten Brennelemente zur zwischenzeitlichen Lagerung und Wiederaufbereitung nach Russland transportiert. Im Jahr 2021 wurde der Betrieb im Trocken-Zwischenlagers CSFSF in Tschernobyl aufgenommen. Es ist unklar, wie viele abgebrannte Brennelemente aus der Lebensdauerverlängerung von SUNPP nach Russland verbracht und wie viele davon im CSFSF gelagert werden. Diese Frage ist noch zu klären. Ebenso zu klären ist die Frage, ob die Kapazität des CSFSF für die abgebrannten Brennelemente aus der Laufzeitverlängerung von SUNPP ausreichen wird, da dieses Zwischenlager für die Lagerung von abgebrannten Brennelementen aller ukrainischer Kernkraftwerke außer Zaporoshe und aller 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 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. Die UVP Unterlagen enthalten keine Informationen zum AMP. Die IAEO PRE-SALTO Mission für SUNPP 3 im Jahre 2018 kam jedoch zu dem Schluss, 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 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 sollten in den UVP-Unterlagen dargestellt werden, insbesondere die sehr wichtige Sicherheitsfrage der Versprödung des Reaktordruckbehälters (RDB).

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 und physischer Trennung und Bevorzugung passiver Sicherheitssysteme nur teilweise modernen Auslegungsprinzipien. Die UVP-Unterlagen beschreiben weder die sicherheitsrelevanten Systeme noch die Kapazitäten, Redundanzen oder physische Trennung. Dieser alte WWER-Reaktortyp weist einige Designdefizite auf, die durch Nachrüstmaßnahmen nicht behoben werden können.

Obwohl die sicherheitsrelevanten Themen noch nicht vollständig geklärt waren, gewährte die die ukrainische Atomaufsichtsbehörde SNRIU (State Nuclear Regulatory Inspectorate of Ukraine) eine Lebensdauerverlängerung von 10 Jahren für die drei Blöcke des SUNPP bis 2013, 2015 und 2020. 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 Programms Comprehensive (Integrated) Safety Improvement Program (C(I)SIP) vorgenommen. Der Abschluss des Programms wurde wiederholt verschoben. Mit Stand 31. März 2021 war noch eine große Zahl an Maßnahmen nicht umgesetzt. Trotz einiger Fortschritte ist das Programm im deutlichen Verzug. Unter dem Aspekt der Sicherheit ist nicht nachvollziehbar, wieso der Abschluss der Maßnahmen keine Voraussetzung für die Lebensdauerverlängerung darstellt.

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. Eine 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 wurde für SUNPP nicht angewandt. In Summe bleibt eine signifikante Kluft zwischen dem erforderlichen Sicherheitsniveau und dem tatsächlichen Sicherheitsniveau der Blöcke des KKW SUNPP bestehen.

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.

Für die Einschätzung von Konsequenzen der BDBA ist es notwendig eine Reihe von schweren Unfällen zu analysieren, einschließlich solcher mit Containmentversagen und Containment-Bypass, schwere Unfälle, die beim WWER-1000 Reaktortyp auftreten können.

Für die Unfallanalyse in der UVP-Dokumentation sollte ein möglicher Quellterm von der Berechnung der aktuellen Probabilistischen Sicherheitsanalyse (PSA) Level 2 abgeleitet werden. Wenn auch die berechneten Wahrscheinlichkeiten für schwere Unfälle mit großen Freisetzungen sehr gering sind, so sind die Konsequenzen dieser Unfälle potenziell sehr groß.

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.

Dem Dokument ENSREG (2015) zufolge ist der Erhalt der Containment-Integrität bei schweren Unfällen ein wichtiger Faktor im Unfallmanagement. Eine geeignete 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 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 war bereits 2015 gesetzt und wurde verlängert. Es ist nicht klar, ob ein Ergebnis erreicht werden wird, das zur Umsetzung einer geeigneten Maßnahme führen wird.

Soweit aus den zur Verfügung gestellten Dokumenten ersichtlich, bleibt auch weiterhin eine hohe Wahrscheinlichkeit bestehen, dass Unfallszenarien sich in schwere Unfälle weiterentwickeln werden, die die Containmentintegrität gefährden und in eine große Freisetzung münden.

Das Ergebnis der EU Stresstests zeigte zahlreiche Defizite in der Vermeidung von schweren Unfällen und der Abmilderung ihrer Konsequenzen auf. Ein Merkmal der nuklearen Sicherheit in der Ukraine ist die erhebliche Verzögerung bei der Umsetzung von Nachrüstmaßnahmen.

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

Ebenso unter Stand der Technik fällt die Verwendung der WENRA “Sicherheitsziele für neue Leistungsreaktoren” als Referenz zur Identifikation von vernünftigerweise durchführbaren Sicherheitsverbesserungen. Die UVP-Unterlagen erwähnen jedoch diese WENRA Sicherheitsziele nicht. Diese WENRA Sicherheitsziele sehen vor, dass Kernschmelzunfälle mit frühen oder großen Freisetzungen praktisch ausgeschlossen sein müssen. Selbst wenn die Wahrscheinlichkeit für einen bestimmten Unfallablauf sehr gering ist, so sollte jedes zusätzliche vernünftigerweise praktikable Auslegungsmerkmal, jede Betriebsmaßnahme oder Maßnahme im Unfallmanagement zur weiteren Senkung des Risikos von SUNPP umgesetzt werden.

Unfälle durch externe Gefahren

Die den ExpertInnen zur Verfügung gestellten Dokumenten enthalten keine systematische Bewertung von Naturgefahren. Die UVP-Unterlagen enthalten keine Informationen dazu, ob alle Naturgefahren mit Relevanz für den Standort bei der Standortbewertung in der jüngsten Periodischen Sicherheitsüberprüfung

(PSÜ) oder im Langzeitbetrieb-Projekt zur Lebensdauerverlängerung betrachtet wurden. Die Dokumente enthalten keine Angaben über die Typen von Gefahren oder Gefahrenkombinationen für den Standort SUNPP, über die Schwere der Gefahren, die Definition eines geeigneten Auslegungsstörfall-Ereignisses mit einer Eintrittshäufigkeit von 10^{-4} pro Jahr und den Schutz von SUNPP gegen diese Naturgefahren. Zur seismischen Gefährdung führt die UVP nur sehr wenig Informationen an. Zusätzlich zu mehr Detailinformation zur seismischen Gefährdung sollten auch Informationen über die externe Überflutung durch Flüsse, über alle Arten von extremen Wetterphänomenen einschließlich des Klimawandels und möglicher Gefahrenkombinationen im UVP-Verfahren zur Verfügung gestellt werden.

Informationen zu Naturgefahren mit potenziell negativen Auswirkungen auf die Sicherheit von SUNPP sind daher unzureichend. Es kann aus den UVP-Unterlagen nicht geschlossen werden, dass die die drei Blöcke von SUNPP adäquat gegen Naturgefahren geschützt wären. Da Österreich durch die Folgen von Unfällen, die aus Naturgefahren entstehen können, gefährdet sein kann, ist diese Tatsache in der aktuellen UVP von Bedeutung.

Unfälle mit Beteiligung Dritter

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

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

Angesichts der enormen Folgen potenzieller Terrorangriffe wären Informationen zu diesem Thema von höchstem Interesse. Insbesondere sollten die UVP-Unterlagen detaillierte Informationen über die Anforderungen an das Design gegen gezielte Abstürze von Verkehrsflugzeugen anführen. Dieses Thema ist vor allem für die Reaktorgebäude von SUNPP wichtig, da diese gegenüber Flugzeugabstürzen vulnerabel sind.

Eine jüngste Untersuchung zur nuklearen Sicherung in der Ukraine zeigte Defizite in den notwendigen Anforderungen für die nukleare Sicherung 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 nur auf Platz 29 von 47 Ländern, woraus auf ein geringes Schutzniveau geschlossen werden kann. Die geringe Punkteanzahl bei "Schutz gegen Insiderangriffe" und "Cybersecurity" verweisen auf Defizite in diesen Bereichen. Es wird empfohlen das International Physical Protection Advisory Service (IPPAS) der IAEO einzuladen, das Staaten bei der Stärkung ihrer nationalen Sicherungsregimes, Systeme und Maßnahmen unterstützt.

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 wie Österreich 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 könnte. Daher könnte Österreich von einem schweren Unfall im KKW Südukraine signifikant betroffen sein.

РЕЗЮМЕ

Южно-Українська атомна електростанція (Южно-Українська АЕС, ЮУАЕС) розташована на річці Південний Буг у Миколаївській області в Україні. На АЕС працює три реактори типу ВВЕР-1000. Реактори були підключені до електромережі у період між 1982 та 1989 роками.

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АЕС належить Державному підприємству «Національна атомна енергогенеруюча компанія “Енергоатом”» (ДП «НАЕК “Енергоатом”» або коротко — «Енергоатом»). ВП «Южно-Українська АЕС» є окремою структурною одиницею компанії «Енергоатом».

З метою продовжити строк експлуатації ЮУАЕС, українська сторона проводить Оцінку впливу на довкілля (ОВД) відповідно до Конвенції Еспо. Україна повідомила про це Австрію, яка вирішила взяти участь в ОВД. В Австрії громадськість може коментувати документацію по ОВД з 21 червня по 30 липня 2021 року.

Метою участі Австрії в процедурі ОВД є мінімізація або навіть усунення можливих значних негативних впливів на Австрію, які можуть виникнути в результаті виконання цього проєкту.

Процедура та альтернативи

Відповідно до Конвенції Еспо, гарантується, що громадськості постраждалої Сторони надається така сама можливість участі, що й громадськості Сторони походження. У цьому випадку так не сталося, оскільки були надані не всі документи ОВД. Громадськість України отримала більше документів.

Подані до Австрії документи ОВД датовані 2015 роком, тому не відображають події та рішення останніх років і потребують оновлення.

Ліцензії на продовження строку експлуатації енергоблоків 1–3 ЮУАЕС вже були видані до завершення транскордонної ОВД. Такі дії не відповідають Конвенції Еспо, яка вимагає проведення ОВД до прийняття рішення про затвердження пропонованої діяльності. Необхідно з’ясувати, чи будуть враховані результати цієї транскордонної ОВД і яким саме чином.

Також бракує оцінки розумних альтернатив та альтернативи бездіяльності. Всі вони повинні оцінюватися в межах ОВД.

Відпрацьоване паливо та радіоактивні відходи

Документи ОВД не містять інформації про обсяги та стан радіоактивних відходів, утворених під час продовження строку експлуатації ЮУАЕС, як і повної інформації про стан об'єктів з обробки радіоактивних відходів, проміжних й остаточних сховищ радіоактивних відходів. Це питання потребує подальшого роз'яснення.

Відпрацьоване паливо відвантажується до Росії для тимчасового зберігання та переробки. У 2021 році почало працювати «сухе» проміжне ЦСВЯП у Чорнобилі. Незрозуміло, яка частина відпрацьованого палива після продовження строку експлуатації ЮУАЕС буде відвантажена до Росії, а скільки зберігатиметься у ЦСВЯП. Цю інформацію необхідно перевірити. Також слід перевірити, чи ємність ЦСВЯП достатня для відпрацьованого палива після продовження строку експлуатації ЮУАЕС, беручи до уваги, що ЦСВЯП використовуватиметься для всіх українських АЕС, крім Запорізької АЕС, та всіх енергоблоків, строк експлуатації яких буде продовжено.

Відпрацьоване паливо та радіоактивні відходи можуть спричинити негативний вплив на довкілля, тому з радістю буде прийнята більш детальна інформація української сторони про національний план поводження з ядерними відходами.

Довгострокова експлуатація реакторів певного типу

Попри те, що старіння конструкцій, систем і компонентів структур, віком 32, 35 і 39 років є питанням безпеки для блоків 1–3 ЮУАЕС, в документах ОВД це питання не розглядається. Потрібна комплексна програма управління старінням (ПУС), щоб принаймні певною мірою обмежити проблеми, пов'язані зі старінням. Але в документах ОВД жодної інформації про ПУС немає. Однак попередня експертна місія МАГАТЕ з перевірки аспектів безпеки продовження експлуатації (PRE-SALTO) для блоку 3 ЮУАЕС у 2018 році виявила, що поточний звіт про аналіз безпеки та періодичний огляд безпеки є недостатньо вичерпними, щоб продемонструвати безпеку протягом довгострокової експлуатації.

Крім того, Тематична партнерська перевірка «Управління старінням», проведена у 2017 році згідно з Директивою про ядерну безпеку 2014/87/ЄВРАТОМ, виявила кілька відхилень очікуваного рівня ефективності, якого слід досягти для забезпечення прийнятного управління старінням в Європі. Результати тематичної партнерської перевірки та заходи щодо усунення недоліків повинні бути представлені в документах ОВД, зокрема, щодо дуже важливого питання безпеки стосовно крихкості корпусів реакторів високого тиску.

Хоча концептуальне старіння також є проблемою для ЮУАЕС, документи ОВД не стосуються жодного з питань безпеки реакторів ВВЕР-1000. Конструкції АЕС, розроблені у 1980-х роках і подібні до реакторів ВВЕР-1000, лише частково відповідають сучасним принципам проєктування щодо надмірності, різноманітності й фізичного розділення надлишкових підсистем або переваг систем пасивної безпеки. Документи ОВД не містять ні опису систем, що стосуються безпеки, ні інформації про потужності, надмірність і фізичне розділення. Реактори старого типу ВВЕР мають кілька конструктивних недоліків, які неможливо усунути виконанням заходів з модернізації.

Хоча питання, які стосуються безпеки, не були повністю вирішені, Державна інспекція ядерного регулювання України (Держатомрегулювання) дозволила продовжити строк експлуатації на десять років для трьох блоків ЮУАЕС у 2013, 2015 та 2020 роках відповідно. Ще в 2011 році стрес-тести ЄС виявили, що українські АЕС відповідають лише 172 зі 194 вимог згідно зі стандартами безпеки проєктування МАГАТЕ, опублікованими у 2000 році. Здійснюється необхідне вдосконалення в рамках поточної Комплексної (зведеної) програми підвищення безпеки. Завершення програми кілька разів відкладалося. Станом на 31 березня 2021 року велика кількість заходів все ще очікує на реалізацію. Попри певний прогрес, програма зазнала великих затримок. З точки зору безпеки, незрозуміло, чому завершення заходу не було обов'язковою умовою продовження строку експлуатації.

У 2014 році WENRA (Асоціація регуляторів Західної Європи) опублікувала переглянуту версію референтних рівнів безпеки для існуючих реакторів з урахуванням уроків, отриманих внаслідок аварії на АЕС «Фукусіма-Дайічі». Україна не впровадила 88 референтних рівнів із 342 до 1 січня 2019 року. Основним оновленням референтних рівнів був перегляд статті F «Запроєктна робота існуючих реакторів», що вводить концепцію запроєктного режиму роботи реактора. Ця концепція не застосовується до ЮУАЕС. Загалом, залишається значний розрив між необхідним стандартом безпеки та фактичним рівнем безпеки блоків ЮУАЕС.

Аналіз аварій

Надані документи ОВД містять інформацію про проєктні аварії, включаючи сценарії, викиди та наслідки. Однак інформація про позапроєктні аварії дуже обмежена. Не передбачені ані можливі сценарії аварій, ані джерела радіоактивності.

Щоб оцінити наслідки позапроєктних аварій, необхідно проаналізувати цілий ряд серйозних аварій, зокрема ті, що включають розгерметизацію та байпас захисної оболонки, важкі аварії, які можуть статися на реакторі типу ВВЕР-1000.

Аналіз аварій у документах ОВД повинен використовувати можливі джерела радіоактивності, отримані з розрахунку поточного імовірнісного аналізу безпеки (ІАБ (PSA) рівень 2). Попри те, що розрахункова ймовірність серйозних аварій з великим викидом дуже мала, наслідки, викликані цими аваріями, потенційно величезні.

На основі наявної інформації не можна погодити висновок Держатомрегулювання про те, що об'єкти працюють безпечно з прийнятним рівнем ризику.

Згідно з інформацією Європейського об'єднання атомних регуляторів ENSREG (2015 рік) підтримка цілісності захисної оболонки в умовах важких аварій залишається важливим питанням для управління аваріями. Фільтроване скидання тиску є добре відомим способом запобіганню надмірному тиску, але він ще не реалізований на 3-му блоці ЮУАЕС. Ба більше, на ЮУАЕС відсутня система охолодження та стабілізації розплавленої активної зони. У рамках стрес-тестів до 2023 року має бути проаналізована стратегія можливого утримання розплаву активної зони в корпусі реактора під тиском. Термін виконання було перенесено з 2015 року. Невідомо, чи буде якийсь результат, який призвів би до здійснення відповідного заходу.

Наскільки видно з наданих і доступних документів, все ще існує велика ймовірність того, що сценарії аварій переростуть у серйозну аварію, що загрожує цілісності захисної оболонки та спричинить великий викид.

Результати стрес-тестів ЄС виявили багато недоліків у запобіганні важким аваріям та в пом’якшенні їх наслідків. Одна з характеристик ядерної безпеки в Україні: постійна серйозна затримка впровадження заходів з модернізації.

Крім того, і що ще більш важливо, все ще не передбачені сучасні стандарти безпеки, як-от врахування запроєктного режиму роботи реактора. Тому навіть після реалізації всіх заходів залишатиметься значний розрив між рівнем безпеки, узгодженим у Європі, та рівнем безпеки ЮУАЕС.

Також вважається доцільним і передовим використання «Цілей безпеки для нових енергетичних реакторів» WENRA як еталона виявлення обґрунтованих і практичних поліпшень безпеки. Однак у документах ОВД не згадуються ці цілі безпеки WENRA. Відповідно до цілей безпеки WENRA повинні бути практично усунені аварії з розплавом активної зони, які призвели б до дочасних або великих викидів. Навіть якщо ймовірність послідовності аварій дуже мала, на ЮУАЕС повинні бути впроваджені будь-які додаткові обґрунтовані та практичні конструктивні особливості, оперативні заходи або процедури управління аваріями для подальшого зниження ризику.

Аварії через зовнішні небезпеки

Доступні експертам документи не містять систематичної оцінки природних небезпек. Документи ОВД не містять інформації про те, чи всі природні небезпеки, що стосуються ділянки, були враховані при оцінці ділянки під час останнього періодичного огляду безпеки або в проєкті довгострокової експлуатації. Документи не містять інформації про типи небезпек або комбінації небезпек, які застосовуються до ЮУАЕС, серйозність небезпек, визначення адекватних подій, включених до проєктних основ, з імовірністю 10^{-4} на рік та захист ЮУАЕС від природних небезпек. ОВД надає мізерну інформацію про сейсмічні небезпеки. Окрім більш детальних даних про сейсмічну небезпеку, в процесі ОВД повинна бути надана інформація про повені, спричинені річками, усі типи екстремальних метеорологічних явищ, включаючи зміну клімату, та можливі комбінації небезпек.

Отже, інформації про природні небезпеки, які потенційно можуть негативно вплинути на безпеку ЮУАЕС, недостатньо. З документів ОВД неможливо зробити висновок, що три енергоблоки ЮУАЕС належним чином захищені від впливу природних небезпек. Оскільки Австрія потенційно може постраждати від наслідків аварій, спричинених природними небезпеками, цей факт є актуальним у поточній ОВД.

Аварії за участю третіх осіб

Терористичні атаки та диверсійні дії можуть мати значний вплив на ядерні об'єкти та спричинити серйозні аварії, зокрема і на ЮУАЕС. Утім, в документах ОВД вони не обговорюються. У порівняльних Звітах ОВД такі події певною мірою розглядались.

Попри те, що наявна система фізичного захисту була значно збільшена після агресивних дій Росії на сході України, а ймовірність терористичних актів і саботажу вважається низькою, такий вид атак можливий. Хоча запобіжні заходи проти саботажу та терактів не можуть бути детально обговорені в процедурі ОВД з міркувань конфіденційності, в документах ОВД повинні бути викладені необхідні законодавчі вимоги.

Інформація про терористичні атаки представляла б великий інтерес, враховуючи великі наслідки потенційних атак. Зокрема, документи ОВД повинні містити детальну інформацію про вимоги до конструкції проти цільового тарану комерційним літаком. Ця тема має особливе значення, оскільки корпуси реакторів усіх блоків ЮУАЕС вразливі до падіння літаків.

Недавня оцінка ядерної безпеки в Україні вказує на недоліки у порівнянні з необхідними вимогами до ядерної безпеки: Індекс Ініціативи зі зменшення ядерної загрози (NTI) 2020 оцінює умови ядерної безпеки, пов'язані із захистом ядерних об'єктів від актів диверсії. Із загальною кількістю у 65 зі 100 балів, Україна посіла лише 29 місце із 47 країн, що свідчить про низький рівень захисту. Слід зазначити, що низькі бали за «Запобігання внутрішній загрозі» та за «Кібербезпеку» вказують на недоліки у цих сферах. Рекомендується запросити Міжнародну консультативну службу з питань фізичного захисту МАГАТЕ, яка надавала допомогу державам у зміцненні їхніх національних режимів, систем і заходів у питаннях ядерної безпеки.

Транскордонні впливи

Для ЮУАЕС не можна виключати тяжкі аварії, включаючи розгерметизацію та байпас захисної оболонки з викидами, що значно перевищують передбачені в документах ОВД рівні. Такі найгірші випадки повинні бути включені в оцінку, оскільки їх наслідки можуть бути широко розповсюдженими й довготривалими, а від них можуть постраждати навіть ті країни, які безпосередньо не межують з Україною, як-от Австрія.

Висновок, зроблений в документах ОВД про відсутність неприйнятних транскордонних впливів, не можна вважати достатньо доведеним, оскільки не проаналізовані найгірші сценарії. Результати проєкту flexRISK показали, що після важкої аварії середні відкладення Cs-137 у ґрунті в більшості районів австрійської території можуть перевищувати поріг заходів сільськогосподарського втручання (наприклад, раннє збирання врожаю, закриття теплиць). Отже, Австрія може суттєво постраждати від важкої аварії на ЮУАЕС.

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. In Austria, the public can comment on the EIA document from 21 June until 30 July, 2021.

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

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

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.

1 PROCEDURE AND ALTERNATIVES

This chapter describes the overall and procedural aspects of the Environmental Impact Assessment (EIA) procedure including the evaluation of the completeness of the provided documents and the fulfilment of the requirements of the Espoo Convention.

1.1 Treatment in the EIA documents

EIA documents and procedure

For the transboundary Environmental Impact Assessment (EIA), two EIA document were provided by the Ukrainian side to the Austrian side:

- SUNPP NON-TECHNICAL SUMMARY (2015): Safety Justification for DS "South-Ukraine NPP" power units operational lifetime extension over the designed period. Non-technical Summary. Ministry of Energy and Coal Industry of Ukraine, National Nuclear Energy Generation Company "Energoatom", detached Subdivision "South-Ukraine NPP". Yuzhnoukrainsk.
- SUNPP EIA REPORT (2015): Report. Development of the materials for assessment of environmental impact in the course of South-Ukraine NPP operation. UDK 550.4:574.3, State № 0115u002736. National Academy of Science of Ukraine, State institution "Institute of Environmental Geochemistry" (RC "IHNS NAS of Ukraine")

Both documents are available at the website of the Environment Agency Austria (https://www.umweltbundesamt.at/uvp-ukraine-kkw-2021).

The original design operation period is 30 years. The State Nuclear Regulatory Inspectorate of Ukraine (SNRIU) issued an operational license for SUNPP 1 valid until 2022. (SUNPP NON-TECHNICAL SUMMARY 2015, p 5)

Alternatives

SUNPP generates electricity in the southern region of Ukraine with a population over 5 million people from Mykolaiv Region, Odessa Region, Kherson region, and the Autonomous Republic of Crimea. The SUNPP ensures more than 10% of the total energy produced in Ukraine. (SUNPP NON-TECHNICAL SUMMARY 2015, p.9f.)

Energoatom considers the option of decommissioning neither as reasonable nor has it resources for decommissioning. Therefore, Energoatom's strategy is the step-by-step lifetime extension of its NPP fleet. (SUNPP NON-TECHNICAL SUMMARY 2015, p. 12)

There is a reference to an analysis of economic, social and ecological impacts of several alternatives in the EIA, but in the provided EIA documents this analysis is not described. (SUNPP NON-TECHNICAL SUMMARY 2015, p. 12)

1.2 Discussion

EIA documents and procedure

The EIA documents that were submitted to Austria are incomplete. According to the content of the SUNPP EIA Report (2015), 10 chapters and additional annexes are available, but only chapter 10 dealing with trans-boundary impacts was provided to Austria.

The following table gives an overview of the timetable of the planned lifetime extensions.

Table 1: SUNPP data and licenses (SUNPP Non-technical Summary 2015, p. 12; https://www.sunpp.mk.ua/en/energocomplex/perspectives, seen 2021-07-09)

Unit No.	Start of commercial operation	Design operation period in years	End of design life	License issued until
SUNPP 1	1982-12-31	30	2013-12-02	2022-12-02
SUNPP 2	1985-01-09	30	2015-05-12	2025-12-31
SUNPP 3	1989-09-20	30	2020-02-10	2030-02-10

The licensing for the lifetime extension of 10 years has already been completed for SUNPP 1-3.

In 2021, the SUNPP units 1-3 lifetimes have already been exceeded by up to eight years. This is not in accordance with the Espoo Convention requiring public participation in an EIA prior to a decision to authorize or undertake the proposed activity. (ESPOO CONVENTION 1991, Art 2.3)

It is not known if ten years will be the maximum lifetime extension for the three SUNPP units.

Information on the steps of the lifetime extension procedure in connection to the EIA is lacking altogether in the EIA documents.

In trans-boundary EIAs with other countries consultations on SUNPP have already been held, together with consultations on ZNPP. (REPORT CONSULTATION 2018) This report informs that the trans-boundary procedures started in October 2015, public consultations were to be held between July and Sept. 2017, and that the results of the trans-boundary consultations will be taken into account during lifetime extension of SUNPP 3 and ZNPP 3-6.

For the Austrian public, the EIA has started in June 2021. But the decisions on lifetime extension of SUNPP 1-3 have already been taken between 2013 and January 2020. Therefore it is highly questionable if the results of the ongoing transboundary EIA will be implemented at all, since the earlier decisions would have to be redrawn.

The Espoo Implementation Committee urges Ukraine to finish the still unfinished trans-boundary EIA procedures and inform the Committee on steps taken by 31 July 2021 (UNECE 2021) All participants in the trans-boundary EIA should also be informed about the next steps.

Alternatives

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

1.3 Conclusions, questions and preliminary recommendations

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 are from 2015 and therefore do 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. This is not in line with the Espoo Convention, which requests an EIA 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)

1.3.1 Questions:

- ***Q 1**: How long is the maximal foreseen lifetime extension of all SUNPP units?*
- ***Q 2**: What are the further steps in the EIA procedure and in the licensing procedure?*
- ***Q 3**: 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?*

1.3.2 Preliminary Recommendations:

- **PR 1**: Ukraine should provide adequate information on the EIA procedure and the further licensing procedure.
- **PR 2**: Alternatives of the lifetime extensions and the no-action alternative should be assessed in the EIA documents.
- **PR 3**: It is recommended to enable public participation in environmental assessments of nuclear projects according to the requirements of the Espoo Convention at a time when all options are still open, that is before a decision is taken.
- **PR4:** It is recommended not to issue the EIA decision until the deficiencies of the EIA have been solved.

2 SPENT FUEL AND RADIOACTIVE WASTE

2.1 Treatment in the EIA documents

Radioactive waste from SUNPP contains low, intermediate and high level waste.

Solid low level radioactive waste (LLW) is stored at the SUNPP site in four storage buildings (SUNPP NON-TECHNICAL SUMMARY 2015, p. 22) Planned steps are implementation of further processing technologies and final disposal. (SUNPP NON-TECHNICAL SUMMARY 2015, p. 68) The planned complex was supposed to be ready in 2018. (SUNPP NON-TECHNICAL SUMMARY 2015, p. 70)

Liquid radioactive waste is temporarily stored at the site in the auxiliary buildings no. 1 and 2. (SUNPP NON-TECHNICAL SUMMARY 2015, p. 21) Parts of the liquid wastes are treated in an evaporation facility on the site. Planned is the implementation of further processing technologies. (SUNPP NON-TECHNICAL SUMMARY 2015, p. 68)

Spent fuel of SUNPP is reloaded into the reactor spent fuel pond where it is stored for 4-5 years. After cooling in the spent fuel pond, it is loaded into special containers.

Concerning backend management, the Non-technical Summary refers to the global current status of science and technology which does not allow to take final solutions regarding further spent fuel management. Globally, there are several approaches, among them deferring the decision and using long-term interim storage of nuclear fuel. This would allow for possible future technologies to be developed. (SUNPP NON-TECHNICAL SUMMARY 2015, p. 22)

Currently, the spent fuel from SUNPP is sent to Russia for temporary storage and subsequent reprocessing in the Federal State Unitary Enterprise “Mining and Chemical Plant” (Krasnoyarsk). The return of reprocessing products was supposed to start in 2020. (SUNPP NON-TECHNICAL SUMMARY 2015, p. 71)

The construction of an interim storage facility for spent fuel is planned in Ukraine and has been licensed in 2017. Energoatom has signed a contract with the US company Holtec International for construction of the centralized spent fuel storage facility (CSFSF) in the Chernobyl exclusion zone. This interim storage facility will be used for the spent fuel from Rivne, Khmelnitsky and South Ukraine NPPs, the total capacity will be 12,500 spent fuel assemblies from VVER-1000 and 4,000 from VVER-440. (SUNPP NON-TECHNICAL SUMMARY 2015, p. 22)

In average from one VVER-1000 reactor 42 spent fuel assemblies are produced per year. Therefore, each year about 126 spent fuel assemblies are produced from SUNPP. (SUNPP NON-TECHNICAL SUMMARY 2015, p. 22)

Reprocessing of spent fuel, as one option, can be performed locally as well as in other countries with return of high active waste to the country of origin. (SUNPP NON-TECHNICAL SUMMARY 2015, p. 24)

2.2 Discussion

Radioactive waste:

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 needs further clarification.

Spent fuel

Concerning a future final repository of spent fuel and high level waste, a project called "Concept of Radioactive Waste Disposal in Ukraine" was conducted with the help of INSC (Euratom Instrument for Nuclear Safety Cooperation). In this project, two general preliminary safety analysis of two concepts of geological disposal were performed, one on a deep geological repository for disposal of vitrified HLW and possibly spent fuel with the use of the KBS-3V concept of Sweden; the other one for an intermediate depth disposal facilities for disposal of long-lived radwaste by using the SFL concept from Sweden. (NATIONAL REPORT UKRAINE 2017)

The KBS-3V method includes using copper canisters and assuming that copper does not corrode significantly. But there are also independent scientific studies showing that the copper canisters may corrode much faster than was assumed. This was also recognised by the Swedish Environmental Court in its 2018 opinion. It should be clarified if Ukraine also plans to use copper for its canisters and how the corrosion problem will be solved.

It is not clear if and when the fuel transports to Russia will come to an end. After that, the spent fuel will have to be stored in an interim storage facility. The construction of the centralized dry interim storage CSFSF in Chernobyl was completed in 2021. (UMWELTBUNDESAMT 2021) It is not clear if it will have enough capacity for the additional spent fuel from the SUNPP lifetime extension, taking into account that it will be used for all Ukrainian NPP except ZNPP and their lifetime extensions.

2.3 Conclusions, questions and preliminary recommendations

The EIA documents do 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 needs 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.

2.3.1 Questions:

- ***Q 4****: 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?*
- ***Q 5****: What is the status of the final disposal for spent fuel?*
- ***Q 6:*** *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?*
- ***Q 7****: What amounts and activities of LILW are expected to arise from lifetime extension of SUNPP?*
- ***Q 8****: Are there enough capacities in interim and final storages for the LILW from SUNPP lifetime extension?*
- ***Q 9****: What is the status of the treatment facilities, interim and final storages for radioactive waste?*
- ***Q 10:*** *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?*
- ***Q 11:*** *How much spent fuel from SUNPP will be sent to Russia for reprocessing in total?*

2.3.2 Preliminary Recommendations:

- **PR 5:** 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.

3 LONG-TERM OPERATION OF REACTOR TYPE

3.1 Treatment in the EIA documents

Chapter 2 of the SUNPP NON-TECHNICAL SUMMARY(2015) deals with the general characteristic of the South-Ukraine NPP (SUNPP). SUNPP is a separate division of the state-owned Enterprise "National Nuclear Energy Generating Company "Energoatom" (NNEGC "Energoatom").

Three reactor units operating at the SUNPP. The following table lists the reactor types and the relevant dates.

Table 2: The units of the South-Ukraine NPP (SUNPP NON-TECHNICAL SUMMARY2015)

SUNPP	Reactor type	Start of construction	Start of commissioning	End of design lifetime
Unit 1	VVER-1000/302	01/03/1977	22/12/1982	02/12/2013
Unit 2	VVER-1000/338	01/10/1979	06/01/1985	12/05/2015
Unit 3	VVER-1000/320	01/02/1985	20/09/1989	10/02/2020

The construction of SUNPP unit 4 was started in 1983. By 1989 a large scope of work had been done in terms of the main building and support facilities, however, on the basis of Resolution No.647 by the Council of Ministers of the USSR dated August 16, 1989, the construction was stopped, and Power Unit No. 4 was restructured into a full-scope simulator for the plant Training Center.

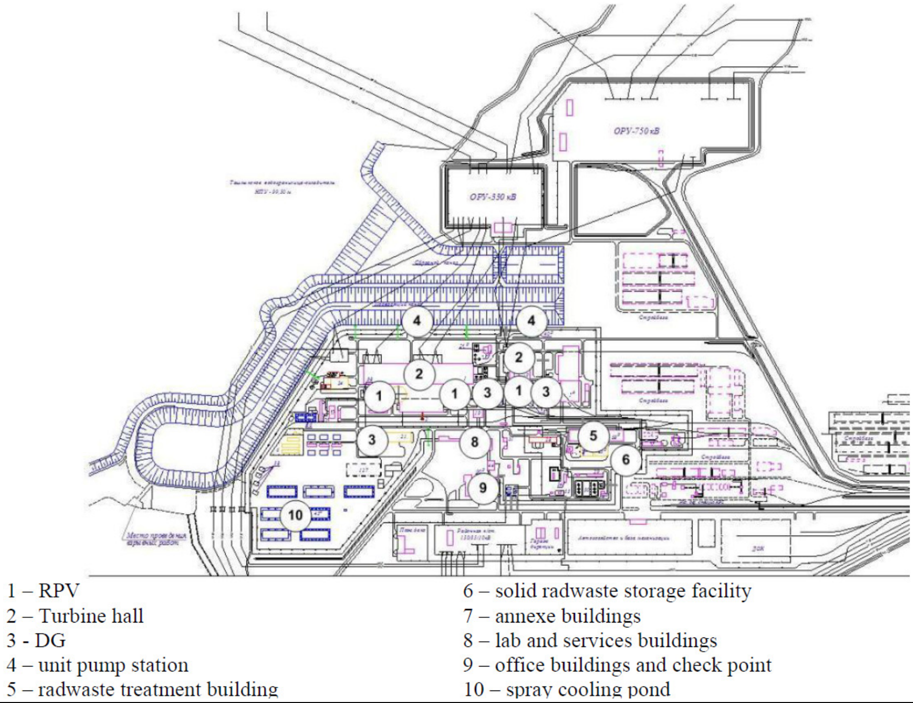
SUNPP is a core of the South-Ukraine Power and Hydro Complex that also comprises Olexandrivka Hydro and Tashlyk PSP. It is the only facility in Ukraine with multi-purpose use of nuclear as baseload combined with pump-storage capacities for electricity generation.

The design life of the units is 30 years. The Ukrainian documents explained that "Energoatom" neither considers decommissioning to be reasonable nor has resources required for decommissioning any NPP units. The company's strategy lies in a step-by-step lifetime extension of its nuclear power plants.

By decision of the Ukrainian regulator's (SNRIU) board, the lifetime of South Ukraine Power Unit No. 1 was extended for 10 years on November 28, 2013. According to the document SUNPP NON-TECHNICAL SUMMARY(2015) the lifetime was extended until02/12/2023 for unit 1, extension is in progress for unit 2 and planned for unit 3.

A short and very general description of the VVER -1000 reactors is given in the SUNPP NON-TECHNICAL SUMMARY(2015) and includes the following plan of the SUNPP site.

Figure 1: Plan of the SUNPP site



Source: SUNPP NON-TECHNICAL SUMMARY 2015

Reports of the Periodic Safety Review of the NPP units

Pursuant to the requirements of NP 306.2.141-2008 "*General provisions of nuclear plant safety*" and SOU-N YaEK 1.004: 2007 *"Requirements to the structure and contents of a Periodic Safety Review report for operating power units*", SUNPP shall perform a periodic safety review of every power unit at regular intervals but at least every 10 years after the start of plant operation or upon demand of the Regulatory Authority. A similar approach is recommended in IAEA Safety Standards Series No. NS-G-2.10.

The objective of a PSR is to determine:

- compliance of the unit safety level with the current codes and regulations for nuclear and radiation safety, norms and codes of design and engineering documentation, a safety analysis report and other documentation listed in an operating license,
- the adequacy of the arrangements that are in place to maintain plant safety until the next PSR or the end of plant lifetime,
- a list and terms of safety improvements to be implemented to resolve the safety issues that have been identified during safety assessment.

Based on the results of the Periodic Safety Review, PSR reports are be prepared for each unit. These reports shall be submitted to the State Nuclear Regulatory Inspectorate of Ukraine (SNRIU). The PSR report is the main document the nuclear regulator bases its decision on the SUNPP license renewal allowing the reactors to operate beyond their design life.

The PSR report includes 15 documents: a comprehensive safety analysis and 14 individual reports for every safety factor:

- SF-1 Plant design;
- SF-2 Actual condition of systems, structures and components;
- SF-3 Equipment qualification;
- SF-4 Ageing of structures, systems and components;
- SF-5 Deterministic safety analysis;
- SF-6 Probabilistic safety analysis;
- SF-7 Internal and external hazard analysis;
- SF-8 Safety performance;
- SF-9 Use of experience from other plants and research findings;
- SF-10 Organization and administration;
- SF-11 Procedures (Operational documentation);
- SF-12 The human factor;
- SF-13 Emergency planning.
- SF-14 Radiological impact on the environment

The PSR report is based on design and operational data, IAEA and WANO reports on safety assessments, the unit's safety cases, etc. The most recent PSR report for unit 1 was prepared in 2013 and the PSR report for unit 2 in 2015.

Both PSR reports showed that:

- Power units are operated according to their designs adhering to Safe Operational Limits and Conditions, licensing documents and current codes and regulations for Nuclear and Radiation Safety;
- Over the reporting period modernizations and modifications were made to the unit components and systems in order to enhance their safety including updating of design documentation and operating procedure;
- SSCs ageing management program has been elaborated and is in place, and justification has been provided to confirm that their actual technical condition can ensure their continued safe operation beyond design life;
- Corrective actions have been implemented or planned to correct or mitigate the revealed non-compliances with current codes and regulations for Nuclear and Radiation Safety;
- Operating procedures, administration charts, internal supervision charts, quality system introduced at all units and at the plant in general meet the safety principles and ensure the effective fulfillment of roles by an operating organization and plant management in accordance with Ukraine Law No. 39/95-VR and appropriate regulations;
- Actual impact of power unit operation on personnel, public and environment does not exceed radiation and environmental safety criteria and limits specified in regulatory documents;
- The existing conditions and outlined safety enhancement plans ensure the required level of safety during power unit continued operation.

Comprehensive analyses allow making and justifying generalized conclusions on technical capability to continue power unit's operation for 10 years after the end of their design life.

3.2 Discussion

The REPORT CONSULTATION (2018) explained that based on the results of periodic safety review (PSR) of units 1 and 2 an assessment of the main safety criteria (core damage frequency and the large release frequency) was carried out for each unit. The assessment showed that the safety criteria do not exceed the criteria established by NP 306.2.141-2008 "General safety provisions for nuclear power plants".

However, the IAEO PRE-SALTO Mission for SUNPP 3 in 2018 found that the current safety analysis report and ongoing periodic safety review are not sufficiently comprehensive to demonstrate the sufficient safety level as condition for LTO period. (See below)

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

- Physical Ageing of structures, systems and components (SSCs), which results in gradual deterioration in their physical characteristics.
- Conceptual and Technological Ageing: obsolescence of technologies and design, i. e. compared to the level of current knowledge, standards and technology the plants have become outdated.

Physical Ageing and Ageing Management

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

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

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

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

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

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

The measures of the intensification of plant monitoring and/or more frequent examinations, coupled with appropriate maintenance both rely on the optimistic assumption that cracks and other damage and degradation would be detected before they lead to failure; this is unrealistic in many cases. Tracking the condition of all the equipment is a complicated task for systems as complex as NPP. Once the reactors have surpassed their design lifetime, the number of failures is likely to start increasing.

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

Although aging is a safety issue for SUNPP, it is not addressed appropriately in the provided EIA documents which only contain the comment that "Structures, systems and components aging" is a safety factor (SF) within the PSR. SSCs ageing management program was described as elaborated and in place, and that evidence showed that their actual technical condition can ensure continued safe operation beyond design life.

During the transboundary consultation on the EIA results for ZNPP and SUNPP it is stated that all the factors impacting safety indicators (including aging of materials) were considered in the Periodic Safety Review report. Based on its results the Comprehensive Integrated Safety Enhancement Program was developed. Realization of this program ensures the increase of safety and reliability of the units. (REPORT CONSULTATION 2018)

As mentioned above the IAEO PRE-SALTO Mission for SUNPP 3 in 2018 found the ageing management programmes in the scope of LTO insufficient. Already earlier, in 2017, the Topical Peer Review (TPR) concluded the same. (see below)

Topical Review of Ageing Management

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

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

Ageing Management in Ukraine

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

Overall Ageing Management

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

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

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

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

Ageing management of electrical cables

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

The Automated Ageing Management System for Power Unit Components has been implemented, which consists of a separate software application integrated in the lists, directories and classifiers of the Ukrainian equipment reliability database.

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

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

Ageing management of concealed pipework

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

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

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

The peer review team criticized in regard of the AM of concealed pipework several issues: Inspection of safety-related pipe work penetrations through concrete structures are not part of ageing management programmes, unless it can be demonstrated that there is no active degradation mechanism. The peer review criticized also the scope of the concealed pipework included in the AMP because non-safety-related pipework whose failure may impact SSCs performing safety functions are not included. The fact that opportunistic inspection of concealed pipework is not undertaken whenever the pipework becomes accessible for other purposes was also pointed out. (ENSREG 2018)

Ageing management of RPV

The Reactor Pressure Vessel (RPV) is a component that cannot be replaced and its current and estimated technical condition affects long-term operation of the power unit. Given this issue, both the operator and regulator pay special attention to RPV ageing management.

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

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

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

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

According to SNRIU (2016), the most important tasks of ageing management and lifetime management are associated with buildings, structures and equipment whose replacement is impossible or extremely expensive, such as reactor pressure vessel lifetime management. Therefore, the following is continuously monitored during operation:

- mechanical properties of reactor pressure vessel materials by periodical testing of surveillance specimens;
- accumulation of fast neutron fluence on reactor pressure vessels in the beltline region by computational and experimental methods;
- impact of operating factors on the occurrence of defects in the most stressed areas of reactor pressure vessels by periodic (every four years) non-destructive examinations of base metal, welds and corrosion-resistant cladding.

Based on the monitoring results, the safety of **reactor pressure vessel** operation is evaluated throughout the design lifetime. The integrity and brittle fracture resistance are justified by calculation, taking account of non-destructive examination results, testing of surveillance specimens, fast neutron fluence accumulated by reactor pressure vessels, as well as IAEA recommendations on pressurized thermal shock analysis for different emergencies. The Experimental Design Bureau *Hydropress* (Russian Federation) as General Designer has justified reactor pressure vessel brittle strength for Khmelnitsky NPP unit 1 for the design lifetime. Similar work was performed for the reactor pressure vessels of Khmelnitsky NPP unit 2, Rivne NPP unit 4 and South Ukraine NPP unit 2.

In preparation for long-term operation, the Řež Nuclear Research Institute (Czech Republic) assessed the technical condition of the reactor at South Ukraine NPP unit 1. Pursuing the safety culture principles and taking into account certain design deficiencies of the standard surveillance programme for VVER-1000 reactor pressure vessels, upon request of the Ukrainian operator, the Řež Nuclear Research Institute conducts research and analysis of surveillance specimens from reactor pressure vessel materials of Khmelnitsky NPP unit 2, Rivne NPP units 3, 4 and Zaporizhzhya NPP unit 6, which were irradiated in the beltline region at Temelin NPP. This allows a comparative analysis and evaluation of changes in the properties of reactor pressure vessel materials depending on irradiation conditions according to the standard and integral programmes. (SNRIU 2016)

The standard surveillance programme for some of the reactors is good but not sufficient. Comprehensive inspections of all RPVs are necessary.

Ageing management of concrete containment structures

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

One of the important factors affecting the determination of the tension is the level of design-basis earthquake. In this case, it is necessary to note that the seismic level of NPP sites was reevaluated over the past 10 years and new level is actually two or three times higher than the design level.[1] Such a calculation, as a rule, is performed with activities on power unit preparation to LTO separately for each power unit, since the seismic level of sites varies and each containment has its own peculiarities, so the calculation is performed individually. Relevant measures on AM are developed according to the calculation results.

[1] The initial seismic design basis applied to the Ukrainian NPPs (PGA=0.05g) is lower than the recommendation of the IAEA (minimum PGA=0.10g). Taking into account IAEA recommendations and conservative approach, design level of PGA was increased 0.12g for SUNPP (30% conservative margin to PGA=0.093g was assumed).

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

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

Pre-Salto Mission

At the invitation of the State Enterprise “National Nuclear Energy Generating Company” (SE NNEGC) EnergoAtom, the IAEA conducted a Pre-SALTO (Safety Aspects of Long-Term Operation) mission at Unit 3 of the South-Ukraine Nuclear Power Plant in Ukraine from 17 April to 25 April 2018. (IAEA 2018)

This Pre-SALTO mission focused on the status of activities for the Long-Term Operation (LTO) assessment of the plant. The team reviewed the completed, in-progress and planned activities related to LTO, including Ageing Management (AM) of the Systems, Structures and Components (SSCs) important to safety and revalidation of Time-Limited Ageing Analyses (TLAAs).

Through the review of available documents, presentations and discussions with counterparts and other members of the plant staff, the IAEA team concluded that the plant had made progress in the field of ageing management and initiated many activities to prepare for safe long-term operation. The LTO project has already addressed several topics as recommended by the IAEA, with some activities partially implemented and many others initiated.

In addition, the team found good practices and good performances, including the following:

- Monitoring of safety indicators including ageing related failures since the start of operation (Current Safety Level Computer-based System);
- Atlas of operational defects in VVER Reactor steam generators tubes;
- Development and implementation of the RPV irradiation embrittlement surveillance programme.

The team found areas which should be improved to reach the level of international good practice. Fifteen issues were raised for further improvement:

- Organizational structure for LTO preparation and implementation is not fully implemented;
- The content of the LTO implementation programme is not complete;
- **The current safety analysis report and ongoing periodic safety review are not sufficiently comprehensive to demonstrate safety for the LTO period;**
- The scope of structure, systems and components (SSCs) that affect the safety of LTO is not complete and the scope setting process is not documented in a sufficient and traceable manner;

- Plant programmes relevant to safety during LTO do not properly identify and address ageing effects and are not linked to the ageing management programmes;
- Management of ageing related data does not fully support effective ageing management of SSCs in the scope of LTO;
- Ageing management review for mechanical, electrical and I&C SSCs within LTO scope is not complete;
- Ageing management programmes for mechanical, electrical and I&C components in the scope of LTO are not comprehensive;
- The relevant TLAAs for mechanical components were not properly identified and revalidated;
- The equipment qualification status is not adequately preserved;
- Technological obsolescence of SSCs important to safety is not managed proactively throughout their service life;
- Containment concrete structure strain monitoring is unavailable;
- Assessment of the safety consequences of containment building foundation movement is not performed for LTO;
- Corrective actions for ageing effects on civil structures have not been implemented in a timely manner;
- The plant has not systematically analysed and implemented all the components of an integrated knowledge management process.

The plant management expressed a determination to address the areas identified for improvement and indicated their intent to invite a 'SALTO Peer Review Mission to South Ukraine Nuclear Power Plant Unit 3' in quarter 4 of 2019 to review of progress in ageing management and LTO activities. The SALTO Mission is now planned for the 24 of August 2021. (IAEA 2021)

The list of deviations from the required safety standards is very long and covers many areas. The scope of the ageing management programme is insufficient, the measures are inadequate and necessary corrections are carried out with long delays.

Conceptual and technological ageing

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

The safety design of nuclear power plants is very important to prevent as well as to deal with incidents or accidents. Therefore, a risk assessment of a nuclear power plant has to consider the design base including the operational experience of all other comparable plants. The concerns are growing due to the Fukushima accident, as it revealed that there could be basic safety problems with the old units, whose design was prepared back in the sixties or seventies.

The old VVER reactor types have several design weaknesses, which cannot be resolved by performing back-fitting measures. The VVER-1000/V320 is fitted with a full-pressure single containment; however, it has a basic shortcoming not encountered in western PWRs. 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, 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 resulting in high releases. The reactor building – including the Main and Emergency Control Rooms (MCR/ECR) – will have to be abandoned (HIRSCH 2005).

Since there is no possibility for cooling the reactor pressure vessel (RPV) from outside in severe accident conditions, the retention of the molten core in the RPV is not assured.

An analysis performed as part of a European Union pre-accession instrument (PHARE project) Kozloduy 5 and 6 discovered a vulnerability of the design consisting of very early (one-hour) containment melt-through via ionization chamber channels situated around the reactor pit. To remedy this dangerous weakness plugging of the channels is planned in the next five years.

In case of a severe accident with core melt, the retention of the molten core inside the vessel is not possible. The design of the VVER-1000/V320 containment and the reactor cavity are such that any water supplied to the containment through the spray system or other means would not reach the reactor cavity. Thus, there is no possibility to directly flood the melt pool in the cavity.

Another weakness is the protection against external hazard. The reactor buildings are only designed against aircraft accidents of small machines.

VVER-1000 V-302 and V-338 reactors are so-called "small series". The V-320 model is a reactor series with individual improvements over its predecessors.

IAEA Recommendations

The stress tests in 2011 revealed that Ukrainian NPPs are compliant only with 172 of the 194 requirements according to the IAEA Design Safety Standards published in 2000.[2] Meanwhile, even this IAEA document is outdated; in January 2012 new safety requirements were published by IAEA (IAEA 2012).

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

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

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

Taking into account the results of implementation of former safety upgrade programs, outcomes from joint IAEA-EU-Ukraine project and strengthening national regulatory requirements, the United Safety Upgrade Program (2010 – 2017) has been developed (BOZKOA 2009).

According to SNRIU (2016), the operator is finalising implementation of the IAEA recommendations related to resolution of safety issues determined in the IAEA reports, namely: safety issues and their ranking for VVER-1000 Model 320 Nuclear Power Plants (IAEA-EBP-VVER-05) and safety issues and their ranking for Small Series VVER-1000 Nuclear Power Plants (IAEA-EBP-VVER-14). To resolve safety issues identified in the above reports, the operator has implemented a significant number of safety upgrades. In particular, they include measures on improvement of control rod insertion reliability (RC2), reactor pressure vessel embrittlement and monitoring (CI1), application of non-destructive testing (visual, ultrasonic, eddy current) (CI2), elimination of ECCS sump screen blocking and replacement of primary equipment insulation at all reactors (S5), replacement of steam generator pilot-operated relief valves at all V-320 power units (S9), replacement of storage batteries and uninterruptible power supply sources with expired lifetime at all power units (EI5), backup of the reactor protection system (I&C5), fire prevention (IH2), etc.

In 2016, still two of the eleven issues with the high safety concern (Rank III) for the VVER-1000 Model 320 have not been implemented. The remaining two recommendations are being resolved under the Comprehensive (Integrated) Safety Improvement Programme (C(I)SIP).

- Issue No. G2: Equipment qualification. The effort was performed under C(I)SIP measure 10101. (SNRIU 2021)
- Issue No. S9: Qualification of steam generator pilot-operated relief vales and BRU-A (steam dump valve to atmosphere) for water and steam-water discharge. Steam generator pilot-operated relief valves have been replaced at all V-320 units. Qualification of steam dump valve drives was performed under C(I)SIP measure 13302. (SRNIU 2021)

In 2016 still one issue of the twelve issues with the high safety concern (Rank III) for the VVER-1000/V-302 and V-338 Nuclear Power Plants have not been implemented. The remaining recommendation is being resolved under C(I)SIP:

- Issue No. S14: To improve the capability of the boron injection system. Engineering analysis has been carried out for both units to identify critical components for first-priority qualification for accident conditions.

Comprehensive Safety Upgrade Programme

Currently, safety upgrades are implemented in line with the ongoing safety improvement programme, **C(I)SIP**, whose status was upgraded after the Fukushima Daiichi accident. Because of delays in obtaining EBRD/Euratom loan for partial financing of C(I)SIP, difficulties in tendering for procurement of equipment and increase in the number of measures due to post-Fukushima measures, duration of the programme has been extended by Resolution of the Cabinet of Ministers of Ukraine to 2020. Under the C(I)SIP, 1275 measures are to be completed by 2020. The number of C(I)SIP measures may change subject to periodic safety review results, operating experience and new research findings in the area of safety, recommendations of international experts, etc. (SNRIU 2016)

But the implementation of the measures was not finished by 2020.

The document REPORT CONSULTATION (2018) explained that information on safety upgrade measures is presented on the Company's official website (www.energoatom.kiev.ua) in the section "Main page / Activities / Complex consolidated safety upgrade program". The most recent document that is published is the status report of the first quarter of 2021. (SNRIU 2021).

Totally, as of March 31 2021, 1020 measures out of 1295 were completed and 275 are to be implemented, including about 90 measures planned to be completed by the end of 2021. The following table shows the status of implementation for the SUNPP (SNRIU 2021).

Table 3: Status of implementation of the C(I)SIP for SUNPP on 31/03/2021 (SNRIU 2021)

Unit	**Total number of measures**	**Completed**	**To be implemented**
SUNPP-1	53	50	3
SUNPP-2	53	45	8
SUNPP-3	77	55	22
Directed at all units	5	4	1
Totally	188	154	134

The tables shows that many measures still await implementation (see also chapter 8.2). It is noteworthy that the total number of measures for unit 1 and 2 is significantly lower than for unit 3.

WENRA Safety Reference Level

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

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

Occurrence of conditions more complex and/or more severe than those postulated as design basis accidents (DBA) cannot be neglected in safety analyses. These conditions shall be investigated as Design Extension Conditions (DEC) so that any reasonably practicable measures to improve the safety of a plant are identified and implemented. (RL F1.1) RL F1.2 defines two categories of DEC:

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

WENRA RHWG (2018a) reports on the implementation of the revised RLs in the national regulatory frameworks of WENRA countries. RHWG suggested and WENRA agreed to restrict the review to the implementation of the RLs that were updated and developed after the accident at Fukushima Dai-ichi NPP. *Table 3* lists the new and revised WENRA RL.

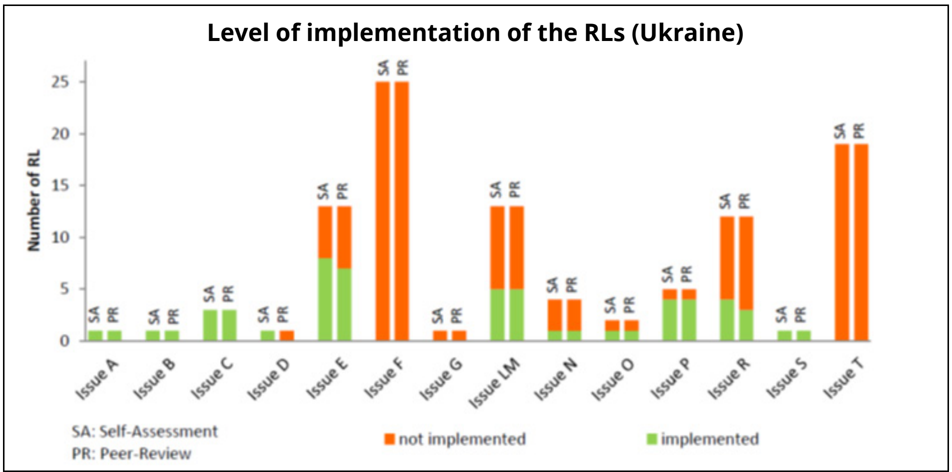
Table 4:Revised or new WENRA reference Levels (WENRA RHWG 2018a)

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

The State Nuclear Regulatory Inspectorate of Ukraine (SNRIU) performed the self-assessment of issues A, B, C, D, G, N, O, P, S. The *Figure 2* shows the status of the self-assessment (November 2015) and the result of the peer-review

(March 2016). It illustrates that Ukraine has not implemented the new RL F and T in the regulations at that time.

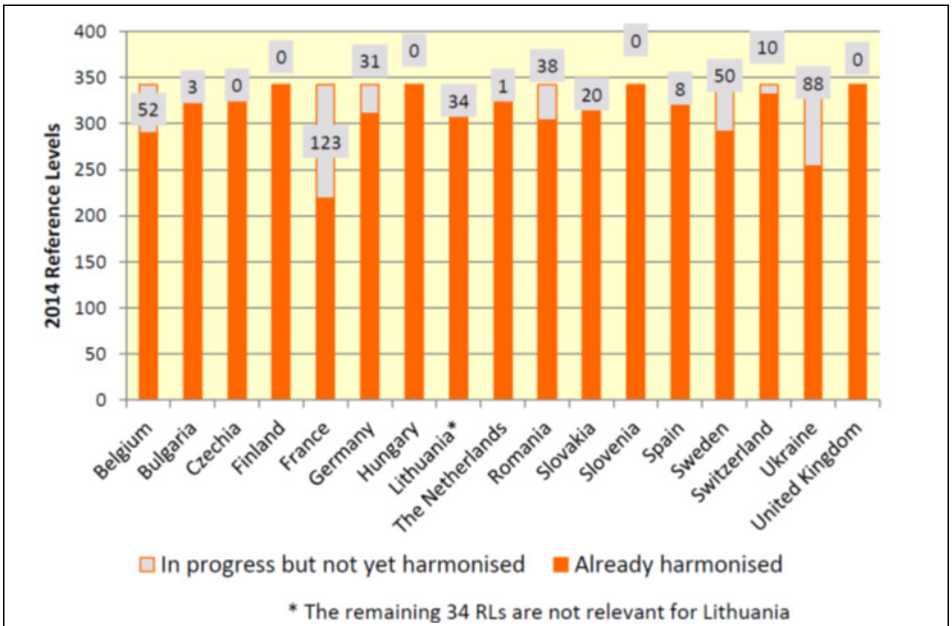
Figure 2: Status of implementation of new and revised RL in Ukraine



Source: WENRA RHWG 2018a umweltbundesamt

Ukraine proposed the full implementation of the remaining 74 RLs into the national regulation until March 2018. However, as of 1 January 2019 Ukraine has not implemented 88 RL out of 342, see *Figure 3*. (WENRA RHWG 2020a)

Figure 3: Reported status of implementation of 2014 RL in 2020



Source: WENRA RHWG 2020a umweltbundesamt

3.3 Conclusions, questions and preliminary 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 IAEO PRE-SALTO Mission for SUNPP 3 in 2018 found that the current safety analysis report and the periodic safety review 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 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.[3] 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.

3.3.1 Questions

- ***Q 12:*** *What is the status of the LTO for the unit 3 of the South Ukraine NPP?*
- ***Q 13:*** *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?*
- ***Q 14:*** *What are the specific findings of the ageing management programme for SUNPP unit 1 to 3? Are there any differences between the units?*
- ***Q 15:*** *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?*
- ***Q 16:*** *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?*
- ***Q 17:*** *Is a systematic evaluation of the SUNPP design deviations from the current international safety standards and requirements envisaged?*

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

- ***Q 18:** Why is the number of measures of the C(I)SIP for SUNPP unit 3 is higher than for SUNPP units 1 and 2?*
- ***Q 19:** When will the WENRA RL be fully implemented in the Ukrainian regulations? Will the application of the RL be binding?*
- ***Q 20:** When will be reviewed whether the RL will be meet for the SUNPP?*
- ***Q 21:** Which WENRA Documents will be mandatory for lifetime extensions?*

3.3.2 Preliminary Recommendations:

- **PR 6:** It is recommended to implement all available design improvements of VVER-1000 reactor for the SUNPP.
- **PR 7:** 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.
- **PR 8:** It is recommended to also 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.

4 ACCIDENT ANALYSIS

4.1 Treatment in the EIA documents

Chapter 2.7 of the SUNPP NON-TECHNICAL SUMMARY (2015) discusses the potential accidents during operation of SUNPP power units. The acceptance criterion for ecological consequences of accidents is established in NRBU-97. To analyse radiation consequences of design basis accidents (DBA) and beyond design-basis accidents (BDBA) at SUNPP the following factors were taken into account:

- maximum design basis accident – accident caused by double-ended rupture of cooling system (loss-of-coolant accident) at the nominal energy level;
- depressurization of cover at steam generator collector;
- accident during fuel handling and spent fuel handling;
- accident caused by cooling line damage outside the reactor.

The documents stated that also an analysis of severe beyond design accidents as a part of safety analysis in the Comprehensive (integrated) Safety Upgrade Program for Power Units of Ukraine Nuclear Power Plants" (C(I)SUP) was conducted.

The following table presents the total release and the release of Caesium-137 and Iodine 131 of all considered accidents.

Table 5: Release of the design basis accidents (SUNPP NON-TECHNICAL SUMMARY 2015)

Accidents	Cs-137 in Bq	I-131 in Bq	Total in Bq
Maximum DBA	5,00E+11	4,98E+12	7,17E+13
Steam generator header cover lift-up emergency spike	5,30E+11	2,53E+13	4,35E+15
Steam generator header cover lift-up pre accident spike	5,30E+11	4,50E+12	2,59E+14
Hydraulic lock drop into the spent fuel pool	5,80E+11	1,65E+13	5,34E+14
Fuel assembly drop on the reactor core and FA top nozzles in the spent fuel pool	6,50E+10	3,80E+11	1,05E+14
Drop of the container with the spent fuel from height of more than 9 meters	7,30E+11	-	2,45E+12
Fuel assembly drop on the reactor core in the reactor	4,63E+12	8,20E+11	1,21E+14
Impulse tube rupture beyond the containment	7,40E+09	6,70E+12	1,32E+14
Planed cool down line rupture	3,70E+07	6,42E+07	6,80E+12
Rupture of the process blow off pipeline of the reactor building	-	-	3,44E+13

Chapter 4 of the SUNPP NON-TECHNICAL SUMMARY (2015) gives some information about the expected exposures after an accident: The maximum exposure doses caused by the design basis accident (DBA) assessed at the boundary of the buffer area show that even in case of DBA the levels of potential exposure are appeared to be significantly below the specified limit justified for population evacuation (50 mSv for whole body).

The estimated maximum exposure doses resulted from DBA at the boundary of the buffer area are presented in the following table:

Table 6. Estimated maximum radiation doses resulted from Design Basis Accidents

Design Basis Accident	External cloud radiation dose, mSv	External radiation dose through ground contamination, mSv	A dose for a thyroid gland through inhalation by a child, mSv
An accident caused by double ended pipe rupture (DBA, Loss-of coolant accident)	0.8	91	63
SG header cover leakage	0.7	75	163
Accidents related to: - SF storage pool leakage; - FA drop into the SF storage pool; - water gate drop into the SF storage pool.	**effective body dose, mSv**	**a dose for a thyroid gland, mGy**	**a dose for a skin, mGy**
	3.44	9.25	66.3

Chapter 6 of the SUNPP NON-TECHNICAL SUMMARY (2015) provides results of calculations radioactive releases into environment at various types of accidents. The software package PC COSYMA, developed at the National Radiological Protection Board (National Committee on Radiation Protection, England) for emergency situations was used for calculations. It is explained that all calculations are done for the conservative conditions of the impurity propagation and formation of doses (maximum doses).

The analysis shows that the amount of potential accidental releases does not exceed the levels which meet the maximum permissible values of radiation criteria for equivalent and absorbed doses on the border and outside the sanitary protection zone, specified in the documents SP AS-88 and NRBU-97. (SUNPP NON-TECHNICAL SUMMARY 2015)

According to the SUNPP EIA REPORT (2015), the analysis results for the beyond design-basis accidents (BDBAs) confirm the surveillance area (30 km), which defines the area of unconditional justification for urgent countermeasures.

The maximum effective dose of the BDBAs for the population within the 30 kilometer area is estimated in the Comprehensive (Integrated) Safety Upgrade Program to be within 5.77 mSv/year which does not exceed 15% of boundary parameter level (40 mSv/year) specified in Radiation Safety Standard of Ukraine. (SUNPP NON-TECHNICAL SUMMARY 2015)

It is concluded that in case of SUNPP power units' lifetime extension the transboundary impacts potentially requiring a response are excluded. (SUNPP NON-TECHNICAL SUMMARY 2015)

The SUNPP EIA REPORT (2015) stated that the analysis allows to make a conclusion about practical absence of harmful transboundary impacts associated with lifetime extension of the SUNPP power units in normal operation or in case of design or beyond design-basis accidents.

Protective measures

The SUNPP NON-TECHNICAL SUMMARY (2015) mentions that one important element for NPP safety is the tightness of premises where radioactive material is kept. SUNPP has a reactor containment system around the primary equipment to prevent the release of radioactive materials in the event of breaks or leaks and to protect the primary circuit against extreme external hazards.

To prevent or mitigate radioactive releases, the following engineering decisions have been elaborated:

- radioactive air purification with filters;
- absorption and filtration of gases containing radioactive isotopes (xenon, krypton) of noble gases;
- installation of safety barriers to confine radioactive materials;
- use of closed loops to prevent radioactive liquid leaking;
- introduced special system for liquid radwaste and solid radwaste collection and storage.

Regarding the mitigation of accident consequences, the SUNPP emergency safety is based on the following safety principles and criteria:

- NPP safety is ensured with
  - physical barriers in the direction of spreading of ionizing radiation and radioactive substances into environment, and
  - systems of technical and organizational measures to protect the barriers and to keep their efficiency for protection of personnel, population and environment.
- During NPP operation they monitor the barriers' integrity in all the direction of spreading of radioactive substances. The NPP operation at power is prohibited if there is a failed barrier that is specified in the plant design or there is a failed equipment protecting this barrier.

Some general information about the physical barriers is given:

- availability of special safety systems based on the parallel trains performing the same function;

- safety system ensures principles of independence, redundancy, physical separation and accounting of every incident;
- high technical features of accident localization system to prevent the radioactive substance spreading into the environment;
- technological processes have a high level of control and automation including an emergency management in the course of the most important phase (first phase) without personnel involvement;
- safety ensuring provided external influence specific for plant under review including nature and technical impact;
- safety ensuring in broad spectrum of initial events with a glance of postulated failures, possible personnel errors and additional impacts;
- use of conservative approach to choose engineering solutions impacting the safety;
- usage of measures and engineering solutions aimed at:
  - protection of accident localization system in case of design basis accident,
  - prevention of initial event transfer into design-basis accident,
  - consequences' mitigation of the accidents if prevention had failed;
- ensuring of possibility to check and test the equipment and systems that are important to safety to maintain them in working condition;
- arrangement of buffer area and radiation control area;
- quality assurance with a glance of requirements of relevant normative documents.

According to SUNPP NON-TECHNICAL SUMMARY (2015), the system of technical and organizational measures has five levels:

- Level 1: Creation of conditions preventing violation of normal operation;
- Level 2: Prevention of design-basis accidents using normal operation system;
- Level 3: Prevention of accidents at safety systems;
- Level 4: Beyond design-basis accidents' management;
- Level 5: Planning of measures on protection of personnel and population.

Comprehensive (integrated) Safety Upgrade Program (C(I)SUP)

According to the SUNPP NON-TECHNICAL SUMMARY (2015) the *"Comprehensive (integrated) Safety Upgrade Program for Power Units of Ukraine Nuclear Power Plants" (C(I)SUP)* is elaborated in accordance with Ukraine's President Executive Order No.585/2011 dated 12/05/2011 on putting into effect the "Decision made by the Ukraine's National Security and Defense Council of April 8, 2011, Concerning safety enhancement of Ukrainian Nuclear Power Plants".

The objective of this program is to:

- Enhance safety and reliability of nuclear power plants;
- Reduce plant accident risks in the event of natural disasters or any other extreme hazard;
- Improve the effectiveness of DBA and BDBA management and to minimize these accidents consequences.

The authors of the C(I)SUP are the Public company "Kyiv Scientific & Research and Design Institute "EnergoProjekt" and Public Limited Company "Kharkiv Scientific & Research and Design Institute "EnergoProekt". To ensure compliance of the C(I)SUP with the environmental protection and environmental safety requirements, an Environmental Assessment (EA) has been performed.

Stress Tests

The SUNPP NON-TECHNICAL SUMMARY (2015) mentioned the EU Stress Tests: Following the accident at the Fukushima Daiichi Unit 1 in Japan, the European Council on 24 March 2011 decided that a comprehensive safety and risk assessment will be conducted for all EU nuclear plants. The European Nuclear Safety Regulators Group (ENSREG) and the European Commission achieved consensus on the stress test specifications. The objective of the stress tests was to assess in detail extreme natural hazards and their combinations to prevent severe accidents resulting from their impact upon plant safety functions.

The Regulatory Authority of Ukraine in collaboration with the State Inspectorate for Safety under man-induced accidents and NNEGC "Energoatom" has elaborated an action plan for a special-purpose out-of-time safety assessment and further safety enhancement of Ukraine Power Units considering lessons learned from the Fukushima-1 disaster. Pursuant to this Plan a special-purpose out-of-time safety assessment was performed at all Ukrainian operating power units. The stress-test results are depicted in a National Report of Ukraine prepared by the Regulatory Authority.

4.2 Discussion

The provided EIA documents provide information about Design Basis Accidents including the scenarios, the releases and the consequences. However, the information about Beyond Design Basis Accidents are very limited. Neither the scenarios nor the possible source terms are provided.

According to SNRIU (2016), the Safety Analysis Reports (SAR), its review and assessment which were conducted by SNRIU allow the following conclusions:

- the units are operated safely with an acceptable risk level. The SAR reports prove that the requirements for reactor safety imposed by the design, scientific and technical documentation and international practices are adequately fulfilled;
- the operator has analysed deviations from current regulatory requirements and has identified appropriate compensatory actions to allow operation of power units within design limits without their shutdown for eliminating the deviations;
- implementation of safety improvements has already resulted in decrease in CDF and LERF for all NPP units.

The above-mentioned conclusion of the SNRIU (power units are operated safely with an acceptable level of risk) cannot be agreed with on the basis of the available information.

According to SNRIU (2016), the **C(I)SIP** was complemented with a series of measures to ensure fuel heat removal during severe accidents (measures for steam generator and spent fuel pool makeup, operability of essential service water system in case of water discharge in spray pools) and emergency power supply using mobile diesel generators in SBO conditions. The C(I)SIP also includes measures on qualification for harsh environments of components that may be involved in severe accident management strategies for primary system makeup under loss of power and/or ultimate heat sink, corium retention in the reactor pressure vessel, etc. In total, *Energoatom* shall implement 101 new measures aimed at preventing accidents similar to the accidents at all units of the Fukushima Daiichi NPP. On top of this the operator shall perform 93 new fire protection measures based on requirements imposed after the Fukushima Daiichi accident.

However, as described in chapter 7.2, the implementation of the measures is still not finished. Furthermore, and even more importantly state of the art safety standard such as “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.

Accident Analyses

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

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

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

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

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

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

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

Containment integrity

According to ENSREG (2015), maintaining containment integrity under severe accident conditions remains an important issue for accident management. Filtered containment venting is a well-known approach to prevent containment overpressure failure in most light water reactor (LWR) and has already been implemented in several countries. It is not implemented at unit 3 of the SUNPP.

There are different approaches for cooling and stabilizing molten core available, but not for the VVER-1000 units so fare. 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 for the results was postponed from 2015. It is not known whether there will be any result.

The EIA documents should explain how the safety issues that endangered the containment integrity (containment bypass scenarios, cliff-edge effects in shutdown states) are solved. As far as can be seen from the documentation 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.

Stress Tests

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

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

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

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

The Ukrainian NAcP of 2013 listed 32 measures. A new measure (No. 33: Implementation of a Reactor Pressure Vessel External Cooling System for the VVER 440 reactors) was added to the NAcP in 2020. (SNRIU 2020a)

A number of measures were defined before the Fukushima event and are subject to the on-going "Comprehensive (Integrated) Safety Improvement Program for Ukrainian NPPs" (C(I)SIP). (See also chapter 7.2) Measures identified from the lessons of the Fukushima accident and of the ENSREG stress tests review have been incorporated into the C(I)SIP. The program was extended by the Cabinet of Ministers of Ukraine in 2019 until 2023 because of delays in obtaining the EBRD/Euratom loan for partial funding of C(I)SIP, difficulties in tenders for equipment purchase and expansion of the program with post-Fukushima measures. (SNRIU 2020a)

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

The evaluation of the Ukrainian NPPs in the light of the Fukushima accident and in accordance with the ENSREG stress tests specification has revealed a number of serious shortcomings.

The stress tests revealed that in case of **Station Blackout (SBO)** reliable measures to prevent core damage do not exist. In case of loss of all power supply (SBO) the time span for operator actions to prevent core damage is only 3.5 to 4 hours.[4] The time available until the fuel stored at the Spent Fuel Pool (SFP) heats up and reaches temperatures above the design limits is 6.5 hours for unit 1 and 2, and 7.5 hours for unit 3.

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

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

- Improvement of the emergency power supply in long-term loss of power (for units 1+2)
- Measures to ensure SG makeup from mobile pumping units (MDGPUs) in case of long-term Station Blackout (SBO)
- Measures to ensure SFP makeup from mobile pumping units (MDGPUs) in case of long-term Station Blackout (SBO)
- Improvement of the functionality of safety relevant equipment fed from the service water system
- Provision of instrumentation during and after accidents (accident and post-accident monitoring system) for unit 1
- Development and Implementation of symptom-oriented emergency operating procedures (EOPs) for management of design-basis and beyond design-basis accidents in low power and shutdown states.
- Replacement of self-contained air conditioners by those qualified for harsh environments and seismic impacts

The implementation of the following measures is still on-going:

- Improvement of the emergency power supply in long-term loss of power (for units 3)
- Detailed analyses of primary system makeup in case of loss of power and/or ultimate heat sink.
- Provision of instrumentation during and after accidents (accident and post-accident monitoring system) (for unit 2 and 3)

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

- Prevention of early containment bypassing in case of molten corium spread to the containment.
- Containment hydrogen control systems for beyond design-basis accidents were implemented.
- Development and implementation of hydrogen mitigation measures for beyond design-basis accidents)

- Implementation of a containment venting system for unit 1 and 2[5]

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

- Implementation of a containment venting system for unit 3

Furthermore, the following analysis should be performed, the time schedules for necessary back-fitting are not mentioned:

- Analysis of the strategy for possible corium confinement within the reactor pressure vessel (Deadline 2023) (postponed from 2015)
- Analysis of the need and possibility to qualify power unit components that may be involved in severe accident management for harsh environments is ongoing (Deadline 2021) (postponed from 2015)
- Detailed analysis and development of conceptual solutions on management with large volumes of contaminated water is ongoing (Deadline 2022) (postponed from 2016)
- Analysis of severe accident phenomena based on available experimental data and improvement of computer models is planned (Deadline 2024) (postponed from 2017)

Clearly the next several years will be the prolongation of the status quo: No appropriate measures are in place to prevent core melt accident and in case of a core melt accident no measures are available to prevent large releases.

Source Term for BDBAs

According to the SUNPP NON-TECHNICAL SUMMARY(2015), an analysis of severe beyond design accidents as a part of the safety analysis in the Comprehensive (integrated) Safety Upgrade Program" (C(I)SUP) were conducted. However, the provided EIA documents do not contain. the source term of the Beyond Design Basis Accidents (BDBAs) for any SUNPP unit.

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

Emergency shutdown at SUNPP unit 3 and fuel issues

Unit 3 at the South Ukraine NPP underwent an emergency shutdown on 27 November 2016. While the cause of the scram was not revealed, Russian experts

[5] In September 2018, a first-of-a-kind installation of a containment filtered venting system for VVER-1000 reactors in Ukraine was completed at South Ukraine 1 and 2. The containment filtered venting system (CFVS) is a dry filtration method that acts as the last barrier for minimising release of radioactive material to the environment should all other systems fail. It is designed and delivered by Westinghouse to protect the containment and facility simultaneously, by depressurising the containment to prevent it from ultimate failure in slow over-pressurisation scenarios. (NEI 2019a)

noted that unit 3 was one of the Ukrainian reactors currently using Westinghouse-manufactured nuclear fuel and that the unit had a long history of problems resulting from this.

The first six fuel assemblies were delivered to the South Ukraine NPP in 2005 "as humanitarian aid, free of charge". The assemblies were placed into the core of the VVER-1000 reactor together with Russian fuel for a period of "pilot operation". They were the test assemblies for a larger batch of 42 expected for delivery in 2009. However, Energoatom complained about the quality of the US fuel, and after prolonged negotiations Westinghouse agreed to improve the first six assemblies. DOE announced in 2007 that it would supply the announced 42, which would be manufactured at the Westinghouse facility in Sweden, and a commercial deal was agreed in 2008 for Westinghouse to supply 630 assemblies for three units at South Ukraine.

However, in late June 2012 Energoatom reported technical problems at South Ukraine units 2 and 3, where the assemblies were on test after a routine inspection revealed that they had suffered structural damage. They were removed and replaced with Russian-made fuel assemblies. Westinghouse submitted a proposal to Ukrainian State Nuclear Regulatory Inspectorate (SNRI) to redesign the assemblies, but inspectors later found further defects and SNRI reacted by banning the use of Westinghouse assemblies pending a damage assessment investigation.

With the regime change in Kiev, however, Ukraine in April 2014 renewed the 2008 contract with Westinghouse. The contract was extended to 2020 with the aim of replacing 25% of the Russian fuel. Westinghouse fuel was reloaded into South Ukraine unit 3 in 2015 with plans to extend its use to other reactors. (NEI 2016a)

4.3 Conclusions, questions and preliminary recommendations

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

4.3.1 Questions:

- ***Q 22:** What are the source terms of the possible BDBAs calculated in the probabilistic safety analyses (PSA) 2 including releases from the spent fuel pools?*
- ***Q 23:** 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?*
- ***Q 24:** What are the parameters of the maximum aircraft crash (plane mass and speed) the buildings of SUNPP can withstand?*
- ***Q 25:** 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?*
- ***Q 26:** Which design basis accidents can develop into a beyond design basis accident?*
- ***Q 27:** Which accidents scenarios with the loss of containment integrity or containment bypass are physical possible for the units of the SUNPP?*
- ***Q 28:** Which additional measures are envisaged to avoid large releases in case of an accident?*
- ***Q 29:** 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?*

4.3.2 Preliminary Recommendations:

- **PR 9:** 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.
- **PR 10:** It is recommended to provide the following information concerning accident analyses and the results of the PSA (Level 1, 2 und 3):
  a) Core damage frequency (CDF) and large (early) releases frequency (L(E)RF)
  b) Contribution of internal events as well as internal and external hazards to CDF and L(E)RF
  c) List of the beyond design basis accidents (BDBAs)
  d) Source terms of all possible BDBAs including releases from the spent fuel pools
  e) Time spans to restore the safety functions after the loss of heat removal and/or station-blackout and cliff edge effects.

5 ACCIDENTS DUE TO EXTERNAL HAZARDS

5.1 Treatment in the EIA documents

The EIA documents available to the experts contain very little and mostly general information about site characteristics, site-specific hazards and the protection of the SUNPP against external hazards.

The experts have access only to the chapter *"Transboundary impacts of SUNPP in standard operation and in emergency situations within the requirements of the Espoo Convention"* of the SUNPP EIA REPORT (2015). Chapters potentially dealing with accidents resulting from external hazards are not included in this document which was made available. The cited document states that the decision on the lifetime extension of SUNPP is based on the results of the periodical safety re-assessment reflected in the Periodical Safety Re-Assessment Report (PSRAR) and on the positive conclusion of the Ukrainian Regulatory Authority for Nuclear and Radiation Safety (p. 5 of the cited document). The PSRAR is said to include a dedicated report on hazard analysis (chapter SF-7 Internal and external hazard analysis; cited in SUNPP NON-TECHNICAL SUMMARY 2015 p. 7).

SUNPP NON-TECHNICAL SUMMARY (2015) claims that possible consequences of all different types of design basis and beyond design basis accidents do not violate *"effective regulations for accidental releases"* beyond a *"buffer area".* The document further concludes that *"in case of SUNPP power units lifetime extension the transboundary impacts potentially requiring a response are excluded"* (p. 74).

The limited information on natural hazards provided by the EIA documents is summarized in the following paragraphs.

Seismic hazards

According to REPORT CONSULTATIONS (2018, p. 44) seismic hazards were analysed based on the following data:

- data of earthquake activity in the Ukraine collected through *"long-term observations"* ;
- analysis of data from the plant's seismic monitoring network;
- data on geodynamics, tectonics, geology and engineering;
- seismic microzoning of the territory.

With respect to seismotectonic hazards the SUNPP NON-TECHNICAL SUMMARY (2015) claims that neotectonic, geodynamic and seismic impacts do not cause any problems for SUNPP's operation (p. 73). Potential threats arising from active faults are excluded by inferring that no fault moved in the last 10.000 to 20.000 years (p. 29).

Flooding

SUNPP is located on the shore of the reservoir lake of the Oleksandrivka Hydropower Plant (Oleksandrivka HPP) and next to the Pivdennyi Buh River (SUNPP NON-TECHNICAL SUMMARY 2015, p. 41-42). The Summary concluded that river floods may be unlikely. The report, however, discusses negative effects on the reservoir such as suspended particles and sediment accumulation in the reservoir lake. Rising water levels of the Tashlyk and Oleksandrivka water storages are not expected to have adverse effects on the SUNPP (p. 73).

Meteorological hazards

SUNPP NON-TECHNICAL SUMMARY (2015, p. 28) notes that the area around SUNPP is subjected to significant temperature increases as indicated by an average temperature increase for about 2°C over the past 30 years.

5.2 Discussion

The documents available to the experts do not contain a systematic assessment of natural hazards. The mention of natural hazards is limited to seismic hazards (e.g., REPORT CONSULTATIONS 2018, p. 44), river floods (TECHNICAL SUMMARY 2015, p. 41-42) and temperature rise (SUNPP NON-TECHNICAL SUMMARY 2015, p. 28). The submitted documents lack information on the types of hazards or hazard combinations which are relevant to the SUNPP site and the severity of hazards, the definition of adequate design basis events as well as the protection of SUNPP against natural hazards. EIA documents should provide information on external flooding caused by river floods, all types of extreme meteorological phenomena and possible hazard combinations.

The conclusion that possible consequences of all types of design basis and beyond design basis accidents will not violate effective regulations for accidental releases beyond a "buffer area" and that "transboundary impacts potentially requiring a response" are excluded (SUNPP NON-TECHNICAL SUMMARY 2015, p. 74) is not demonstrated for any external hazard by comparing hazard levels, design basis values and proving adequate protection of SSCs important to safety.

It is not clear whether or to what extent site-specific natural hazards were dealt with as part of Periodic Safety Reviews (PSRs), the Periodical Safety Re-Assessment Report (PSRAR) or as part of the LTO project. WENRA (2021) requires a regular review of possible effects of natural hazards at least as part of the PSAs which are carried out a time interval of ten years (WENRA 2021, Issue P; WENRA, The results of the review should, if necessary, lead to the update of the design basis and be included in the assessment of beyond-design basis accidents (DEC analysis; WENRA 2015, 2021). However, it is not clear from the available documents whether this process was carried out for the effects of natural hazards as part of the PSRs and/or the LTO project.

Seismic hazards

Information from the EU Stress Tests (ENSREG 2012) indicates that SUNPP was originally designed for a DBE with exceedance probability of 10^{-4} per year (called Maximum Calculated Earthquake, MCE, in Ukrainian documents) of Intensity I=6 on the MSK-64 intensity scale which corresponds to a peak ground acceleration PGA=0.05g. Hazard reassessments carried out in 2009-2010 determined a new value of PGA=0.093g due to the exposure of the SUNPP to the distant Vrancea seismic source. ENSREG (2012) further indicates that only very small safety margins with respect to seismic loads were in place at the time of the Stress Tests by stating the resistance of the primary coolant piping, the pressurizer surge line and the reactor containment with PGA=0.1g. It is also mentioned that the design level for SUNPP should be increased to 0.12g. Compliance with the updated seismic design basis of PGA=0.12g was one of the conditions for the lifetime extension of SUNPP beyond 30 years. For the LTO the operator was required to fully implement measures to ensure robustness of equipment, piping, buildings and structures required for the main safety functions to seismic impacts of 0.12g (regulator's Resolution No. 13 of 24-25 November 2011). At this point it is not known if the corresponding upgrading measures have been completed.

The update of the seismic design basis was initiated with a view to the seismic hazard resulting from earthquakes in the Vrancea zone (Romania), about 300km WSW of the SUNPP. The Vrancea zone is known for causing frequent and very strong earthquakes (e.g., 1802, Mw=7.9; 1940, Mw=7.7; 1977, Mw=7.2). These earthquakes have caused relatively strong ground shaking at even distant locations due to their large hypo-central depth of several hundred kilometres.

With respect to active faults in the area of SUNPP, SUNPP NON-TECHNICAL SUMMARY (2015, p. 29) states that threats arising from active faults are excluded by inferring that no fault moved in the last 10.000 to 20.000 years. It must be noted that the time interval 10.000 to 20.000 years is too short to exclude active faulting in intraplate areas such as the Ukraine. IAEA (2010, 2015) proposes to consider much longer periods, e.g. Pliocene – Quaternary to present, to define a fault as active (capable) or inactive.

Flooding

The lack of information in the EIA documents does not allow a discussion of potential flooding hazards. It is unknown if flooding hazards were analysed in accordance with IAEA (2011) and WENRA (2015; 2016b; 2021).

Extreme weather

Documents available to the experts do not contain information on regulatory basis, safety requirements and protection of SUNPP against meteorological hazards. The EU Stress Tests (ENSREG 2012) and documents available from the EIA for the lifetime extension of the reactors Rivne 1&2 (EIA REPORT BOOK 1 2018) suggest that international and national standards such as the RNiP (СНиП) building codes are used as design standards for the Ukrainian NPPs to ensure protection against wind, flooding by precipitation, snow loads etc. These codes are much less stringent than IAEA guidelines (IAEA 2011) and the WENRA Safety Reference Levels that require protection against design basis events with occurrence probabilities of 10^{-4} per year (WENRA, 2021).

The mentioning of a significant average temperature increase for about 2°C over the last about 30 years (SUNPP NON-TECHNICAL SUMMARY 2015, p. 28) indicates that the area around SUNPP is subjected to significant impacts of climate change. The EIA documents, however, provide no information if potentially hazardous effects of climate change such as extreme temperatures of air and cooling water have been analysed. WENRA (2016a) suggests considering effects of climate change in the assessment of meteorological hazards.

5.3 Conclusions, questions and preliminary recommendations

Information on natural hazards that have potentially negative impacts on the safety of the SUNPP is insufficient. The EIA documents do 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.

5.3.1 Questions:

- ***Q 30:*** *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).*
- ***Q 31:*** *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?*
- ***Q 32:*** *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?*
- ***Q 33:*** *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?*
- ***Q 34:*** *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?*
- ***Q 35:*** *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?*
- ***Q 36:*** *Has the upgrading of the seismic resistance of all SSCs important to safety to the new DBE of PGA=0.12g as announced in the Stress Tests been completed for SUNPP?*
- ***Q 37:*** *Which faults in the region around SUNPP have been analysed with respect to active faulting, and what are the results of these investigations?*
- ***Q 38:*** *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)?*
- ***Q 39:*** *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)?*
- ***Q 40:*** *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?*

5.3.2 Preliminary Recommendations:

- **PR 11:** 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 Doel 1 & 2 are taken into account.
- **PR 12:** Whether all hazard combinations were taken into account in the assessment of the site, as required by WENRA (2021) and further explained by WENRA (2015) 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.
- **PR 13:** 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 2016a).
- **PR 14:**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.
- **PR 15:** The expert team recommends the application of the WENRA approach of analysing Design Extension Conditions (DEC) for natural hazards and updates of the protection concepts against natural hazards. DEC are not analysed in the available EIA document. This is in violation of the WENRA requirement that DEC analysis shall be undertaken with the purpose of further improving the safety of existing nuclear power plants and enhancing their capability to withstand more challenging events or conditions than those considered in the design basis.

6 ACCIDENTS WITH THIRD PARTIES' INVOLVEMENT

6.1 Treatment in the EIA documents

Chapter 5 of the SUNPP NON-TECHNICAL SUMMARY(2015) deals with the "impact on the anthropogenic environment" explaining the probability and potential risks of terrorist attacks have not been addressed in the reports on SUNPP safety analysis.

The SUNPP NON-TECHNICAL SUMMARY (2015) also stated that the physical protection and monitoring system operate in such a manner that the likelihood for the occurrence of such accidents was considered as being very low.

6.2 Discussion

Nuclear power plants are in general vulnerable to a broad spectrum of possible attacks. Terrorist attacks or acts of sabotage on SUNPP may have significant impacts. However, in the provided EIA documents malicious acts of third parties against the SUNPP and their possible effects are not discussed. The REPORT CONSULTATION (2018) confirmed that terrorist acts have not been addressed in the PSR report. The physical protection system has been significantly strengthened after Russia's aggressive actions in eastern Ukraine; it is considered being effective to exclude the probability of a terrorist attack.

However, in comparable EIA procedures such events were addressed to some extent. (UMWELTBUNDESAMT 2018)

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

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

No studies about the consequences of a deliberate aircraft crash against the SUNPP are available. It is, however, possible to draw conclusions from the results of studies carried out in other countries e. g. Germany and general considerations regarding the possible effects of such an aircraft crash. A generic study commissioned by the German Federal Environment Ministry revealed that even a small commercial aircraft (e.g. an Airbus A320) would cause major damage to the reactor building with a wall thickness of 0.6 to 1 metres. (BMU 2002)

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

Although precautions against 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.

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

SNRIU (2016) referred to the ongoing military actions in eastern Ukraine explaining that SNRIU together with the relevant ministries and continuously work to strengthen the physical protection of nuclear installations. At present, available law enforcement can ensure NPP protection against external actions, such as military aggression, sabotage and terrorist acts, criminal assaults. In 2015, exercises were held at all NPPs to train actions in case of sabotage under different situations. All special forces keeping guard at NPPs participated with relevant rotation in the anti-terrorist operation to gain field experience for service. The documents on protection of the most important facilities have been revised and improved at all Ukrainian NPPs.

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

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

In the NTI Index scores of 100 represent the highest possible score. Ukraine with a total score of 65 points only ranked 29 out of 47 countries, which indicates a low protection level. Table 6 shows some details about the NTI Index for Ukraine.

Table 7: The 2020 Nuclear Security Index for Ukraine (NTI 2020)

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

It has to be pointed out that the low scores for "Insider Threat Prevention" and "Cybersecurity" indicate deficiencies in these issues.[6]

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

Physical protection

The IAEA plays a key role in helping states protect their civilian nuclear materials and facilities. It supports States by undertaking and organizing advisory security assessment and peer-review missions through its **International Physical Protection Advisory Service (IPPAS**). An IPPAS mission is an assessment of the existing practices in a state, in the light of relevant international instruments and IAEA nuclear security publications, and an exchange of experience and accepted international practices aimed at strengthening the nuclear security organization, procedures and practices being followed by a State. (IAEA 2014) To date, no International Physical Protection Advisory Service (IPPAS) has been conducted in Ukraine. (IAEA 2021)

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

6.3 Conclusions, questions and preliminary recommendations

Terrorist attacks and acts of sabotage can have significant impacts on nuclear facilities and cause severe accidents – also on the 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 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 29 out of 47 countries, which indicates a low protection level. It has to be pointed out that the low scores for "Insider Threat Prevention" and "Cybersecurity" indicate deficiencies in these issues. It is recommended to invite the International Physical Protection Advisory Service (IPPAS) of the IAEA that assisted states, in strengthening their national nuclear security regimes, systems and measures.

6.3.1 Questions:

- ***Q 41****: What are the requirements with respect to the NPP design against the deliberate crash of a commercial aircraft?*
- ***Q 42:*** *Against which external attacks must the reactor building, and other safety relevant buildings be designed? Is this protection still guaranteed despite adverse ageing effects?*
- ***Q 43:*** *Is a peer-review mission of the IAEA International Physical Protection Advisory Service (IPPAS) planned?*

6.3.2 Preliminary Recommendations:

- **PR 16**: 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.
- **PR 17**: 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.

7 TRANS-BOUNDARY IMPACTS

7.1 Treatment in the EIA documents

According to the EIA documents, no non-acceptable negative trans-boundary impacts could be identified:

"This analysis shows that currently no reasons to be concerned about possible SUNPP negative impact on the neighbouring countries in case of any accident scenario, as well as assumptions for such concern in future can be identified." (SUNPP NON-TECHNICAL SUMMARY 2015, p. 74)

7.2 Discussion

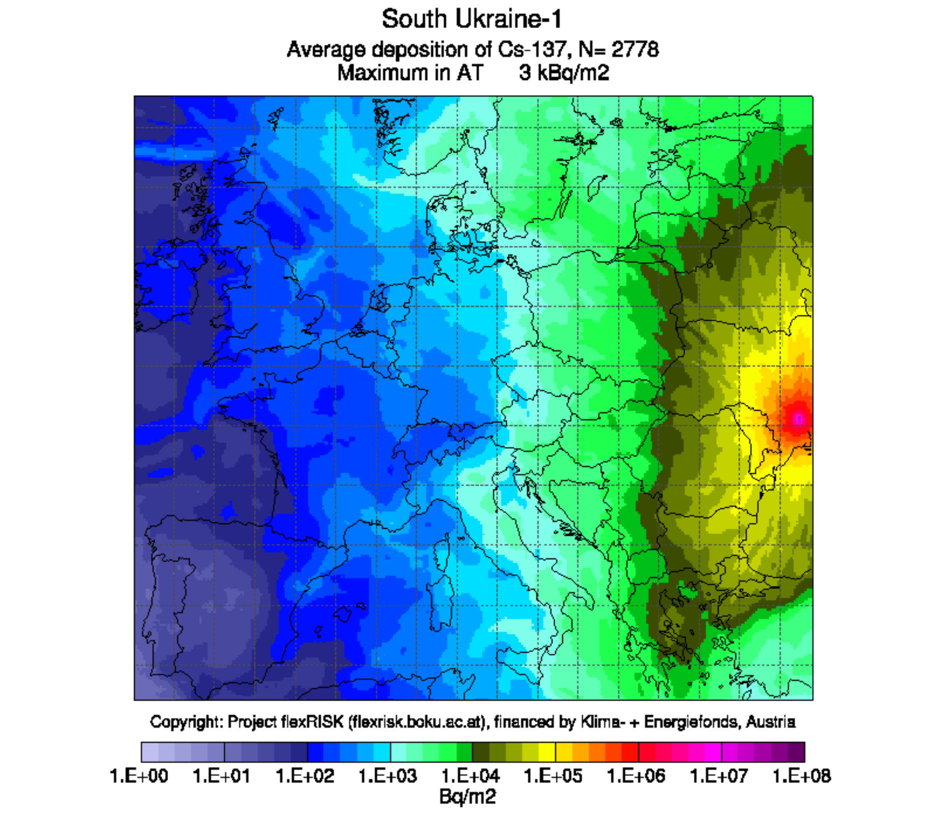
As already discussed in chapter 8 of this expert statement, in order to assess the consequences of BDBAs, it is necessary to analyse a range of severe accidents, including those with containment failure and containment bypass. These kinds of severe accidents are possible for the VVER-1000 reactor type. A systematic analysis of BDBAs is missing in the provided EIA documents.

The project flexRISK made an assessment of source terms and identified for SUNPP a possible source term of 204.22 PBq Cs-137. (FLEXRISK 2013) This source term is calculated with respect to the behavior of the plant in case of a severe accident and the possible release.

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

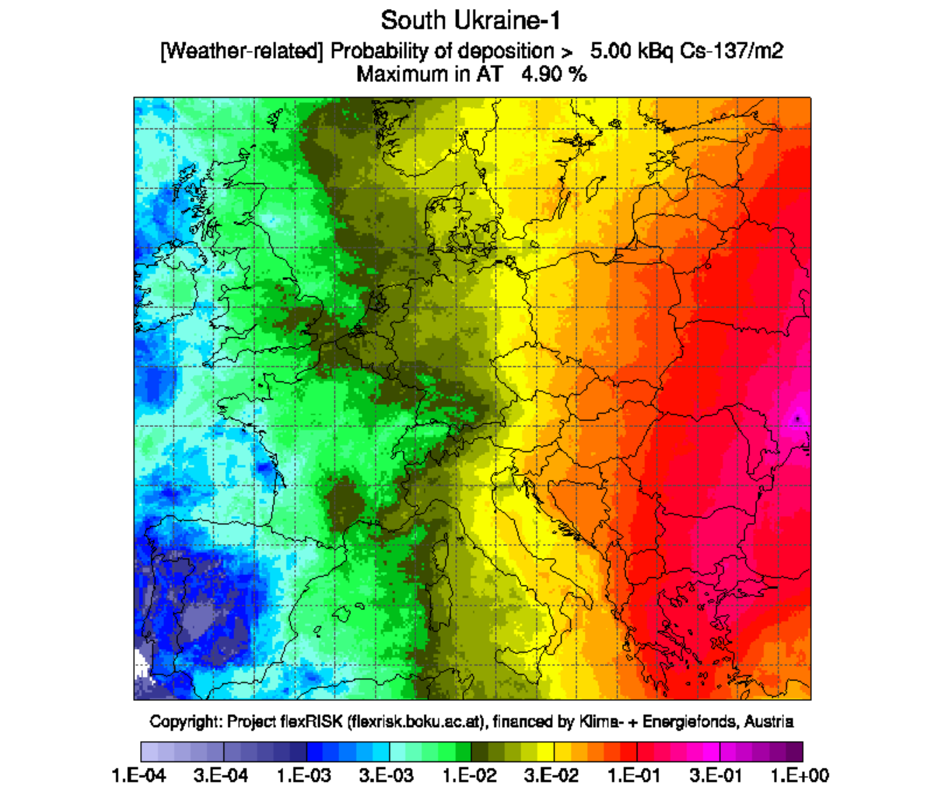
Figure 4 illustrates the average deposition of Cs-137 after a severe accident at SUNPP 1 with the Cs-137 release of 204.22 PBq. Such an accident could result in a considerable contamination of the Austrian territory; the average deposition of Cs-137 in the simulation is up to 3,000 Bq/m².

Figure 4: Average deposition of Cs-137 after a hypothetical BDBA in SUNPP 1.



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

Figure 5: Weather-related probability for a contamination exceeding 5 kBq Cs-137/m2as a consequence of a severe accident at SUNPP 1.



Source: *http://flexrisk.boku.ac.at/en/evaluationAggUnit.phtml* umweltbundesamt flexRISK determined the weather-related probability for a contamination of Austrian territory with more than 5 kBq Cs-137/m^2 with 4.9% (see Figure 5). The weather-related probability for a contamination above37 kBq Cs-137/m^2 is 1.68%, for more than 185 kBq Cs-137/m^2 0.36%, respectively.

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

Table 8: Levels for the agricultural countermeasures A07 (BMLFUW 2014)

	I-131 Bq*h/m^3	**I-131 Bq/m^2**	**Cs-137 Bq*h/m^3**	**Cs-137 Bq/m^2**
Start of measure A07	170	700	350	650

A contamination of 5 kBq Cs-137/m^2 as shown in Figure 5 is much higher than the level for the Cs-137 contamination in the above table, therefore agricultural countermeasures could be necessary on Austrian territory in case of a severe accident at the South Ukraine site.

To exclude the possibility of transboundary severe impacts, including the necessity of agricultural countermeasures, dispersion calculations and dose calculations should be performed for distances up to Austria. Those figures need to be put into relation to the Austrian levels from the catalogue of countermeasures (BMLFUW 2014), but also the dose levels specified in the Austrian Emergency Plan (BMK 2020). Also proof has to be provided that releases caused by accidents are excluded; otherwise calculations with the highest possible source term and under the assumption of the most negative weather condition for Austrian territory are necessary.

7.3 Conclusions, questions and preliminary 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.

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 concerning trans-boundary effects 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.

7.3.1 Questions:

- ***Q 44:*** *Please provide the quantitative results of the calculated ground deposition of I-131 and Cs-137 for the distance to Austria.*

7.3.2 Preliminary Recommendations:

- **PR 18**: It is recommended to perform a dispersion calculation using a source term that is based on specific severe accident analyses of the SUNPP

8 SUMMARY OF QUESTIONS AND PRELIMINARY RECOMMENDATIONS

8.1 Procedure and alternatives

8.1.1 Questions:

- ***Q 1**: How long is the maximal foreseen lifetime extension of all SUNPP units?*
- ***Q 2**: What are the further steps in the EIA procedure and in the licensing procedure?*
- ***Q 3**: 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?*

8.1.2 Preliminary Recommendations:

- **PR 1**: Ukraine should provide adequate information on the EIA procedure and the further licensing procedure.
- **PR 2**: Alternatives of the lifetime extensions and the no-action alternative should be assessed in the EIA documents.
- **PR 3**: It is recommended to enable public participation in environmental assessments of nuclear projects according to the requirements of the Espoo Convention at a time when all options are still open, that is before a decision is taken.
- **PR4:** It is recommended not to issues the EIA decision until the deficiencies of the EIA have been solved.

8.2 Spent Fuel and radioactive waste

8.2.1 Questions:

- ***Q 4**: 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?*
- ***Q 5**: What is the status of the final disposal for spent fuel?*
- ***Q 6:** 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?*
- ***Q 7**: What amounts and activities of LILW are expected to arise from lifetime extension of SUNPP?*
- ***Q 8**: Are there enough capacities in interim and final storages for the LILW from SUNPP lifetime extension?*
- ***Q 9**: What is the status of the treatment facilities, interim and final storages for radioactive waste?*

- ***Q 10:*** *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?*
- ***Q 11:*** *How much spent fuel from SUNPP will be sent to Russia for reprocessing in total?*

8.2.2 Preliminary Recommendations:

- **PR 5:** 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.

8.3 Long-term operation of reactor type

8.3.1 Questions

- ***Q 12:*** *What is the status of the LTO for the unit 3 of the South Ukraine NPP?*
- ***Q 13:*** *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?*
- ***Q 14:*** *What are the specific findings of the ageing management programme for SUNPP unit 1 to 3? Are there any differences between the units?*
- ***Q 15:*** *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?*
- ***Q 16:*** *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?*
- ***Q 17:*** *Is a systematic evaluation of the SUNPP design deviations from the current international safety standards and requirements envisaged?*
- ***Q 18:*** *Why is the number of measures of the C(I)SIP for SUNPP unit 3 is higher than for SUNPP units 1 and 2?*
- ***Q 19:*** *When will the WENRA RL be fully implemented in the Ukrainian regulations? Will the application of the RL be binding?*
- ***Q 20:*** *When will be reviewed whether the RL will be meet for the SUNPP?*
- ***Q 21:*** *Which WENRA Documents will be mandatory for lifetime extensions?*

8.3.2 Preliminary Recommendations:

- **PR 6:** It is recommended to implement all available design improvements of VVER-1000 reactor for the SUNPP.

- **PR 7:** 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.
- **PR 8:** It is recommended to also 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.

8.4 Accident analysis

8.4.1 Questions:

- ***Q 22:*** *What are the source terms of the possible BDBAs calculated in the probabilistic safety analyses (PSA) 2 including releases from the spent fuel pools?*
- ***Q 23:*** *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?*
- ***Q 24:*** *What are the parameters of the maximum aircraft crash (plane mass and speed) the buildings of SUNPP can withstand?*
- ***Q 25:*** *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?*
- ***Q 26:*** *Which design basis accidents can develop into a beyond design basis accident?*
- ***Q 27:*** *Which accidents scenarios with the loss of containment integrity or containment bypass are physical possible for the units of the SUNPP?*
- ***Q 28:*** *Which additional measures are envisaged to avoid large releases in case of an accident?*
- ***Q 29:*** *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?*

8.4.2 Preliminary Recommendations:

- **PR 9:** 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.
- **PR 10:** It is recommended to provide the following information concerning accident analyses and the results of the PSA (Level 1, 2 und 3):
  a) Core damage frequency (CDF) and large (early) releases frequency (L(E)RF)
  b) Contribution of internal events as well as internal and external hazards to CDF and L(E)RF
  c) List of the beyond design basis accidents (BDBAs)
  d) Source terms of all possible BDBAs including releases from the spent fuel pools
  e) Time spans to restore the safety functions after the loss of heat removal and/or station-blackout and cliff edge effects.

8.5 Accidents due to external hazards

8.5.1 Questions:

- ***Q 30:*** *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).*
- ***Q 31:*** *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?*
- ***Q 32:*** *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?*
- ***Q 33:*** *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?*
- ***Q 34:*** *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?*
- ***Q 35:*** *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?*
- ***Q 36:*** *Has the upgrading of the seismic resistance of all SSCs important to safety to the new DBE of PGA=0.12g as announced in the Stress Tests been completed for SUNPP?*
- ***Q 37:*** *Which faults in the region around SUNPP have been analysed with respect to active faulting, and what are the results of these investigations?*
- ***Q 38:*** *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)?*
- ***Q 39:*** *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)?*
- ***Q 40:*** *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?*

8.5.2 Preliminary Recommendations:

- **PR 11:** 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 Doel 1 & 2 are taken into account.
- **PR 12:** Whether all hazard combinations were taken into account in the assessment of the site, as required by WENRA (2021) and further explained by WENRA (2015) 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.
- **PR 13:** 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 2016a).
- **PR 14:**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.
- **PR 15:** The expert team recommends the application of the WENRA approach of analysing Design Extension Conditions (DEC) for natural hazards and updates of the protection concepts against natural hazards. DEC are not analysed in the available EIA document. This is in violation of the WENRA requirement that DEC analysis shall be undertaken with the purpose of further improving the safety of existing nuclear power plants and enhancing their capability to withstand more challenging events or conditions than those considered in the design basis.

8.6 Accidents with third parties’ involvement

8.6.1 Questions:

- ***Q 41****: What are the requirements with respect to the NPP design against the deliberate crash of a commercial aircraft?*
- ***Q 42:*** *Against which external attacks must the reactor building, and other safety relevant buildings be designed? Is this protection still guaranteed despite adverse ageing effects?*
- ***Q 43:*** *Is a peer-review mission of the IAEA International Physical Protection Advisory Service (IPPAS) planned?*

8.6.2 Preliminary Recommendations:

- **PR 16**: 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.
- **PR 17**: 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.

8.7 Trans-boundary impacts

8.7.1 Questions:

- ***Q 44:*** *Please provide the quantitative results of the calculated ground deposition of I-131 and Cs-137 for the distance to Austria.*

8.7.2 Preliminary Recommendations:

- **PR 18**: 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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12 GLOSSARY

AAMS.................................Automated Ageing Management System

AM ....Ageing Management

AMP..................................Ageing Management Programme

BDBA.................................Beyond Design Basis Accident

Bq ....Becquerel

C(I)SIP...............................Comprehensive (Integrated) Safety Improvement Program

CDF...................................Core Damage Frequency

CRWP................................Complex for radioactive waste processing

CSFSF................................Centralized spent fuel storage facility (interim storage for spent fuel)

Cs-137 ....Caesium-137

DBA ....Design Basic Accident

DEC...................................Design Extension Conditions

DSFSF ....Dry Spent Fuel Storage Facility

EBRD ....European Bank for Reconstruction and Development

EC.....................................European Commission

ECR ....Emergency Control Room

EIA ....Environmental Impact Assessment

ENSREG ....European Nuclear Safety Regulators Group

EOP...................................Emergency Operating Procedures

EU ....European Union

EUR...................................European Utility Requirements

g..Gravitational acceleration of the Earth (9.82ms-²)

I... Earthquake intensity

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

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

I-131 ....Iodine-131

IAEA..................................International Atomic Energy Agency

ILW .... Intermediate level radioactive waste

INSC .... Instrument for Nuclear Safety Cooperation

IPPAS .... International Physical Protection Advisory Service

IVMR .... In-Vessel Melt Retention

IVR .... In-Vessel Retention

LLW .... Low level radioactive waste

LOCA .... Loss of Coolant Accident

LRF .... Large Release Frequency

LTO .... Long-Term Operation

LWR .... Light Water Reactor

MCR .... Main Control Room

MDBA .... Maximum Design Basis Accident

MDGPU .... Mobile Diesel Generators and Pumping Unit

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

NAcP .... National Action Plan

NDE .... Non-Destructive Examination

NDI .... Nondestructive Inspection

NPP .... Nuclear Power Plant

NTI .... Nuclear Threat Initiative

OBE .... Operating Base Earthquake

OZ .... Observation Zone (30km)

PBq .... PetaBecquerel

PGA .... Peak Ground Acceleration

PSA .... Probabilistic Safety Assessment

PSHA .... Probabilistic Seismic Hazard Assessment

PSR .... Preliminary Safety Report

PSR .... Periodic Safety Review

PWR .... Pressurized Water Reactor

RHWG .... Reactor Harmonization Working Group

RL..Reference Level

RPV ....Reactor Pressure Vessel

SAM ....Severe Accident Management

SAMG ....Severe Accident Management Guideline

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

SC.......................................Sealed Containment

SE NNEGC..........................State Enterprise National Nuclear Generating Company

SEA ....Strategic Environmental Assessment

SF.......................................Safety Factors

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

SG ....Steam Generator

SNRIU ....State Nuclear Regulatory Inspectorate of Ukraine

SPZ.....................................Sanitary Protection Zone (2.5km)

SSC ....Structure, Systems and Components

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

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

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

TBq ....Tera-Becquerel, E12 Bq

TCA ....Technical Condition Assessment

TLAA .... Time Limited Ageing Analysis

TPR ....Topical Peer Review

UNECE...............................United Nations Economic Commission for Europe

VVER ....Water-Water-Power-Reactor, Pressurized Reactor originally developed by the Soviet Union

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

ZNPP ....Zaphorizhzhya NPP

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