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NPP Zaporizhzhya

Lifetime Extension EIA

Expert Statement

Federal Ministry
Republic of Austria
Climate Action, Environment,
Energy, Mobility,
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pulswerk
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NPP ZAPORIZHZHYA LIFETIME-EXTENSION ENVIRONMENTAL IMPACT ASSESSMENT

Expert Statement

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REPORT
REP-0775

VIENNA 2021

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Title photograph © iStockphoto.com/imagestock

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

GZ: BMNT-UW.1.1.2/0019-I/6/2018

Publications For further information about the publications of the Umweltbundesamt please go to: https://www.umweltbundesamt.at/

Imprint

Owner and Editor: Umweltbundesamt GmbH
Spittelauer Laende 5, 1090 Vienna/Austria

This publication is only available in electronic format at https://www.umweltbundesamt.at/.

ISBN 978-3-99004-598-5

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SUMMARY

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

For the lifetime extension of Zaporizhzhya the Ukrainian side is conducting an Environmental Impact Assessment (EIA) under the Espoo Convention. Austria has been notified by Ukraine and decided to participate in the EIA. 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

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

According to the Espoo Convention it shall be ensured that the opportunity to participate provided to the public of the affected Party is equivalent to that provided to the public of the Party of origin. This has not been the case here because not all documents were provided. To the public in Ukraine more documents were made available, among those also newer documents.

The EIA documents that were submitted to Austria are from 2015 and therefore do not reflect the recent developments and they need to be updated.

The licenses for the lifetime extensions for ZNPP 1-5 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 ZNPP 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 stored at the interim dry storage DSFSF on site, capacities are sufficient for the lifetime extension. It has to be verified for how long the interim storage can be prolongated if no final repository or reprocessing possibilities will be available after the 50 years of interim storage.

The containers in the DSFSF are not placed in a building instead they are simply surrounded by a wall. Proof needs to be provided showing that this type of dry storage is designed to withstand external hazards and airplane crashes.

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 old structures, systems and components is a safety issue for the ZNPP units, 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 Topical Peer Review (TPR) "Ageing Management" under the Nuclear Safety Directive 2014/87/EURATOM, carried out in 2017, 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 ZNPP, the EIA documents do not deal with any of the safety issues of the VVER-1000 reactors. NPP designs that were developed in the 1980s, like the VVER-1000 reactors, only partly meet modern design principles concerning redundancy, diversity and physical separation of redundant subsystems or the preference of passive safety systems. The 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 EU Stress Tests had revealed already in 2011 that Ukrainian NPPs are compliant only with 172 of the 194 requirements according to the IAEA Design Safety Standards published in 2000. Implementation of necessary improvements is on-going in the framework of the Comprehensive (Integrated) Safety Improvement Program (C(I)SIP). The completion of the program was postponed several times. As of 31/03/2021 still a lot of measures have to be implemented. In spite of some progress, the program ran into a long delay. From a safety point of view, it is incomprehensible that the completion of the measure was not a prerequisite for the lifetime extension.

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 ZNPP. All in all, a significant gap remains between the required safety standard and the actual safety level of the ZNPP 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. These kinds of severe accidents are possible for 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. The Core Damage Frequency (CDF) and the Large Release Frequency (LRF) values show that almost every core melt accident will result in an accident with a large release of radioactive substances. Because of the outdated design of the VVER-1000, there are no effective measure in place to avoid a large release after a core melt accident.

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

The documents provided and available lead to the conclusion that a high probability exists for accident scenarios to 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 ZNPP.

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

Accidents due to external hazards

The documents available to the experts do not contain a systematic assessment of natural hazards, only seismic hazards are listed as 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 ZNPP site nor the severity of hazards, the definition of adequate design basis events with occurrence probabilities of 10^{-4} per year, and the protection of ZNPP against natural hazards. In addition to more detailed data on seismic hazards, information on external flooding caused by river floods and/or dam breaks upstream of the Dnjepr, all types of extreme meteorological phenomena including climate change and possible hazard combinations should be provided in an EIA process.

Information provided on natural hazards with potentially negative impacts on the safety of the ZNPP is therefore insufficient. It cannot be concluded from the EIA documents that the 6 units of ZNPP are adequately protected from the effects of natural hazards. Since Austria can be potentially affected by the consequences of accidents caused by natural hazards, this fact is relevant for the ongoing EIA process.

Accidents with third parties' involvement

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

Even if the current physical protection system that was increased significantly 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 ZNPP 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 ZNPP severe accidents including containment failure and containment bypass with releases considerably higher than assumed in the EIA document cannot be excluded. Such worst case accidents should be included in the assessment since their effects can be widespread and long-lasting and even countries not directly bordering Ukraine, 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 ZNPP.

ZUSAMMENFASSUNG

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

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

Während Österreich für eine UVP zur Lebensdauerverlängerung für die ZNPP Blöcke 3-6 notifiziert wurde, enthalten die zur Verfügung gestellten Dokumente vor allem Informationen zu den Blöcken 1 und 2 und für ZNPP als Ganzes. Es gilt zu klären, für welche Blöcke des ZNPP die UVP durchgeführt wird.

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, darunter auch Dokumente neueren Datums.

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 ZNPP 1-5 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 ZNPP erzeugt werden wird, ebenso fehlen umfassende Angaben zum Status der Konditionierungsanlagen, der Zwischenlager und Endlager für radioaktive Abfälle. Dazu sind weitere Information zur Verfügung zu stellen.

Abgebrannte Brennelemente werden im Trocken-Zwischenlager DSFSF am Standort gelagert, die Kapazitäten sind für die Lebensdauerverlängerung ausreichend. Es ist zu überprüfen, für wie lange der Betrieb des Zwischenlagers verlängert werden kann, sollte kein Endlager oder keine Wiederaufbereitungsmöglichkeit nach 50 Jahren Zwischenlagerung zur Verfügung stehen.

Die Behälter im DSFSF sind nicht in einem Gebäude aufgestellt, sondern nur von einer Mauer umgeben. Es ist der Nachweis zu erbringen, dass diese Art von Trockenlager auch gegen externe Gefahren und Flugzeugabstürze ausgelegt ist.

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

Langzeitbetrieb des Reaktortyps

Obwohl Alterung der alten Strukturen, Systeme und Komponenten ein Sicherheitsproblem für die Blöcke des ZNPP 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.

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 ZNPP auch ein Problem darstellt, befassen sich die UVP-Unterlagen nicht mit den Sicherheitsdefiziten der WWER-1000 Reaktoren. KKW Designs, die in den 80er-Jahren entwickelt wurden wie die WWER-1000, entsprechen bei Redundanz, Diversität 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.

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 die 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 ZNPP nicht angewandt. In Summe bleibt eine signifikante Kluft zwischen dem erforderlichen Sicherheitsniveau und dem tatsächlichen Sicherheitsniveau der Blöcke des ZNPP 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 oder 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.

Die Kernschadenshäufigkeit (CDF) und die Häufigkeit für große Freisetzungen (LRF) zeigen, dass nahezu jeder Kernschmelzunfall zu einem Unfall mit einer hohen Freisetzung an radioaktiven Stoffen führen wird. Aufgrund des veralteten Designs der WWER-1000 stehen keine effektiven Maßnahmen zur Verhinderung großer Freisetzungen nach einem Kernschmelzunfall zur Verfügung.

Dem Dokument ENSREG (2015) zufolge ist der Erhalt der 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 noch in keinem Block des ZNPP installiert wurde. Darüber hinaus verfügt ZNPP über kein System zur Kühlung und Stabilisierung des geschmolzenen Reaktorkerns. Im Rahmen der Stresstests sollte bis 2023 eine Strategie für einen möglichen Rückhalt der Kernschmelze innerhalb des Reaktordruckbehälters erarbeitet werden. Diese Deadline 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 ZNPP bestehen bleiben.

Ebenso unter Stand der Technik fällt die Verwendung der WENRA „Sicherheitszeile 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 ZNPP 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 ZNPP, über die Schwere der Gefahren, die Definition eines geeigneten Auslegungsstörfall-Ereignisses mit einer

Eintrittshäufigkeit von 10^{-4} pro Jahr und den Schutz von ZNPP 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 und/oder Dammbrüche flussaufwärts des Dnjepr, 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 ZNPP sind daher unzureichend. Es kann aus den UVP-Unterlagen nicht geschlossen werden, dass die die sechs Blöcke von ZNPP 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 ZNPP. Dennoch werden diese in den UVP-Unterlagen nicht erwähnt, während solche Ereignisse in vergleichbaren UVP-Berichten in einem gewissen Umfang angesprochen werden.

Terrorangriffe und Sabotageakte können nicht ausgeschlossen werden, auch wenn die nun bestehenden physischen Schutzsysteme 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 alle Reaktorgebäude von ZNPP 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 Sicherungsregime, Systeme und Maßnahmen unterstützt.

Grenzüberschreitende Auswirkungen

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

РЕЗЮМЕ

Запорізька атомна електростанція (ЗАЕС) розташована на річці Дніпро на лівому березі Каховського водосховища. Об’єкт розташований в Запорізькій області в Україні. На ЗАЕС працює шість реакторів типу ВВЕР-1000. Реактори були підключені до електромережі у період між 1984 та 1995 роками. АЕС належить Державному підприємству «Національна атомна енергогенеруюча компанія “Енергоатом”» (коротко — «Енергоатом»). ВП ЗАЕС є окремою структурною одиницею компанії «Енергоатом».

З метою продовжити строк експлуатації ЗАЕС, 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

Хоча Австрії було повідомлено про проведення ОВД щодо продовження строку експлуатації енергоблоків 3–6 ЗАЕС, надані документи містять інформацію здебільшого про блоки 1 та 2, а також про ЗАЕС в цілому. Слід пояснити, для яких енергоблоків ЗАЕС проводиться ОВД.

Відповідно до Конвенції Еспо, гарантується, що громадськості постраждалої Сторони надається така сама можливість участі, що й громадськості Сторони походження. У цьому випадку цього не сталося, оскільки були надані не всі документи. Громадськість в Україні має доступ до більшої кількості документів, серед яких також наявні й новіші документи.

Подані до Австрії документи ОВД датовані 2015 роком, тому не відображають останні події та рішення й потребують оновлення.

Ліцензії на продовження строку експлуатації енергоблоків 1–5 ЗАЕС 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 ЗАЕС, 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 зберігається у проміжному сухому сховищі відпрацьованого ядерного палива на місці. Ємність достатня для продовження строку експлуатації. Потрібно перевірити, на який часу можна продовжити використання проміжного сховища, якщо після 50 років проміжного зберігання не буде доступним кінцеве сховище чи можливості переробки.

Контейнери в проміжному сухому сховищі відпрацьованого ядерного палива не розміщуються в будівлі. Натомість вони просто оточені стіною. Потрібно надати підтвердження того, що такий тип сухого зберігання може протистояти зовнішнім небезпекам та аваріям літаків.

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 є питанням безпеки для блоків ЗАЕС, 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.

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 ЗАЕС, 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.

Вже у 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 ще має бути здійснено багато заходів. 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 ЗАЕС. Загалом, залишається значний розрив між необхідним стандартом безпеки та фактичним рівнем безпеки блоків ЗАЕС.

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. Подібні важкі аварії 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. Значення частоти пошкодження активної зони ядерного реактора та періодичності значних викидів свідчать, що майже кожна аварія з розплавом активної зони призведе до аварії з великим викидом радіоактивних речовин. Через застарілу конструкцію ВВЕР-1000 не існує ефективних заходів уникнення великого викиду після аварії з розплавом активної зони.

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 жодному з блоків ЗАЕС. Ба більше, на ЗАЕС 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.

Надані та доступні документи дозволяють зробити висновок, що існує велика ймовірність того, що сценарії аварій переростуть у важку аварію, яка загрожує цілісності захисної оболонки й спричиняє 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 ЗАЕС.

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 ЗАЕС 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, лише сейсмічні небезпеки перераховані як природні небезпеки. 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 ЗАЕС, серйозність небезпек, визначення адекватних подій, включених до проєктних основ, з імовірністю 10^{-4} на рік та захист ЗАЕС від природних небезпек. Окрім більш детальних даних про сейсмічну небезпеку, в процесі ОВД повинна бути надана інформація про повені, спричинені річками або проривами дамб вище за течією Дніпра, усі типи екстремальних метеорологічних явищ, включаючи зміну клімату, та можливі комбінації небезпек.

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

INTRODUCTION

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

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

For the lifetime extension of Zaporizhzhya, the Ukrainian side is conducting an Environmental Impact Assessment (EIA) under the Espoo Convention. Austria has been notified by Ukraine and decided to participate in the EIA. 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), the Ukrainian submitted to the Austrian side two EIA documents:

- ZNPP NON-TECHNICAL SUMMARY (2015): Development of the materials for assessment of Environmental Impact in the course of Zaporizhzhya NPP operation. Non-technical summary. Ministry of Energy and Coal Industry of Ukraine, State Enterprise National Nuclear Energy Generating Company "Energoatom" SE "Zaporizhzhya NPP", approved. (pdf, 54 pages)
- ZNPP EIA BOOK 7 (2015): Report. Development of the materials for assessment of environmental impact in the course of Zaporozhye NPP operation (final). Book 7, transboundary environmental impact of industrial activities. Reg.No.641-11_ NIL. Ministry of Energy and Coal Industry of Ukraine, State Concern "Nuclear Fuel", State Enterprise "Ukrainian Scientific Research and Design Institute for Industrial Technology", SE "SR&&D Institute for Industrial Technology", approved. (pdf, 44 pages)

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

Information in the conclusion of ZNPP NON-TECHNICAL SUMMARY (2015, p. 53) refers to the operation of units 1 and 2 of Zaporizhzhya NPP, units 3-6 go unmentioned.

The original design operation period is 30 years, and the expected period of extension 15 years. (ZNPP EIA BOOK VOL 7 2015, p. 7)

According to the Non-technical Summary, the results of the Stress Tests are reflected in the National Report of Ukraine developed by the SNRIU. The most recent document "Report on periodic safety reassessment of ZNPP Units 1, 2" was developed in 2015 (Energorisk Ltd.). It proposes to extend the lifetime of ZNPP 1&2 not only for 15 but for 30 years (No.1 by 23/12/2045, No.2 by 19/02/2046) if safety upgrade measures are implemented. (ZNPP NON-TECHNICAL SUMMARY 2015, p. 9)

Alternatives

The operation of the units of the Ukrainian NPPs is determined by the “Energy strategy for Ukraine for the period until the year 2030". (ZNPP NON-TECHNICAL SUMMARY 2015, p. 5)

Annual output of ZNPP is over20 % of total electricity power generated in Ukraine which covers the demand of over 9 million people. ZNPP is also a heat source for an industrial area and the nearby satellite town of Energodar. Total installed heat power is 1200 Gkal/year (200 Gkal/year per each power unit). (ZNPP NON-TECHNICAL SUMMARY 2015, p. 14)

No alternatives and no zero option for the lifetime extension of ZNPP are discussed. Data on electricity and heat demand are lacking.

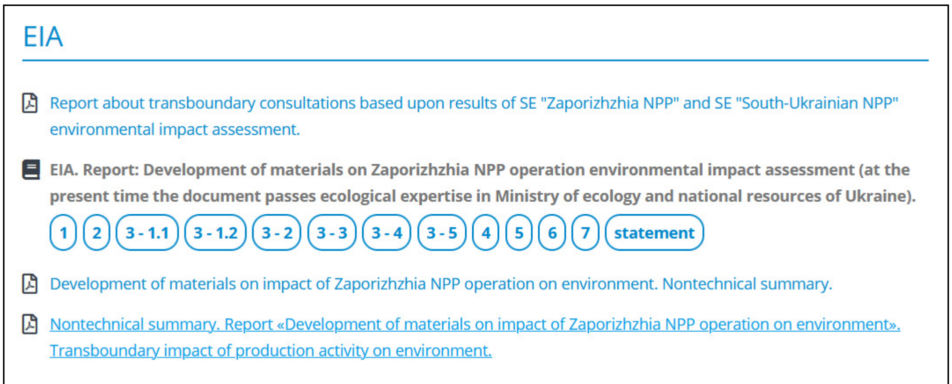
1.2 Discussion

EIA documents and procedure

The EIA documents that were submitted to Austria are incomplete and it is unclear for which units the EIA is conducted. Austria has been notified that this EIA is preparing the lifetime extension of units 3-6, but the EIA documents refer to unit 1 and 2 or to ZNPP as a whole. Moreover, the lifetime extension for ZNPP-6 is due in 2026, the procedure has not started yet.

On the website of ZNPP a long list of EIA documents is made available, including specific documents for ZNPP units 1-5 and general documents for the lifetime extension EIA. The following screenshot from this website shows the general EIA documents that are publicly available, but only in Ukrainian language despite the English file names.

Figure 1: Documents and useful information about lifetime extension.



Source: Screenshot from ZNPP website: https://www.npp.zp.ua/index.php/en/activities/lifetime-extension/docs (seen 2021-07-04)

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Only EIA Book 7 dealing with trans-boundary impacts was provided to Austria, but not the other EIA Books (1-6) or the report about trans-boundary consultations. The latter is available in English on the website of Energoatom. (REPORT CONSULTATION 2018) Only one of the two non-technical summary documents was translated into English and made available to Austria. The other non-technical summary, focusing on trans-boundary impacts, seems to be a short version of EIA Book 7.

On the abovementioned website of ZNPP, three English documents are available in the section for specific documents for ZNPP units 1-5 – the non-technical summaries of ZNPP 1-5. (ZNPP 1 AND 2 NON-TECHNICAL SUMMARY 2015, ZNPP 3 AND 4 NON-TECHNICAL SUMMARY 2016, ZNPP 5 NON-TECHNICAL SUMMARY 2020)

The comparison of the three non-technical summaries showed that the non-technical summary that has been submitted to Austria, is not identical. Especially the most recent one (ZNPP 5 NON-TECHNICAL SUMMARY 2020) contains more up-to-date information.

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

Table 1: ZNPP status data (ZNPP 1 AND 2 NON-TECHNICAL SUMMARY 2015, p. 12)

Unit No.	Date of connection to the grid	Start of commercial operation	Design operation period in years	Design operation expiration	Expected period of operation extension in years
ZNPP 1	1984-12-10	1985-12-23	30	2015-12-23	15
ZNPP 2	1985-07-22	1986-02-19	30	2016-02-19	15
ZNPP 3	1986-12-10	1987-03-05	30	2017-03-05	15
ZNPP 4	1987-12-18	1988-04-04	30	2018-04-04	15
ZNPP 5	1989-08-14	1990-05-27	30	2020-05-27	15
ZNPP 6	1995-10-19	1996-10-21	30	2026-10-21	15

According to this table the 30-year original lifetime started with commercial operation.

In 2021, ZNPP 1-5 units' lifetimes have already been exceeded by up to six 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)

Clarification is needed concerning the 30-year lifetime extension for ZNPP 1 and 2 instead of 15 years as mentioned in ZNPP NON-TECHNICAL SUMMARY (2015, p. 9) with reference to a proposal in the most recent PSR.

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

The licensing for the lifetime extension of 10 years has already been completed for ZNPP 1-5 according to the following information on the website of ZNPP[1].

Figure 2: Dates when licenses for lifetime extension for ZNPP 1-5 were issued

- September 13, 2016, State Nuclear Regulatory Inspectorate of Ukraine affirmed a decision to extend power unit №1 operational lifetime till December 23, 2025
- October 3, 2016 - power unit №2 operational lifetime extended till February 19, 2026
- November 3, 2017 - power unit №3 operational lifetime extended till March 5, 2027
- October 11, 2018, State Nuclear Regulatory Inspectorate of Ukraine affirmed a decision to extend power unit №4 operational lifetime and set date of the following Periodic Safety Reassessment of the power unit on April 04, 2028.
- On January 4, 2021, the State Nuclear Regulatory Committee of Ukraine decided to extend the lifetime of Unit 5 of Zaporizhzhia Nuclear Power Plant and set the date of the next periodic safety reassessment of ZNPP Unit 5 - May 27, 2030.

Source: Screenshot from ZNPP website: https://www.npp.zp.ua/index.php/en/activities/lifetime-extension/docs (seen 2021-07-04)

In trans-boundary EIAs with other countries consultations on ZNPP have already been held, together with consultations on SUNPP. (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 ZNPP 1-5 have already been taken between 2016 and January 2020. Therefore it is highly questionable if the results of the ongoing trans-boundary EIA will be implemented at all, that is if the before made decisions will be revised.

The Espoo Implementation Committee urges Ukraine to complete 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 assessed for their environmental impacts. However, in the submitted EIA documents alternatives were not discussed. Data on the future energy demand were not presented.

[1] https://www.npp.zp.ua/index.php/en/activities/lifetime-extension, seen 2021-07-04

1.3 Conclusions, questions and preliminary recommendations

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

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

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

The licenses for the lifetime extensions for ZNPP 1-5 have already been issued before the trans-boundary EIA has been finished. 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****: Which ZNPP units are subject to the ongoing EIA?*
- ***Q 2****: How long is the maximal foreseen lifetime extension of all ZNPP units?*
- ***Q 3****: What are the further steps in the EIA procedure and in the licensing procedure?*
- ***Q 4****: How will the results of the EIA be taken into account? Will the decisions on lifetime extension of ZNPP 1-5 be revised according to the EIA results? How will the EIA results be taken into account in the decision on lifetime extension of ZNPP 6?*

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 ZNPP includes low, intermediate and high level waste.

Solid low level radioactive waste (LLW) is treated in the compaction and ignition facilities on the ZNPP site. Conditioned and non-conditioned solid waste of all activities is stored at three different interim storages: storage in special building 1, storage in special building 2 and storage in the processing building. (ZNPP NON-TECHNICAL SUMMARY 2015, p. 25)

Liquid radioactive wastes is treated in facilities on the site. The products of the special water treatment plant (ion-exchange resins in the mixture with different sorbents and dispersed deposition and salt fusion cakes and evaporator sludge) are transported to respective storages on the site. Contaminated oil is subject to regeneration or it shall be ignited in the ignition plant. (ZNPP NON-TECHNICAL SUMMARY 2015, p. 19)

Spent fuel of ZNPP 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 casks and transported to the Dry Spent Fuel Storage Facility (DSFSF). The DSFSF was constructed based on the technology of the US company “Duke Engineering & Services”. Around the DSFSF site a wall has been erected to avoid radiation impacts on ZNPP staff, population and environment. The DSFSF interim storage is designed for 380 casks for a total of 9,000 spent fuel assemblies. The DSFSF capacity is sufficient for the ZNPP spent fuel for its overall period of operation. Interim storage in the DSFSF is foreseen for 50 years, then the decision on further storage, reprocessing or disposal shall be taken. (ZNPP NON-TECHNICAL SUMMARY 2015, p. 24)

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. (ZNPP NON-TECHNICAL SUMMARY 2015, p. 24)

In average from one VVER-1000 reactor 42 spent fuel assemblies are produced per year. Therefore, each year about 252 spent fuel assemblies are produced from ZNPP. As of 30 Sept 2015, 131 casks were installed on the DSFSF storage site. (ZNPP NON-TECHNICAL SUMMARY 2015, p. 24)

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. (ZNPP 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 ZNPP lifetime extension or complete information on the status of conditioning facilities, interim and final storages for the radioactive waste. This needs further clarification.

More information can be found in other documents:

A new radwaste treatment facility at ZNPP should have been completed by 2017. (NATIONAL REPORT UKRAINE 2017) On the website of ZNPP the start of the new project on radwaste treatment was announced on 19 February, 2019.[2] The same website also informed: "Nowadays the majority of waste is kept unprocessed, as there is still no determined technology of its treatment to the appropriate state for disposal."

In the report on trans-boundary consultations the year 2021 is given as commissioning date for a storage facility for conditioned solid radioactive waste, where the waste will be stored in 280 litre containers. Salt float containers will be packed in concrete containers. With the 4-tiered storage method, the design capacity of this storage facility will be between 1,000 and 1,500 concrete containers. Subsequently, concrete containers will be sent for final disposal under condition of readiness for the reception of radwaste from NPP by the specialized enterprise SSE "CERAWM" (State specialized enterprise "Central enterprise on radioactive waste handling"). These measures will ensure the storage of radioactive waste throughout the period of operation of power units, as well as in the over-project period of operation. (REPORT CONSULTATION 2018, p. 71-73)

Spent Fuel

Concerning spent fuel, the information level is higher and additional information can be obtained from other sources:

According to the Non-technical summary of ZNPP 5, spent fuel will be stored for 7-10 years in the spent fuel pools. (ZNPP 5 NON-TECHNICAL SUMMARY 2020, p. 15). In (ZNPP NON-TECHNICAL SUMMARY 2015), a storage period of 4-5 years in the spent fuel pools was defined. The storage racks in the spent fuel pools were compacted to increase capacity at ZNPP. (NATIONAL REPORT UKRAINE 2017, p. 20)

As of February 1, 2020, 155 containers are placed in DSFSF facility, housing 3,714 spent nuclear fuel assemblies. (ZNPP 5 NON-TECHNICAL SUMMARY 2015, p. 15)

In the DSFSF is an open storage facility, the concrete containers stand outdoors surrounded by a wall.

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2 https://www.npp.zp.ua/en/node/633, seen 2021-07-08

Figure 3: ZNPP dry interim storage for spent fuel (DSFSF)

Source: NATIONAL REPORT UKRAINE 2017, p. 21

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It is not clear if these containers are designed to withstand an airplane crash and external hazard.

According to the Ukrainian Energy Strategy from 2017, the decision to reprocess or to choose direct final dispose of the spent fuel is deferred. Reprocessing would take place in the Russian Federation. (NATIONAL REPORT UKRAINE 2017, p. 19)

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 analyses 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.

2.3 Conclusions, questions and preliminary recommendations

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

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

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

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

2.3.1 Questions:

- ***Q 5****: 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 6****: What is the status of the final disposal for spent fuel?*
- ***Q 7:*** *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 8****: What amounts and activities of LILW are expected to arise from lifetime extension of ZNPP?*
- ***Q 9****: Are there enough capacities in interim and final storages for the LILW from ZNPP lifetime extension?*
- ***Q 10****: What is the status of the treatment facilities, interim and final storages for radioactive waste?*
- ***Q 11:*** *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 12:*** *Do the containers in the dry interim storage DSFSF withstand an airplane crash and external hazards?*

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

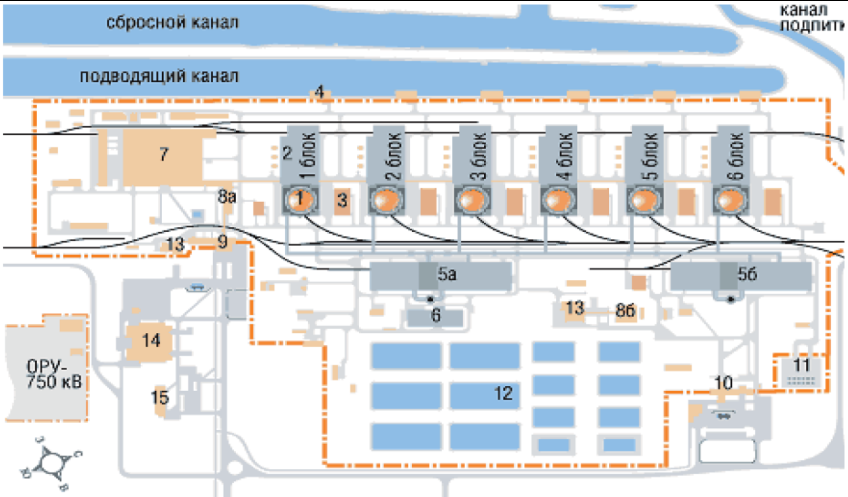
Currently six units are in operation at Zaporizhzhya NPP, installed electric capacity of each unit is 1000 MW. In the period of 1984 to 1987, the first four units were commissioned into operation. Unit 5 was commissioned in 1989, and Unit 6 in 1995.

Chapter 1.1 of the ZNPP EIA BOOK 7 (2015) provides a very brief description of the NPP units and the involved technological processes. The power unit is located on a separate main building of the NPP and consists of the reactor compartment, turbine compartment, and deaerator stack with the rooms of electrical devices. Main buildings of the power units are oriented to the water- cooling pond – a source of NPP circulating water supply. There are unit pumping plants and industrial water pipelines between the water-cooling pond and main buildings of the power units. The connection of Zaporizhzhya NPP with the unified power grid of Ukraine is provided by means of three 750 kV transmission lines and one 330 kV transmission line. Each of six power units of ZNPP includes the following equipment:

- VVER-1000 reactor;
- K-1000-60/1500-2 type turbine;
- TVV-1000-4 type electric generator.

An overview of the Zaporizhzhya NPP site is given in Figure 4.

Figure 4: The Zaporizhzhya NPP site



1. reactor vessel
2. turbine building
3. diesel generator
4. unit pumping plant
5. radwaste treatment buildings a and б
6. solid radwaste storage
7. additional buildings
8. laboratory and service structures a and б
9. administration buildings and Check Gate 1
10. Check Gate 2
11. dry spent fuel storage facility
12 spray ponds
13 canteen
14. Full Scope Simulator
15. Training Center

Source: ZNPP EIA BOOK 7 2015

3.2 Discussion

The original design lifetime of the Zaporizhzhya NPP units 1, 2, 3 expired between 2016 and2017. Energoatom selected the option of long-term operation in accordance with requirements of NP 306.2.099-2004 "General Safety Requirements for NPP Long-Term Operation Based on Periodic Safety Review", namely: power unit shutdown after operation expiry, organisational and technical measures for long-term operation and operation restoration. The SNRIU approved licensing plans and programmes for preparation of Zaporizhzhya NPP units 1, 2, 3 for long-term operation, according to which activities are performed on technical condition assessment and long-term operation of equipment, piping and building structures. (SNRIU 2016)

The State Nuclear Regulatory Inspectorate of Ukraine has approved a ten-year extension of the operating licence for unit 4 of Ukraine's Zaporizhzhya nuclear plant in October 2018. The unit is permitted to operate until 4 April 2028. (NEI 2018a) Zaporizhzhya 5 received a licence from the State Nuclear Regulatory Inspectorate of Ukraine (SNRIU) on 5 January 2021 and the unit was reconnected to the grid on 15 January 2021. (NEI 2021a)

Based on the results of re-assessment, the power unit Periodic Safety Review Report is developed and submitted to the Regulatory Authority together with the proposals as for re-assignment of the lifetime. A similar approach for the PSR is recommended by the IAEA document SSG-25 and reference levels of the WENRA. The PSR Report is developed in accordance with the requirements of the Ukrainian regulatory documents and IAEA standards[3] and the WENRA Safety Reference Levels (WENRA RHWG 2014a).

While the PSR report meets the requirements of the WENRA reference level, the safety of the plant does not meet the WENRA reference level (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. the plants becoming out of date in comparison with current knowledge, standards and technology.

Although aging is a safety issue for the ZNPP, it is not addressed in the provided EIA documents.

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.

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3 Fundamental Safety Principles. SF-1», “Periodic Safety Review of Nuclear Power Plants. Specific Safety Guide. SSG-25”, Governmental, Legal and Regulatory Framework for Safety. GSR Part 1, Safety Assessment for Facilities and Activities. GSR Part 4, Safety of Nuclear Power Plants Design. SSR-2/1, Safety of Nuclear Power Plants Commissioning and Operation. SSR-2/2

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 – except 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.

According to the REPORT CONSULTATION (2018), issues of physical aging of the elements and structures of the plant are considered in the safety factor "Aging of elements and structures" of the Report on the periodic safety review. In this safety factor, the effects of aging and the mechanisms of degradation of the elements and structures are considered, and measures are taken to mitigate their degradation during operation period. Furthermore, it is explained that the program for management of the equipment and pipelines ageing has been established. Impacts of various factors are regularly monitored in order to ensure timely repair, modernization or replacement of the required component.

To establish general requirements for the organization and implementation of the aging management system, including the determination of the scope and sequence of technical measures to ensure a systematic and effective management of the aging of elements and structures at the NPP power units was developed the “Typical program PM-D.03.03.222-14”. The requirements of this program are mandatory for the NPP units, carrying out activities related to prevention of degradation of elements and structures of the power unit due to their aging and deterioration, below acceptable limits.

In accordance with the requirements, the ability of structures, systems and elements important for safety, to ensure the performance of the safety functions entrusted to them during the life of the power unit, taking into account the influence of aging and degradation, should be evaluated. (REPORT CONSULTATION 2018)

However, the Topical Peer Review in 2017 found out that the ageing management programmes in the Ukraine are not sufficient.

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 implementation of ageing management approaches at Ukrainian NPPs started at this point in time.

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 lies in combining aspects of AM and LTO, rather than the operator having two separate documents to apply. Currently, this drawback has been practically removed by the operator through development of two separate industry standards to manage AM and LTO.

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

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

Ageing management of electrical cables

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

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

SNRIU states that the ageing management of electrical cables at NPP units is paid proper attention 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. That opportunistic inspection of concealed pipework is not undertaken whenever the pipework becomes accessible for other purposes was another point of criticism (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. There are improvements in the methodology for calculation of fluence, thermohydraulic parameters and strength calculation, which are reflected in TLAA used to justify safety of reactor pressure vessel long-term operation.

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

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

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

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

Taking into account the potential for long-term operation of NPPs, special attention is paid to **ageing management** and lifetime management. 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 designed 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.

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 tendon tension is the level of design-basis earthquake. In this case, it is necessary to note that the seismic level of NPP sites was reevaluated over the past 10 years and new level is actually two or three times higher than the design level.[4] 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.

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.

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.

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[4] 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 to 0.1g for ZNPP.

The old reactor types VVER has 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 accidents of small aircrafts.

IAEA recommendations

The Stress Tests revealed that Ukrainian NPPs are compliant only with 172 of the 194 requirements according to the IAEA Design Safety Standards published in 2000.[5] Meanwhile, even this IAEA document is outdated; in January 2012 new safety requirements were published by IAEA (IAEA 2012).

The lack of compliance with the IAEA Safety Standards is remarkable, because during the last decade, the European Commission, the EBRD, EURATOM and the

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[5] 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.

IAEA supported the safety analysis of VVER reactors and provided significant funds to enhance the safety of these plants[6]:

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). 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 is still ongoing under C(I)SIP measure 10101.
- 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 is still ongoing under C(I)SIP measure 13302.

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

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. It remains to implement 642 measures. 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 ones were completed and 275 ones are to be implemented, including about 90 measures planned to be completed to the end 2021. The following table shows the status of implementation for the ZNPP (SNRIU 2021).

Table 2: Status of implementation of the C(I)SIP for ZNPP on 31/03/2021 (SNRIU 2021)

Unit	Total Number of Measures	Completed	To implement
ZNPP-1	77	68	9
ZNPP-2	77	68	9
ZNPP-3	76	63	13
ZNPP-4	76	63	13
ZNPP-5	76	60	16
ZNPP-6	77	42	35
Common	3	2	1
Totally	**462**	**366**	**96**

The tables shows that many measures still await implementation (see also chapter 8.2).

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.

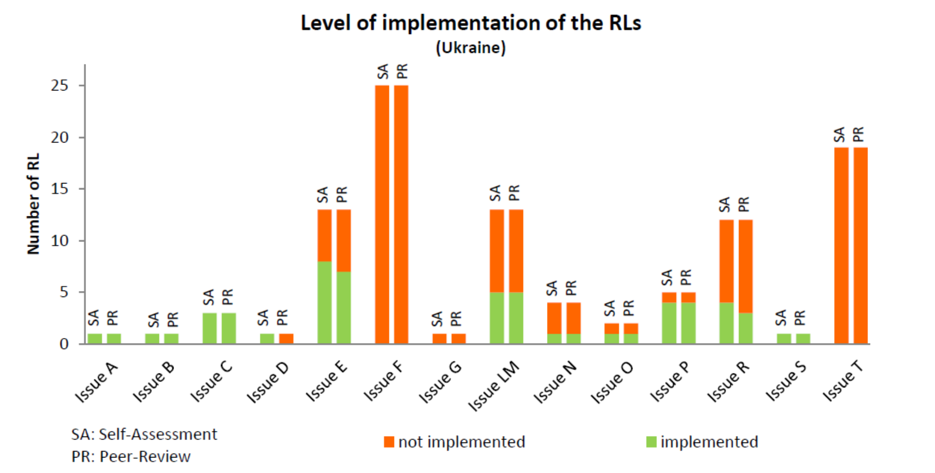
Table 3: Revised or new WENRA reference Levels (WENRA RHWG 2018a)

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* 5 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.

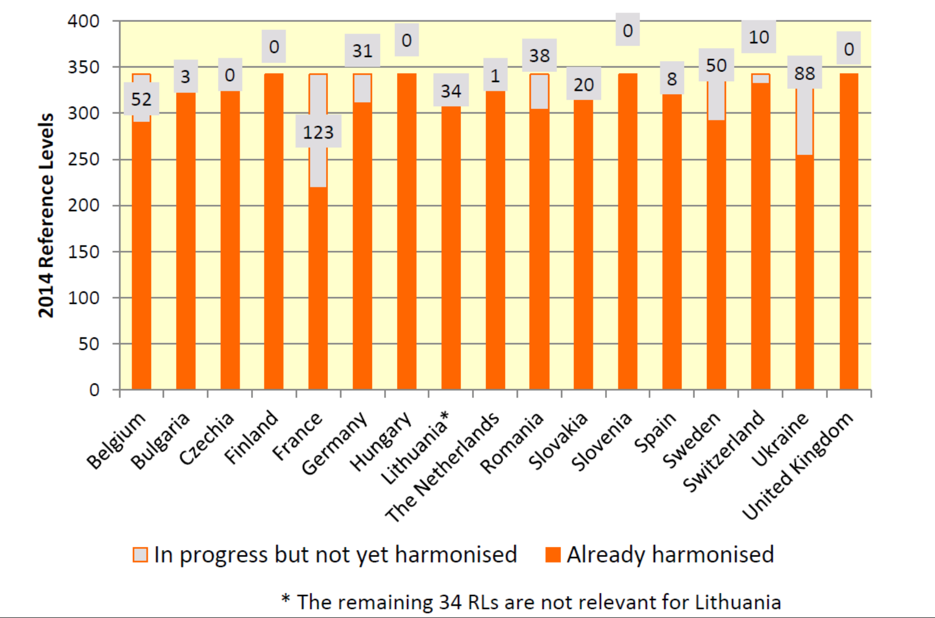
Figure 5: Status of implementation of new and revised RL in Ukraine



Source: WENRA RHWG 2018a

Ukraine proposed the fully implementing the remaining 74 RLs into the national regulation until March 2018. However, it has to be noted that Ukraine has not implemented 88 RL of the 342 at the 1 January of 2019, see *Figure 6*. (WENRA RHWG 2020a)

Figure 6: Reported status of implementation of 2014 RL in 2020



Source: WENRA RHWG 2020a

3.3 Conclusions, questions and preliminary recommendations

Although ageing of the up to 38 years old structures, systems and components (SSCs) is a safety issue for the ZNPP, it is not addressed in the provided EIA documents. The adverse effect of ageing depends also on the inspection, restoration and protection measures taken. A comprehensive ageing management program (AMP) is necessary to limit ageing-related failures at least to a certain degree. However, information of an ageing management programme (AMP) is also not given in the provided EIA documents.

Ukraine participated in the Topical Peer Review (TPR) “Ageing Management” in the framework of the Nuclear Safety Directive 2014/87/EURATOM, carried out in 2017/18. Several “areas for improvement” were identified, i.e. deviation of the TPR expected level of performance for ageing management that should be reached to ensure consistent and acceptable management of ageing throughout Europe. The results of the TPR and the activities to remedy the weaknesses should be presented in the EIA documents, in particular the very important safety issue of the embrittlement of the RPVs should be discussed. The standard surveillance programme for some of the Ukrainian reactors (including unit 6 of the ZNPP) is good but it is not sufficient. Comprehensive inspections of all RPVs are necessary.

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

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

The stress tests revealed 2011 that Ukrainian NPPs are compliant only with 172 of the 194 requirements according to the IAEA Design Safety Standards published in 2000. Implementation of necessary improvements is on-going under the Upgrade Package. This includes the Comprehensive (Integrated) Safety Improvement Program (C(I)SIP). The completion of the program was postponed several times. As of March 31, 2021 still a lot of measures have to be implemented (96 out of 466 measures).

A significant gap remains between the required safety standard and the actual safety level of the ZNPP units. In spite of some progress, the 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. But lifetime extension is already granted for units 1-5 of the ZNPP.

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

3.3.1 Questions:

- ***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) based on Article 8e of Directive 2014/87/EURATOM?*
- ***Q 14:*** *What are the specific findings of the ageing management programme for ZNPP 3-6? 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 ZNPP 3-6? Are there any differences between the units?*
- ***Q 16:*** *What are the results of the embrittlement of the reactor pressure vessels (RPVs) for ZNPP 3-6? Are there any differences between the units?*
- ***Q 17:*** *Is there a systematic evaluation of the ZNPP design deviations from the current international safety standards and requirements envisaged?*
- ***Q 18:*** *When will the WENRA RL be fully implemented in the Ukrainian regulations? Is the application of the RL binding?*
- ***Q 19:*** *When will a reviewed be conducted if the RL will be met for the ZNPP?*
- ***Q 20:*** *Which WENRA Documents are mandatory for the lifetime extension?*

3.3.2 Preliminary Recommendations:

- **PR 6:** It is recommended to implement all available design improvements of VVER-1000 reactor for the ZNPP.
- **PR 7:** It is recommended to undertake a comparison of the design and measures of the ZNPP with all requirements of SRL F. In case of deviations will be found and accepted the reasons for this decision should be explained.

- **PR 8:** It is recommended provide the following further information:
  - a) a detailed description of the safety systems, including information on requirements for the important safety-relevant systems and components. Furthermore, detailed description of the measures taken to control severe accidents or to mitigate their consequences.
  - b) Information about the applied national requirements and international recommendations.
  - c) comprehensible presentation and overall assessment of all deviations from the current state of the art in science and technology. This presentation should include:
    - All deviations from the modern requirements for redundancy, diversity and independence of the safety levels.
    - Incompleteness of the database and plant documentation used.
    - Presentation of all safety assessments or parameter definitions by personal expert assessments ("engineering judgement").
    - Presentation of the general dealing of uncertainties and non-knowledge and its effects on risk
    - Deviations from the state of the art in science and technology with regard to the detection methods used, the technical estimates and calculation procedures.
    - The safety margins available for the individual safety-relevant components and their respective ageing related changes compared to the original condition.

d) Information to the ageing management program, the following issues should be presented in the EIA documents:
  - The national action plan relating to the Topical Peer Review (TPR) "Ageing Management" under the Nuclear Safety Directive 2014/87/EURATOM and its progress.
  - The very important safety issue of the ageing of the RPVs (embrittlement), including definition and justification of appropriate safety margins.
  - Evaluation of the conditions of the RPV internals and head penetrations including trends of events, and envisaged exchange measures.
  - Evaluation of the conditions of components of the primary circuit components and of the electrical installations including trends of events, and envisaged exchange measures.

e) Regarding operation experience, the EIA documents should present an evaluation of safety relevant events including the lessons learned.

4 ACCIDENT ANALYSIS

4.1 Treatment in the EIA documents

Chapter 3 of ZNPP NON-TECHNICAL SUMMARY (2015) provides some information about potential accidents during the operation of the ZNPP. For the analysis of radiation consequences of accidents at Zaporizhzhya NPP the following design basis accidents were looked into:

- Maximum design basis accident.
- Break of collector cover of steam generator - emergency spike.
- Break of collector cover of steam generator - pre-emergency spike.
- The fall of the hydraulic locking to the spent fuel pool.
- The fall of a cassette of spent fuel to the reactor core and to the heads of the cassettes in the spent fuel pool.
- The fall of the container with the spent nuclear fuel from height more than 9 meters.
- The fall of assembly to the reactor core.
- The break of impulse piping outside the containment.
- The line break of planned cooldown.
- Rupture of the supply pipeline of technology blowing into the purification in a system of operating blowing in the reactor building.

It is stated that in addition, the consequences of beyond design basis accidents were considered.

Total release of radioactive substances in consequence of these accidents can be:

- Break of collector cover of steam generator - emergency spike: 4.35 E15 Bq;
- The fall of assembly to the reactor core: 1. 21 E14 Bq;
- Maximum design accident: 7.17 E15 Bq;
- The fall of the hydraulic locking to the spent fuel pool: 5.34 E14 Bq

It is explained that under the most adverse conditions the individual equivalent doses for 1 year on thyroid gland due to the inhalation body and external radiation do not exceed the threshold values 0.3Sv/year and 0.1Sv/year according to SR ASS-88 at the border of the sanitary protection area and outside its borders. (ZNPP NON-TECHNICAL SUMMARY 2015)

The following table provides the parameters of radionuclide release under maximum (ultimate) design-basis accident (accident 1) and two more accidents (steam-generator collector cover lift-up for two scenarios – accidents 2, 3), which are inferior to it in the release value. All the rest of accidents causing less radionuclide releases are not considered. (ZNPP EIA BOOK 7 2015)

Table 4: Activity of releases in three accidents at the ZNPP in Bq (ZNPP EIA BOOK 7 2015)

Radionuclide	Ultimate design-basis accident (accident 1)	Steam-generator collector cover lift-up – accidental spike (accident 2)	Steam-generator collector cover lift-up – pre-accidental spike (accident 3)
Kr-87		6.50E+13	
Kr-88	2.00E+13	2.00E+14	2.00E+13
Sr-90	3.10E+11		
Ru-103	4.50E+12		
Ru-106	6.60E+11		
I-131	4.98E+12	2.53E+13	4.50E+12
I-132	2.70E+12	9.20E+13	1.60E+13
I-133	4.00E+12	8.44E+13	1.54E+13
I-134		1.00E+14	1.70E+13
I-135	2.30E+12	7.90E+13	1.30E+13
Cs-134	7.80E+11	2.10E+11	2.10E+11
Cs-137	5.00E+11	5.30E+11	5.30E+11
La-140	8.40E+12	2.60E+12	2.60E+12
Ce-141	1.40E+13		
Ce-144	8.60E+12		
Xe-133		2.00E+15	

The expected effective doses in case of maximum (ultimate) design-basis accident (accident 1) is approximately 50 % higher than in case of accident 2. Comparison of radionuclides and their activity released in the course of accident 2 and accident 3 demonstrate that in the course of accident 3 the effective doses will be even less.

The design basis accident most dangerous to human health in the period of 2 days and 2 weeks is the accident «Break of collector`s cover of steam generator – emergency spike», with a dose of up to 0.19 mSv and 0.32 mSv, respectively, at the boundary of sanitary protection area. (ZNPP NON-TECHNICAL SUMMARY 2015)

For the period of 1 year, the accident most dangerous to human health is the design basis accident "fall of assembly to the reactor core", the maximum design accident and design accident "the fall of the hydraulic locking to the spent fuel pool" – 1.44 mSv, 1.28 mSv and 1.17 mSv. (ZNPP NON-TECHNICAL SUMMARY 2015)

In the case of beyond design basis accidents, maximum activity of radionuclides in the near-surface layer of atmospheric air and the density of precipitation onto the surface of the soil is expected within the sanitary protection area. The effective doses of the population exposure for 2 days, 2 weeks and 1 year will amount to 0.43 Sv, 1.79 Sv and 9.46 Sv. The levels of unconditional justification for the use of countermeasures are exceeded and there will be the need to use all kinds of countermeasures, including evacuation. (ZNPP NON-TECHNICAL SUMMARY 2015)

Mitigation of the accident consequences

Regarding the mitigation of accident consequences, the ZNPP emergency safety as based on the following safety principles and criteria with the following formulations:

- NPP safety is ensured with successive use of:
  - physical barriers on the way of spreading of ionizing radiation and radioactive substances to the environment;
  - the system of technical and organizational measures to protect barriers and maintain their efficiency for the protection of personnel, population and the environment;
- In the course of NPP operation, the integrity of the barriers on the way of spreading of radioactive substances is controlled. During normal operation, all barriers and their protection are in working condition. According to the safe operation conditions, the operation of the NPP for power is forbidden if there is any failed barrier or failed means of its protection, provided for in the plant design.

Some general information about the physical barriers is given:

- availability of special safety systems, which are based on the principle of installation of parallel channels and perform the same function;
- ensuring the principles of independence, redundancy, physical distribution and accounting of every incident while creating a security system;
- high technical characteristics of the localization system to prevent the release of reactive substances to environment;
- high level of monitoring and process automation, it provides overcoming of emergency situations during the most important (first) stage of the accident without personnel participation;
- security subject to external influences, specific for sites that are considered, including natural and anthropogenic impact;
- security in a wide range of initial events with regard to postulated failures, possible personnel errors and additional influences;
- taking a conservative approach to the choice of technical solutions that affect safety;
- the use of measures and technical solutions aimed at:
  - the protection of localization systems during design basis accidents,
  - prevention of an initial event transfers to the design basis accident,
  - mitigating of the accident consequences that could not be avoided,
- ensuring of inspection and testing of equipment and systems that important to safety, with the aim of supporting them in working condition;
- organization of the sanitary protective zone and the surveillance zone;
- quality assurance with regard to the requirements of the relevant regulations.

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

- Level 1: Installation of conditions that prevent violation of normal operation;
- Level 2: Preventing design basis accidents by normal operation systems;
- Level 3: Prevention of accidents with safety systems;
- Level 4: Management of beyond design basis accidents;
- Level 5: Planning of measures for the personnel and population protection.

It is concluded that there is a probability of potential consequences of design and beyond design basis accident of various types. Simulation of different situations, in terms of estimation of influence of the emergency emissions to the environment and the population, showed that in any scenario, outside of the sanitary protection area (radius of 2.5 km around the plant), existing regulations will not be violated. The transboundary impact in the course of continued operation of NPP power units (that could potentially require a response) is excluded. (ZNPP NON-TECHNICAL SUMMARY 2015)

4.2 Discussion

The provided EIA documents give information about Design Basis Accidents including the scenarios, the releases and the consequences. However, the information about beyond design basis accidents is very limited. Neither the scenarios nor the possible source terms are provided.

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

- power units are operated safely with an acceptable level of risk. The submittals 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.

Consideration and assessment of incidents at the NPP, including the worst case scenarios, have been covered with the Safety Analysis Reports, as well as in the frames of development of the Severe Accidents Management Guidelines. Deterministic and probabilistic analyses have been performed. The scenarios included analysis of the following events:

- internal events: fires, floods, toxic gases, explosions, fall of heavy objects, pipeline breaks, steaming, spraying;
- external events: floods, hurricanes and tornados, maximal and minimal temperatures, earthquakes, crash of aircrafts, explosions, toxic gases.

Based on the results of the periodic safety review, for unit 1 of the ZNPP (REPORT CONSULTATION 2018):

- the calculated value of the total core damage frequency (CDF) is 6.37E-06 1/year;
- the calculated value of the total large release frequency (LRF) is 4.92E-06 1/year.

For unit 2 of the ZNPP

- the calculated value of the total core damage frequency (CDF) is 5.97E-06 1/year;
- the calculated value of the total large release frequency (LRF) is 4.96E-06 1/year.

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. **The values of the CDF and LRF show that almost every core melt accident will result in a large release. This proves the outdated design of the VVER-1000: in case of a core melt accident there are no effective measure to avoid a large release.**

The REPORT CONSULTATION (2018) explained that for all ZNPP units assessments of radiological consequences of severe accidents with the consideration of the severe accident management strategy have been performed in accordance with the "Work Program for Analysis of Severe Accidents and Development of Severe Accident Management Guidelines" and the "Activity 29204 of Comprehensive Safety Improvement Program for Power Units of Ukrainian NPPs". Analyses of radiological consequences have been performed for the following situations:

- severe core damage with bypassing of the containment with the consideration of actions for reduction of release to the environment from the steam generator;
- non-localization of the containment of actions for reduction of release to the environment from the containment;
- containment failure to localize the melt within the reactor;
- containment failure after the melt outflow from the reactor.

For the scenarios with the severe accident management actions, radiological consequences for the population have been mitigated to different extent. For the scenarios with the containment integrity maintaining, the severe accident management actions achieved a reduction of the radiological consequence for the population to levels which do not require protective measures.

At present, for the ZNPP power units the measures have been implemented, which promote preservation of the containment integrity in case of a beyond-design accident (prevention of early bypassing, discharge from the containment, passive autocatalytic recombiners, mobile pump stations).

However, accident scenarios with a compromised containment integrity would result in a very large release of radioactive substances. As mentioned before, most of the core melt accidents will result in a large release.

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, in order to support the degree of confidence claimed.

The demonstration should not be claimed solely based on compliance with a general cut-off probabilistic value.

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

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

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

Containment integrity

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

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) will be 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 to take into account peer review recommendations.

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

The Ukrainian NAcP of 2013 listed 32 measures. A new measure (No. 33: Implementation of a Reactor Pressure Vessel External Cooling System for the Reactor type VVER-440) 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 envisaged end of implementation is now 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.[7] The time available until the fuel stored at the Spent Fuel Pool (SFP) heats up and reaches temperatures above the design limits are 7.5 hours.

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

- Improvement of the emergency power supply in long-term loss of power (for units 1-5)
- 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 1-5
- 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 (for unit 1-4)

The implementation of following measures is still on-going:

- Improvement of the emergency power supply in long-term loss of power (for units 6)
- Provision of instrumentation during and after accidents (accident and post-accident monitoring system) (for unit 6)
- Detailed analyses of primary system makeup in case of loss of power and/or ultimate heat sink.
- Replacement of self-contained air conditioners by those qualified for harsh environments and seismic impacts (for unit 5 and 6)

The stress tests revealed also 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

[7] 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.

low power and shutdown states, and accidents in the spent fuel pools) were developed. Furthermore, only the following new measures have been completed since 2011:

- Development and implementation of hydrogen mitigation measures for beyond design-basis accidents
- Containment hydrogen control systems for beyond design-basis accidents were implemented (for unit 1 – 5)
- Prevention of early containment bypassing in case of molten corium spread to the containment

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

- Implementation of a containment venting system
- Containment hydrogen control systems for beyond design-basis accidents were implemented (for unit 6).

Furthermore, the following analysis should be performed, but 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: 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 a severe accident. This might result in very serious consequences: Large radioactive releases.

According to SNRIU (2016), the C(I)SIP was complemented with a series of measures to ensure 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. Besides, 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 measures have not been fully implemented. Furthermore, and even more importantly, state of the art safety standard like consideration of "design extension condition" are still not envisaged. Thus, even after the implementation of all measures there will remain a considerable gap between the safety level agreed in Europe and the safety level of the ZNPP.

Multi-Unit Accidents

During the consultation, it was noted by the German delegation that the EIA documents do not give any attention to the following issues:

- multi-unit incidents and accidents (not assessed);
- problems caused by incidents or accidents in other units on the site (not assessed)

Regarding the multi-unit accidents, for ZNUPP the following answer was given: Calculation data for the cumulative impact on the environment and the population in case of damage to all six reactors is not available due to the absence of the requirements to provide it in the national regulatory documents. However, for preliminary qualitative evaluation, the following simple calculation could be suggested. Get the value of radioactive release for the damaged six reactors by multiplying the value of radioactive release for 1 damaged reactor by six.

But the issue of a multi-unit accident is different. It is the question of sufficient resources (material and personnel) for an accident in several units. Also, the release of one unit could threaten the measures in another unit. Assessing multi-unit events was one of the most important lessons learned from the Fukushima accident.

Source Terms of BDBAs

According to the ZNPP TECHNICAL SUMMARY (2015), beyond design basis accidents (BDBAs) are considered. But no further information is provided. The source term of a beyond design basis accident (BDBA) at any unit of the ZNPP to calculate the possible consequences was not given in the provided EIA documents.

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 is very large. The accident analyses in the EIA Report should use a possible source term derived by the calculation of the current probabilistic safety analysis (PSA) 2.

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 accident 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. The CDF and LRF values show that almost every core melt accident will result in an accident with a large release of radioactive substances. Because of the outdated design of the VVER-1000, there are not effective measure to avoid a large release after a core melt accident.

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

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

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

The results of the EU Stress Tests have revealed a lot of shortcomings of the severe accident management (SAM) (i.e. the prevention of severe accidents and the mitigation of its consequences) at the Ukrainian NPPs. Comprehensive improvements are required by the regulator; however, further improvements are recommended by the ENSREG peer review team. This is one example for the gap between the Ukraine and the EU safety standards and requirements. The Stress Tests showed that after decades of implementing safety programs, Ukrainian reactors continue posing exceptionally high risk. One characteristic of nuclear safety in the Ukraine: the constant severe delay of the implementation of upgrading measures.

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

It is also state of the art to use the WENRA “Safety Objectives for New Power Reactors” as a reference for identifying reasonably practicable safety improvements. However, the EIA documents do not mention this WENRA safety objectives. According to the WENRA safety objective core melt accidents which would lead to early or large releases would have to be practically eliminated. Even if the probability of an accident sequence is very low any additional reasonably practicable design features, operational measures or accident management procedures to lower the risk further should be implemented for ZNPP.

4.3.1 Questions:

- ***Q 21:*** *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 22:*** *What is the currently valid time schedule for the implementation of all required SAM features for ZNPP? When will the implementation of all C(I)SIP measures be finished?*
- ***Q 23:*** *What are the parameters of the maximum aircraft crash (plane mass and speed) the buildings of ZNPP can withstand?*
- ***Q 24:*** *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 25:*** *Which design basis accidents can develop into a beyond design basis accident?*
- ***Q 26:*** *Which accidents scenarios with the loss of containment integrity or containment bypass are physical possible for the units of the ZNPP?*

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 ZNPP. 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 only very general information about site characteristics, site-specific hazards and the protection of the ZNPP against natural hazards. ZNPP 1 AND 2 NON-TECHNICAL SUMMARY (2015, p. 22-23) refers to the consideration of external hazards for the ZNPP units 1 and 2 as follows:

- *"The designs of all nuclear power plants in operation take into account all possible extreme hazards."*
- *"NPP operated in Ukraine have safety reserve in relation to external hazards …"*
- *"To ensure constant heat removal in conditions of external hazards, NPP sites have additional capabilities to ensure power supply during total blackout, and activities implemented for constant emergency heat removal."*

The same statement is repeated for units 3 and 4 (ZNPP 3 AND 4 NON-TECHNICAL SUMMARY 2016) and unit 5 (ZNPP 5 NON-TECHNICAL SUMMARY 2020, p. 23). The latter document states that the cited conclusions resulted from the *"Action Plan for Targeted Unscheduled Assessment and Further Improvement of Ukrainian NPPs Safety with Consideration of Fukushima-1 Events"* in connection with the EU Stress Tests.

Some aspects of seismic hazards were briefly discussed in REPORT CONSULTATIONS (2018). According to the report experts of Unix CZ s.r.o. (Czech Republic) and Paul C. Rizzo Associates (USA) performed a probabilistic analysis of seismic hazards (PSHA) for the ZNPP site in 2013-2014. The analysis is said to be based on the PSHA (SSG-9) methodology and having been prepared in accordance with the *"Methodical Bases of Seismic Hazard Probabilistic Analysis"*. The probabilistic analysis was apparently based on updated data obtained from investigations addressing the geological and tectonic conditions of the district and site of ZNPP that were conducted between 2011 and 2014. It seems that the PSHA reports were subjected to a review involving Riskaudit experts in the frame of the international project INSC U3.01/11A (UK/TS/47). The PSHA results were later endorsed by the Regulatory Authority of Ukraine (REPORT CONSULTATIONS (2018, p. 44).

ZNPP 3 AND 4 NON-TECHNICAL SUMMARY (2016, p. 33; 35) and ZNPP 5 NON-TECHNICAL SUMMARY (2020, p. 34) provide some further information on seismic hazards stating that the Design Basis Earthquake with an occurrence probability of once in 10.000 years (DBE, termed Maximum Credible Earthquake (MCE) in the cited reports) was determined with *"7 points"* [8]. It is further stated that the Vrancea Zone in south-east Romania (located about 600 km SSW of the

[8] It is assumed that *„7 points"* refers to intensity I=7 of the MSK64 intensity scale. This value is equal to PGA=0.1g.

site) is considered the main source of seismic hazard. The so-called Kohkskyy rift is mentioned as a possible seismic source that was investigated in the near-region of ZNPP. For unit 5 of ZNPP an assessment of the seismic resistance of SSCs is said to confirm that all SSCs withstand the seismic effects of a DBE of *"7 points".* It is further claimed that, for the DBE of *"7 points"* no risks arise from earthquake-induced water waves and *"shifting soil".*

Hazards other than seismic are not covered by the EIA documents.

Probabilities of severe accidents and large releases for ZNPP unit 1 and 2 are listed in REPORT CONSULTATIONS (2018, Annex 2, p. 13). Periodic safety reassessments revealed integrated Core Damage Frequency (CDF) of 6.37E-06 1/year and an integral Large Release Frequency (LRF) is 4.92E-06 1/year for unit 1. A CDF of 5.97E-06 1/year and a LRF is 4.96E-06 1/year is stated for unit 2. No information is provided on how these values were derived.

5.2 Discussion

The documents available to the experts do not contain a systematic assessment of natural hazards, only seismic hazards are listed as natural hazards. (e.g., REPORT CONSULTATIONS 2018, p. 44). Documents do not provide information on the types of hazards or hazard combinations which are possible at the ZNPP site nor the severity of hazards, the definition of adequate design basis events and the protection of ZNPP against natural hazards. EIA documents should provide information on external flooding caused by river floods and/or dam break upstream of the Dnjepr[9] and all types of extreme meteorological phenomena and possible hazard combinations.

It is not clear whether or to what extent site-specific natural hazards were dealt with as part of Periodic Safety Reviews (PSRs) 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, 2015). The results of the review should, if necessary, lead to the update of the design basis of the system 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.

[9] ZNPP is located at the Khakovs'ke reservoir of the Dnjepr.

Seismic hazards

According to ENSREG (2012) ZNPP was originally designed for a Design Basis Earthquake (DBE)[10] with an exceedance probability of 10^{-4} of intensity 6 on the MSK-64 intensity scale which corresponds to the Peak Ground Acceleration PGA=0.05g. The initial seismic design basis is lower than the recommendation of the IAEA (2010) suggesting a minimum protection for PGA=0.10g. Taking into account the IAEA recommendations, the design level of PGA was therefore increased to 0.1g (ENSREG, 2012). According to ENSREG (2012) achieving compliance with the updated seismic design basis of PGA=0.1g was one of the conditions for the lifetime extension of the NPP units. EIA documents, however, do not contain information on this issue and it remains unknown if the upgrade of all SSCs relevant to safety to resist 0.1g has been completed.

According to REPORT CONSULTATIONS (2018 p. 44) the seismic hazard assessment for the ZNPP site was updated by a PSHA 2013-2014. Information on the results of the assessment in terms the updated hazard level and information on the adequacy of protection of ZNPP against earthquake was, however, not provided. The same applies to considerations of seismic loads exceeding the design basis (DEC).

Flooding

ZNPP is located at the Dniepr and downstream of five reservoirs and dams. The EU Stress Tests found no satisfactory information with respect to the plant's compliance with requirements for design basis floods (i.e., external flooding caused by river floods or dam break upstream of ZNPP; ENSREG, 2012). ENSREG (2012), however, listed evidence form calculations of worst case scenarios stating that dam failure would result in flood level below the elevation of the plant site. EIA documents do not contain information on the issue.

Extreme weather

Documents available to the experts did not provide information on the regulatory basis, safety requirements and protection of ZNPP against meteorological hazards. The EU Stress Tests (ENSREG 2012) provide information that hazard assessment considering high wind, tornado and forest fire were available at the time of the 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) further 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, however, are much less stringent than the 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, 2020).

[10] The DBE is referred to as Maximum Calculated Earthquake or Maximum Credible Earthquake, MCE, in Ukrainian documents.

WENRA (2016a) also suggests considering the 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 ZNPP is insufficient. The EIA documents do not contain any 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 6 units of ZNPP are adequately protected from the effects of natural hazards. Since Austria can be potentially affected by the consequences of accidents caused by natural hazards, this fact is relevant in the ongoing EIA.

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

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

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

5.3.1 Questions:

- ***Q 27:** Were the original design bases with regard to natural hazards and the protection systems against the effects of natural hazards systematically reassessed as part of the EIA process and / or as part of the extension of the operating license (LTO) for ZNPP?*
- ***Q 28**: 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 29:*** *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 30:*** *Have new hazard analyses for natural hazards other than seismic been carried out for ZNPP as part of the EIA process and / or as part of the extension of the operating license (LTO) and / or other projects?*
- ***Q 31****: 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 32****: Has the upgrading of the seismic resistance of all SSCs important to safety to the new DBE of PGA=0.1g as announced in the Stress Tests been completed for ZNPP?*
- ***Q 33****: What are the results of the latest seismic hazard assessment (PSHA 2013-2014) in terms of the design basis earthquake? Are the new design basis values enveloped by the seismic resistance of all SSCs relevant to safety?*
- ***Q 34****: 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.*
- ***Q 35****: Is the hazard of external flooding, in particular river floods and floods by the possible break or mismanagement of Dniepr dams upstream of ZNPP, appropriately taken into account in the definition of the design basis flood, i.e., by referring to occurrence probabilities of 10^{-4} per year (average recurrence period of 10,000 years)?*
- ***Q 36****: The EIA document REPORT CONSULTATIONS (2018, Annex 2, p. 13) states the following CDF and LRF values for units 1 and 2 of ZNPP: unit1 – CDF=6.37E-06 1/year, LRF=4.92E-06 1/year; unit 2 - CDF=5.97E-06 1/year, LRF=4.96E-06 1/year.*
  - *Are the values derived from an **extended** Level 2 PSA?*
  - *Which types of initiating events (internal hazards, internal fire, seismic, flooding etc.) are considered in the PSA?*
  - *Does the analysis consider potential releases from the spent fuel pool?*
  - *Why is the LRF value larger than the CDF?*
  - *What are the CDF and LRF values of the units 3 to 6 of ZNPP, should such data be available?*

5.3.2 Preliminary Recommendations:

- **PR 11**: It remains unclear whether all natural hazards relevant to the site were taken into account in the site safety analysis, as required by WENRA (2021) and further explained by WENRA (2015). The team of experts recommends using the "Non-Exhaustive List of Natural Hazards" (WENRA 2015) as a starting point to ensure that all site-specific hazards affecting ZNPP are taken into account.
- **PR 12**: It seems uncertain whether all hazard combinations were taken into account in the assessment of the site, as required by WENRA (2021) and

further explained by WENRA (2015). The team of experts recommends using a hazard correlation diagram (e. g. DECKER & BRINKMAN 2017) as a starting point to ensure that all relevant combinations are taken into account.

- **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 identified for the site and use the derived parameters to develop adequate protection concepts.
- **PR 15:** The expert team recommends to apply the WENRA approach of analysing Design Extension Conditions (DEC) for natural hazards and updates of the protection concepts against natural hazards. DEC are not analysed in the available EIA document. This is in violation of the WENRA requirement that DEC analysis shall be undertaken with the purpose of further improving the safety of existing nuclear power plants and enhancing their capability to withstand more challenging events or conditions than those considered in the design basis.

6 ACCIDENTS WITH THIRD PARTIES' INVOLVEMENT

6.1 Treatment in the EIA documents

In the provided EIA documents of the ZNPP, both terror acts and sabotage go unmentioned.

6.2 Discussion

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

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

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

No studies about the consequences of a deliberate aircraft crash against the ZNPP 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 ZNPP.

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 Report.

Furthermore, additional attack scenarios demand attention: Experts voiced concerns that cyber security has not been fully anticipated as indicated by the nuclear security index of the Nuclear Threat Initiative (NTI). Recent attacks against banking and 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 5 shows some details about the NTI Index for Ukraine.

Table 5: 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	

	Scores	Scores
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. 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 ZNPP. (WN 2019)

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)

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 ZNPP. Nevertheless, they are not mentioned in the provided EIA documents for the ZNPP. In comparable EIA Reports such events were addressed to some extent.

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

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

A recent assessment of the nuclear security in Ukraine points to shortcomings compared to necessary requirements for nuclear security: The 2020 NTI Index assesses nuclear security conditions related to the protection of nuclear facilities against acts of sabotage. With a total score of 65 out of 100 points, Ukraine ranked only 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 37:*** *What are the requirements with respect to the NPP design against the deliberate crash of a commercial aircraft?*
- ***Q 38:*** *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 39:*** *Is a peer-review mission of the IAEA International Physical Protection Advisory Service (IPPAS) planned?*

6.3.2 Preliminary Recommendations:

- **PR 16**: The EIA documents should present the general requirements with respect to the protection against the deliberate crash of a commercial aircraft and other terror attacks and acts of sabotage.

- **PR 17**: In the light of the special situation in Ukraine, the effects of third parties (terrorist attacks or acts of sabotage of the plant) should be given high priority. Protection against cyber-attacks and the treat of insiders should be improved. The IAEA's International Physical Protection Advisory Service (IPPAS) should be used to improve the security.

7 TRANS-BOUNDARY IMPACTS

7.1 Treatment in the EIA documents

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

"[…] no substantial transboundary impact is observed and according to the Convention on Environmental Impact Assessment in a Transboundary Context there is no affected party." (ZNPP EIA BOOK VOL 7 2015, p. 42)

7.2 Discussion

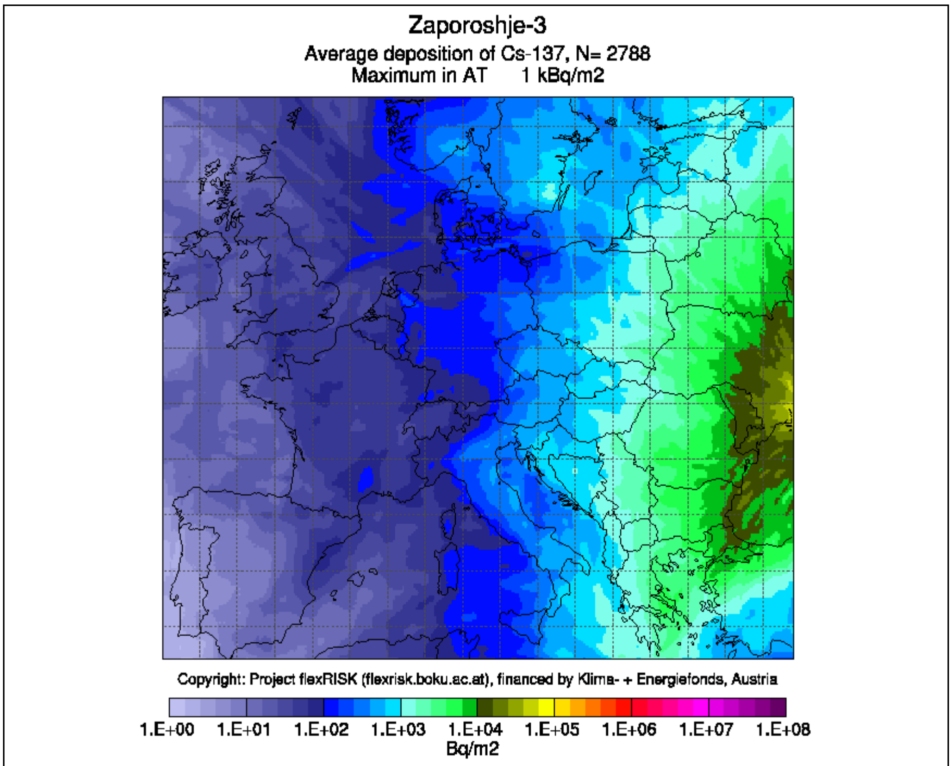
As already discussed in chapter 8 of this expert statement, in order to assess the consequences of BDBAs, it is necessary to analyse a range of severe accidents, including those with containment failure and containment bypass. These kinds of severe accidents are possible for the VVER-1000 reactor type.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

The project flexRISK made an assessment of source terms and identified for ZNPP a possible source term of 51.05 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 ZNPP. The flexRISK project modelled the geographical distribution of severe accident risk arising from nuclear power plants in Europe. Using source terms and accident frequencies as input, for the large-scale dispersion of radionuclides in the atmosphere was simulated more than 2,000 meteorological situations.

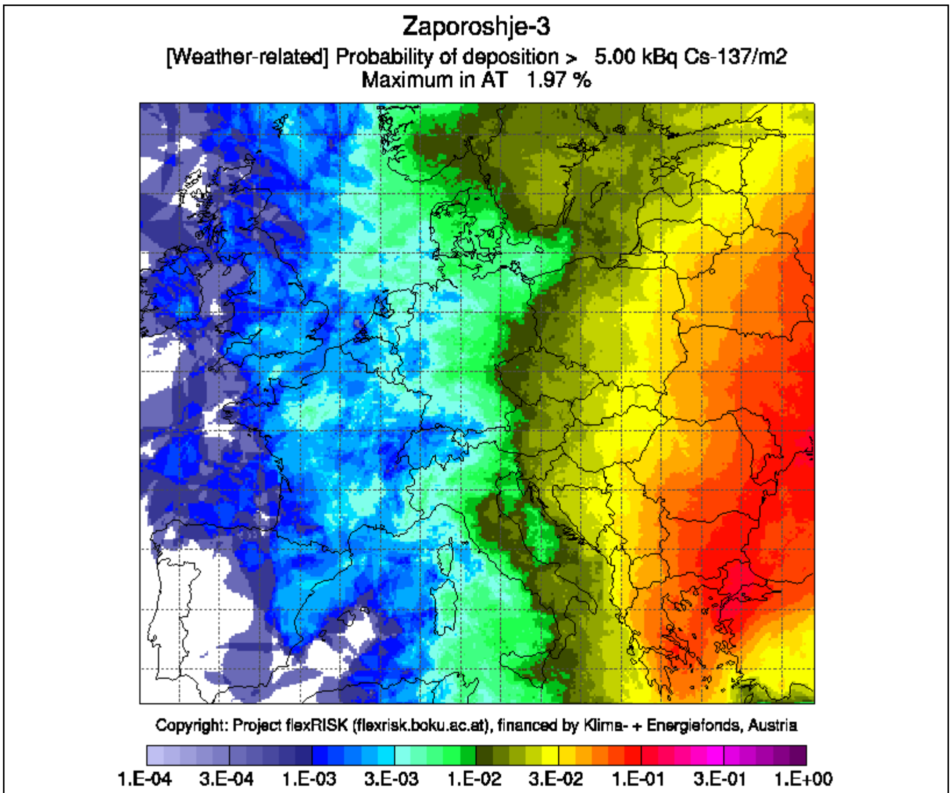
Figure 7 illustrates the average deposition of Cs-137 after a severe accident at ZNPP-3 with the Cs-137 release of 51.05 PBq. Such an accident could result in a considerable contamination of the Austrian territory; the average deposition of Cs-137 in the simulation is up to 1,000 Bq/m^2.

Figure 7: Average deposition of Cs-137 after a hypothetical BDBA in ZNPP 3.



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

Figure 8: Weather-related probability for a contamination exceeding 5 kBq Cs-137/m2as a consequence of a severe accident at ZNPP 3.



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/m² with 1.97% (see Figure 5). The weather-related probability for a contamination above 37 kBq Cs-137/m² is 0.43%, for more than 185 kBq Cs-137/m² 0.07%, 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 6: Levels for the agricultural countermeasures A07 (BMLFUW 2014)

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

A contamination of 5 kBq Cs-137/m² as shown in Figure 8 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 Zaporizhzhya 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 ZNPP severe accidents scenarios including containment failure and containment bypass with releases considerably higher than assumed in the EIA documents were not analysed but cannot be excluded. Such worst case accidents should be included in the assessment since their effects can be widespread and long-lasting and even countries not directly bordering Ukraine, like Austria, can be affected.

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

The conclusion drawn in the EIA documents 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 ZNPP.

7.3.1 Questions:

- ***Q 40:*** *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 ZNPP

8 SUMMARY OF QUESTIONS AND PRELIMINARY RECOMMENDATIONS

8.1 Procedure and alternatives

8.1.1 Questions:

- ***Q 1****: Which ZNPP units are subject to the ongoing EIA?*
- ***Q 2****: How long is the maximal foreseen lifetime extension of all ZNPP units?*
- ***Q 3****: What are the further steps in the EIA procedure and in the licensing procedure?*
- ***Q 4****: How will the results of the EIA be taken into account? Will the decisions on lifetime extension of ZNPP 1-5 be revised according to the EIA results? How will the EIA results be taken into account in the decision on lifetime extension of ZNPP 6?*

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 issue the EIA decision until the deficiencies of the EIA have been solved.

8.2 Spent fuel and radioactive waste

8.2.1 Questions:

- ***Q 5****: 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 6****: What is the status of the final disposal for spent fuel?*
- ***Q 7:*** *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 8****: What amounts and activities of LILW are expected to arise from lifetime extension of ZNPP?*

- ***Q 9**: Are there enough capacities in interim and final storages for the LILW from ZNPP lifetime extension?*
- ***Q 10**: What is the status of the treatment facilities, interim and final storages for radioactive waste?*
- ***Q 11:** 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 12:** Do the containers in the dry interim storage DSFSF withstand an airplane crash and external hazards?*

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 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) based on Article 8e of Directive 2014/87/EURATOM?*
- ***Q 14:** What are the specific findings of the ageing management programme for ZNPP 3-6? 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 ZNPP 3-6? Are there any differences between the units?*
- ***Q 16:** What are the results of the embrittlement of the reactor pressure vessels (RPVs) for ZNPP 3-6? Are there any differences between the units?*
- ***Q 17:** Is there a systematic evaluation of the ZNPP design deviations from the current international safety standards and requirements envisaged?*
- ***Q 18:** When will the WENRA RL be fully implemented in the Ukrainian regulations? Is the application of the RL binding?*
- ***Q 19:** When will a reviewed be conducted if the RL will be met for the ZNPP?*
- ***Q 20:** Which WENRA Documents are mandatory for the lifetime extension?*

8.3.2 Preliminary Recommendations:

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

- **PR 7:** It is recommended to undertake a comparison of the design and measures of the ZNPP with all requirements of SRL F. In case of deviations will be found and accepted the reasons for this decision should be explained.
- **PR 8:** It is recommended provide the following further information:
  a) a detailed description of the safety systems, including information on requirements for the important safety-relevant systems and components. Furthermore, detailed description of the measures taken to control severe accidents or to mitigate their consequences.
  b) Information about the applied national requirements and international recommendations.
  c) comprehensible presentation and overall assessment of all deviations from the current state of the art in science and technology. This presentation should include:
     - All deviations from the modern requirements for redundancy, diversity and independence of the safety levels.
     - Incompleteness of the database and plant documentation used.
     - Presentation of all safety assessments or parameter definitions by personal expert assessments (“engineering judgement”).
     - Presentation of the general dealing of uncertainties and non-knowledge and its effects on risk
     - Deviations from the state of the art in science and technology with regard to the detection methods used, the technical estimates and calculation procedures.
     - The safety margins available for the individual safety-relevant components and their respective ageing related changes compared to the original condition.
  d) Information to the ageing management program, the following issues should be presented in the EIA documents:
     - The national action plan relating to the Topical Peer Review (TPR) “Ageing Management” under the Nuclear Safety Directive 2014/87/EURATOM and its progress.
     - The very important safety issue of the ageing of the RPVs (embrittlement), including definition and justification of appropriate safety margins.
     - Evaluation of the conditions of the RPV internals and head penetrations including trends of events, and envisaged exchange measures.
     - Evaluation of the conditions of components of the primary circuit components and of the electrical installations including trends of events, and envisaged exchange measures.
  e) Regarding operation experience, the EIA documents should present an evaluation of safety relevant events including the lessons learned.

8.4 Accident analysis

8.4.1 Questions:

- ***Q 21:*** *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 22:*** *What is the currently valid time schedule for the implementation of all required SAM features for ZNPP? When will the implementation of all C(I)SIP measures be finished?*
- ***Q 23:*** *What are the parameters of the maximum aircraft crash (plane mass and speed) the buildings of ZNPP can withstand?*
- ***Q 24:*** *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 25:*** *Which design basis accidents can develop into a beyond design basis accident?*
- ***Q 26:*** *Which accidents scenarios with the loss of containment integrity or containment bypass are physical possible for the units of the ZNPP?*

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 ZNPP. 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 27:*** *Were the original design bases with regard to natural hazards and the protection systems against the effects of natural hazards systematically reassessed as part of the EIA process and / or as part of the extension of the operating license (LTO) for ZNPP?*
- ***Q 28****: 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 29:*** *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 30:*** *Have new hazard analyses for natural hazards other than seismic been carried out for ZNPP as part of the EIA process and / or as part of the extension of the operating license (LTO) and / or other projects?*
- ***Q 31****: 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 32****: Has the upgrading of the seismic resistance of all SSCs important to safety to the new DBE of PGA=0.1g as announced in the Stress Tests been completed for ZNPP?*
- ***Q 33****: What are the results of the latest seismic hazard assessment (PSHA 2013-2014) in terms of the design basis earthquake? Are the new design basis values enveloped by the seismic resistance of all SSCs relevant to safety?*
- ***Q 34****: 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.*
- ***Q 35****: Is the hazard of external flooding, in particular river floods and floods by the possible break or mismanagement of Dniepr dams upstream of ZNPP, appropriately taken into account in the definition of the design basis flood, i.e., by referring to occurrence probabilities of 10^{-4} per year (average recurrence period of 10,000 years)?*
- ***Q 36****: The EIA document REPORT CONSULTATIONS (2018, Annex 2, p. 13) states the following CDF and LRF values for units 1 and 2 of ZNPP: unit1 – CDF=6.37E-06 1/year, LRF=4.92E-06 1/year; unit 2 - CDF=5.97E-06 1/year, LRF=4.96E-06 1/year.*
  - *Are the values derived from an **extended** Level 2 PSA?*
  - *Which types of initiating events (internal hazards, internal fire, seismic, flooding etc.) are considered in the PSA?*
  - *Does the analysis consider potential releases from the spent fuel pool?*
  - *Why is the LRF value larger than the CDF?*
  - *What are the CDF and LRF values of the units 3 to 6 of ZNPP, should such data be available?*

8.5.2 Preliminary Recommendations:

- **PR 11**: It remains unclear whether all natural hazards relevant to the site were taken into account in the site safety analysis, as required by WENRA (2021) and further explained by WENRA (2015). The team of experts recommends using the "Non-Exhaustive List of Natural Hazards" (WENRA 2015) as a starting point to ensure that all site-specific hazards affecting ZNPP are taken into account.
- **PR 12**: It seems uncertain whether all hazard combinations were taken into account in the assessment of the site, as required by WENRA (2021) and further explained by WENRA (2015). The team of experts recommends using a hazard correlation diagram (e. g. DECKER & BRINKMAN 2017) as a starting point to ensure that all relevant combinations are taken into account.
- **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 identified for the site and use the derived parameters to develop adequate protection concepts.
- **PR 15:** The expert team recommends to apply the WENRA approach of analysing Design Extension Conditions (DEC) for natural hazards and updates of the protection concepts against natural hazards. DEC are not analysed in the available EIA document. This is in violation of the WENRA requirement that DEC analysis shall be undertaken with the purpose of further improving the safety of existing nuclear power plants and enhancing their capability to withstand more challenging events or conditions than those considered in the design basis.

8.6 Accidents with third parties' involvement

8.6.1 Questions:

- ***Q 37:*** *What are the requirements with respect to the NPP design against the deliberate crash of a commercial aircraft?*
- ***Q 38:*** *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 39:** *Is a peer-review mission of the IAEA International Physical Protection Advisory Service (IPPAS) planned?*

8.6.2 Preliminary Recommendations:

- **PR 16**: The EIA documents should present the general requirements with respect to the protection against the deliberate crash of a commercial aircraft and other terror attacks and acts of sabotage.
- **PR 17**: In the light of the special situation in Ukraine, the effects of third parties (terrorist attacks or acts of sabotage of the plant) should be given high priority. Protection against cyber-attacks and the treat of insiders should be improved. The IAEA's International Physical Protection Advisory Service (IPPAS) should be used to improve the security.

8.7 Trans-boundary impacts

8.7.1 Questions:

- ***Q 40:*** *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 ZNPP

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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 ($9.82 ms^{-2}$)

I .... Earthquake intensity

HLW .... High level radioactive waste

I&C .... Instrumentation and Control

I-131 .... Iodine-131

IAEA .... International Atomic Energy Agency

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

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

IPPAS................................International Physical Protection Advisory Service

IVMR.................................In-Vessel Melt Retention

IVR ....In-Vessel Retention

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

LOCA ....Loss of Coolant Accident

LRF....................................Large Release Frequency

LTO ....Long-Term Operation

LWR ....Light Water Reactor

MCR..................................Main Control Room

MDBA ....Maximum Design Basis Accident

MDGPU ....Mobile Diesel Generators and Pumping Unit

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

NAcP ....National Action Plan

NDE ....Non-Destructive Examination

NDI ....Nondestructive Inspection

NPP...................................Nuclear Power Plant

NTI ....Nuclear Threat Initiative

OBE...................................Operating Base Earthquake

OZ.....................................Observation Zone (30km)

PBq ....PetaBecquerel

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

PSA ....Probabilistic Safety Assessment

PSHA ....Probabilistic Seismic Hazard Assessment

PSR ....Preliminary Safety Report

PSR ....Periodic Safety Review

PWR..................................Pressurized Water Reactor

RHWG...............................Reactor Harmonization Working Group

RL..Reference Level

RPV ....Reactor Pressure Vessel

SAM ....Severe Accident Management

SAMG ....Severe Accident Management Guideline

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

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

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

SEA ....Strategic Environmental Assessment

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

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

SG ....Steam Generator

SNRIU ....State Nuclear Regulatory Inspectorate of Ukraine

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

SSC ....Structure, Systems and Components

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

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

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

TBq ....Tera-Becquerel, E12 Bq

TCA ....Technical Condition Assessment

TLAA .... Time Limited Ageing Analysis

TPR ....Topical Peer Review

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

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

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

ZNPP ....Zaphorishshya NPP

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ISBN 978-3-99004-598-5