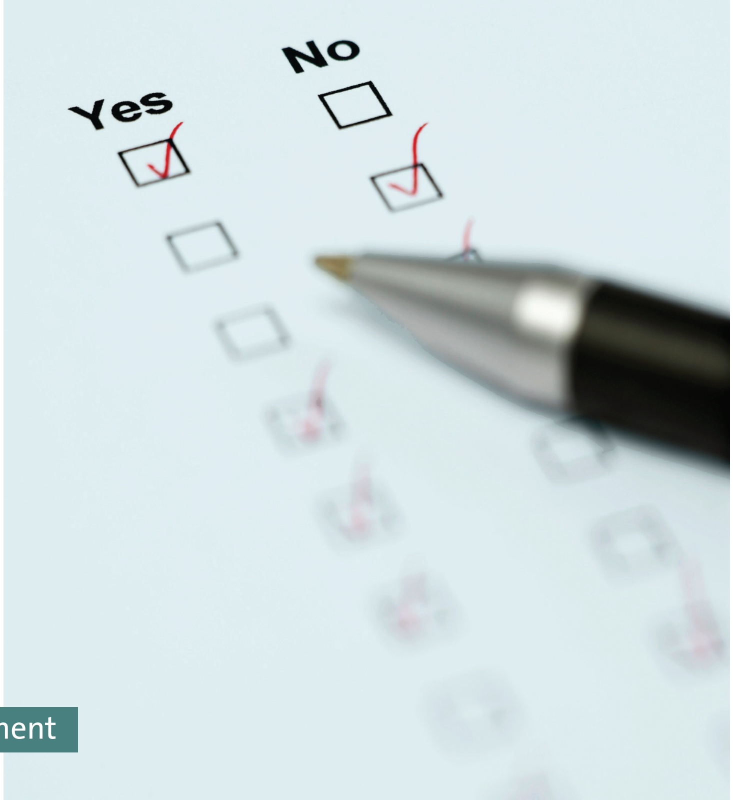
ENVIRONMENT AGENCY AUSTRIA umweltbundesamt

EIA NPP Khmelnitsky 3&4

Procedure 2019



Bundesministerium
Nachhaltigkeit und
Tourismus

pulswerk
Das Beratungsunternehmen des Österreichischen Ökologie-Instituts

Expert Statement

EIA NPP KHMELNITSKY 3&4 PROCEDURE 2019

Expert Statement

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Commissioned by

Austrian Ministry of Sustainability and Tourism

Directorate I/6

General Coordination of Nuclear Affairs

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

Federal Ministry
Republic of Austria
Sustainability and Tourism

pulswerk
Das Beratungsunternehmen des Österreichischen Ökologie-Instituts

REPORT

REP-0692

Vienna 2019

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

Imprint

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

The Environment Agency Austria prints its publications on climate-friendly paper.

ISBN 978-3-99004-511-4

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SUMMARY

At the Khmelnitsky site in Ukraine, the state enterprise "National Nuclear Energy Generating Company Energoatom" is preparing the completion of nuclear power plant units 3 and 4 (KhNPP-3&4). At the site, two units VVER-1000/V-320 are already in operation.

Construction of KhNPP-3&4 started in 1985/1986 and was halted due to the 1990 moratorium on the construction of nuclear power units in the former USSR. In 2005, the Cabinet of Ministers of Ukraine decided to renew the construction. The reactor VVER-1000/V-392 (Atomstroyexport) was chosen and this decision became law in 2012. Due to the deteriorating relations between Ukraine and Russia this law ceased to be in force in 2015. Energoatom chose Škoda JS a.s. as the reactor supplier.

An environmental impact assessment (EIA) under the Espoo Convention started in 2010. Austria has participated in this procedure since 2011 and submitted an expert statement (UMWELTBUNDESAMT 2013[1]) in 2013; in August 2013 bilateral consultations with the Ukrainian side took place. The objective of the Austrian participation in the Espoo procedure is to give recommendations on minimising or even eliminating possible significant adverse impacts on Austria.

Overall and procedural aspects

Most of the EIA documents provided in 2013 have remained unchanged, with the exception of documents on the recently selected reactor type VVER 1000/V-320. No new assessments of possible trans-boundary impacts have been provided.

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

Spent fuel and radioactive waste

Important information on the management of the spent fuel and radioactive waste from KhNPP-3&4 is lacking in the EIA documents: The expected inventory of spent fuel from KhNPP-3&4 is not given. Information on the status of the central interim storage where the spent fuel from KhNPP-3&4 shall be stored is missing. No information was provided about the planned options for the back-end of the fuel chain (reprocessing, final disposal in Ukraine, international disposal?). Spent fuel and radioactive waste can cause adverse environmental impacts and therefore the EIA should assess the nuclear waste management.

[1] It can be downloaded at: http://www.umweltbundesamt.at/umweltsituation/uvpsup/espooverfahren/espoo_ukraine/kkwkhmelnitsky34/

Reactor Type

For the completion of KhNPP-3&4, it is planned to use the buildings and structures already built in the 1980s. Information about the conditions of the existing buildings, structures and equipment are not provided in the EIA documents.

An over 10-year-old survey performed between 2005 and 2009 concluded that the **existing buildings and structures** are in an operable condition – no reference to a more recent survey is made in the EIA documents. In this year an inspection confirming the durability and reliability of the building and structures of KhNPP-3&4 shall be performed. The EIA documents do not provide information about the resistance against external impacts of the KhNPP-3&4.

All in all, there is no convincing evidence today that the existing building, structures and equipment are in a condition to ensure 50 years of safe operation. Buildings and structures originally designed for operation of 40 years have to be kept operable for about 100 years.

An ageing management programme (AMP) is not mentioned, despite the fact that ageing of the more than 30-year-old structures, buildings and equipment is an issue even without operational loads. The negative effect of ageing depends also on the inspection, restoration and protection measures taken (AMP). The first Topical Peer Review (TPR) based on Article 8e of Directive 2014/87/EURATOM focused on ageing management. For Ukraine, this assessment revealed several deviations from the safety expectations for an acceptable ageing management in Europe. At KhNPP 3&4, one of the expected TPR performance levels, which is not met, is of particular concern: "*During long construction periods of NPPs, relevant ageing mechanisms are identified, and appropriate measures are implemented to control any incipient ageing or other effects*". (ENSREG 2018)

The improved VVER-1000/V-392B safety concept (with passive safety systems) for the completion of KhNPP-3&4 was selected and approved in 2008. The VVER 1000/V-320 design on the contrary does not comply with modern safety standards.

To choose from the VVER-1000 reactor family for the completion of KhNPP-3&4 is comprehensible to some extent, given the fact that nearly all of the operating reactors in Ukraine are VVER-1000 reactors. However, advanced VVER-1000 reactors with enhanced safety features have been available for several years and have already been built.

The EIA documentation does not deal with any of the known safety issues of the VVER-1000/V-320 reactors. It is very important to understand how the KhNPP-3&4 units will overcome the various shortcomings of the VVER1000/V-320 reactors in general and more concretely in this project in Ukraine.

An analysis performed in the framework of the EU pre-accession instrument (PHARE project) in Bulgaria at units 5&6 of the Kozloduy NPP discovered a vulnerability of the VVER-1000/V-320 design consisting in early containment melt-through via the ionization chamber (IC) channels situated around the reactor pit. The Bulgarian regulator demanded the realization of a specific engineering solution as a pre-condition for licensing Kozloduy. It is not mentioned in the EIA documents whether plugging the IC channels at KhNPP-3&4 is foreseen.

The high-energy pipelines at the Temelín NPP (VVER 1000/V-320) are situated without partition walls and without protection between the containment and the turbine hall at the level of the 28.8 m platform. The EIA documentation does not explain how the issue of high-energy pipelines will be dealt with at KhNPP-3&4.

Key safety feature of the envisaged KhNPP-3&4 reactor units is the external cooling of the molten core in case of a core melt accident. The development of this feature for the “In Vessel Melt Retention” (IVMR) is still underway, for example at the reference units at the Temelín NPP.

The EIA documents do not provide a detailed description of the safety-relevant systems, most of them are only listed without any information about the capacities, redundancies and physical separation. NPP designs developed in the 1980s, like the VVER-1000/V-320, only partly meet modern design principles concerning redundancy, diversity and physical separation of redundant subsystems or the preference of passive over active safety systems. (See IAEA 2016a, WENRA 2013)

According to WENRA (2013), the WENRA Safety Objectives for new NPPs shall also be used as a reference for identifying reasonably practicable safety improvements for “deferred plants” like KhNPP-3&4. However, the EIA documents do not mention this WENRA safety objectives.

According to ENERGOATOM (2017a), a power uprate to 104% of the design power and load-following operation are planned for KhNPP-3&4. The load-following mode causes technical disadvantages, because plant components are exposed to numerous thermal stress cycles; this leads to faster ageing and requires more sophisticated systems for reactor monitoring and control. An increase of reactor power reduces safety margins and accelerates ageing processes at the same time.

Incidents and accidents without involvement of third parties

A systematic analysis of design basis accidents (DBA) and beyond design basis accidents (BDBA) is not presented in the EIA documents; only the radiological consequences of one DBA and one BDBA are discussed. The considered BDBA is a loss of coolant accident with the failure of the active systems of the emergency core cooling and the sprinkler system. The calculated probability of this BDBA is 4.29*E-7 per reactor year. This BDBA does not constitute a worst case scenario. To calculate the possible (transboundary) consequences of this BDBA, it was assumed that the core melt will remain within the reactor pressure vessel (RPV). This assumption is not duly justified, because features to ensure the retention of the corium in the RPV (In-Vessel Melt retention -IVMR) are not available yet. Furthermore, if this feature could be realized it would only reduce the risk of radioactive release in most but not in all severe accident scenarios.

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/V-320 reactor type. Although their probability is below a specific value this type of such severe accidents cannot be excluded. A report published in 2012 by the Norwegian Radiation Protection Authority (NRPA) calculated the possible consequences for a VVER-1000/V-320 reactor with source terms considerably higher compared to those used in the EIA documents.

The results of the EU stress tests have revealed that the severe accident management (SAM) (i.e. the prevention of severe accidents and the mitigation of its consequences) at the Ukrainian NPPs shows a lot of shortcomings. 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.

According to current international requirements for new nuclear power plants (IAEA 2012 and WENRA 2013), accident sequences with early or large releases have to be practically eliminated. The concept of "practical elimination" of early or large releases is not mentioned for KhNPP-3&4 in the EIA documents. Quite the opposite: ENERGOATOM (2017a) states the probability of severe accidents (e.g. with containment failure) that could have a major release are negligible. This approach does not comply with the state of the art. Although probabilistic targets can be set, "practical elimination" cannot be demonstrated by showing the compliance with a general probabilistic value. According to IAEA (2016a) 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 accidents.

External hazards

The information provided in the EIA documents shows that the site evaluation is not complying with current **international requirements**, because the quoted international recommendations are outdated. According to SNRIU (2017), the seismic hazards have to be re-evaluated, the FS was approved with the condition to elaborate and/or clarify the calculation of the site's peak ground acceleration (PGA). The KhNPP site is located in a **tornado hazardous area**. Thus, the location can only be used as a site for new reactors if appropriate technical provisions are taken.

The 2011 feasibility study of has been approved with the condition that an in-depth assessment of the impact of extreme external events of natural and man-made nature as well as their combinations will be included in the Preliminary Safety Report (SNRIU 2012b). This condition is not included in conditions for the approval of the current FS (SNRIU 2017).

According to WENRA (2013), the safety assessment for new nuclear power plants should demonstrate that threats from external hazards are either removed or minimized as far as reasonably practicable. Information whether this WENRA recommendation is to be applied for KhNPP-3&4 is not provided in the EIA documents.

Incidents and accidents with involvement of third parties

The effects of third parties (terrorist attacks or acts of sabotage) can have a considerable impact on nuclear facilities and thus also on the KhNPP-3&4 in Ukraine. Nevertheless, they are not mentioned in the EIA documents for KhNPP-3&4. In comparable EIA documents such events were addressed to some extent.

Although precautions against interference by third parties cannot be discussed in detail in the EIA process for reasons of confidentiality, the necessary legal requirements should be set out in the EIA documents. 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, as the wall thickness of the reactor building/containment of KhNPP-3&4 is only about 1,000-1,200 mm. Therefore, the units could be vulnerable against terror attacks (including airplane crash). In 2013, the resistance of KhNPP-3&4 against the accidental or deliberate crash of a large (commercial) airplane was not required by the Ukrainian regulator.

A recent assessment of the nuclear security in the Ukraine points to shortcomings compared to necessary requirements for nuclear security: The 2018 NTI Index assesses nuclear security conditions related to the protection of nuclear facilities against acts of sabotage.

With a total score of 70 out 100 points, Ukraine ranked only 30 out of 45 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.

Transboundary Impacts

Severe accidents with releases considerably higher than assumed in the EIA documents cannot be excluded for the KhNPP-3&4, even if their probability is required to be below a specific value. Such worst case accidents should be included in the assessment since their effects can be widespread and long-lasting and even countries not directly bordering Ukraine, like Austria, can be affected.

Because of the lack of analysis of the worst case scenarios, the conclusion of the EIA documents concerning transboundary effects is not appropriate.

The results of the calculations made by the Austrian Institute of Ecology (1998) indicated that a severe accident (worst case scenario) at KhNPP would contaminate several regions in Europe. For the Eastern part of Austria, the calculation resulted in values up to approx. 1,000 kBq/m² of caesium-137 contamination (which is about 5 times the highest values measured in Austria in 1986).

Furthermore, the results of the flexRISK project indicated that after a severe accident, the average caesium-137 ground depositions at most areas of the Austrian territory would be higher than the threshold for agricultural intervention measures (e.g. earlier harvesting, closing of greenhouses). Therefore, Austria would be affected by a severe accident at KhNPP-3&4.

ZUSAMMENFASSUNG

Auf dem KKW-Standort Khmelnitsky in der Ukraine beabsichtigt der staatliche Atomenergiekonzern Energoatom die Fertigstellung der Atomkraftwerksblöcke 3 und 4 (KhNPP-3&4). An diesem Standort sind bereits zwei WWER-1000/V-320 Reaktoren in Betrieb.

Die Errichtung der KhNPP-3&4 begann 1985/1986 und wurde aufgrund des Moratoriums für die Errichtung von KKW in der ehemaligen UdSSR im Jahre 1990 abgebrochen. Im Jahre 2005 beschloss der Ministerrat der Ukraine die Errichtung wieder aufzunehmen. Es wurde der Reaktor WWER-1000/V-392 von Atomstrojexport gewählt und diese Entscheidung erlangte im Jahre 2012 Gesetzeskraft. Aufgrund der sich verschlechternden Beziehung zwischen Ukraine und Russland trat das Gesetz im Jahre 2015 außer Kraft. Energoatom entschloss sich dann für Škoda JS a.s als Reaktorlieferanten.

Eine Umweltverträglichkeitsprüfung (UVP) gemäß Espoo-Konvention begann 2010. Österreich beteiligte sich an diesem Verfahren ab 2011 und übermittelte 2013 eine Fachstellungnahme (UMWELTBUNDESAMT 2013[2]). Im August 2013 fanden bilaterale Konsultationen mit der ukrainischen Seite statt. Das Ziel der Teilnahme Österreichs an dem Espoo-Verfahren ist, Empfehlungen zur Minimierung oder wenn möglich Verhinderung von möglichen erheblichen nachteiligen Umweltschäden für Österreich zu geben.

Allgemeine und prozedurale Aspekte

Der Großteil der UVP-Unterlagen aus dem Jahre 2013 blieb unverändert, mit der Ausnahme der Unterlagen zu dem jüngst ausgewählten Reaktortyp WWER 100/V-320. Es wurden keine neuen Abschätzungen zu den möglichen grenzüberschreitenden Folgen zur Verfügung gestellt.

Laut Espoo-Konvention ist eine Beschreibung und Prüfung vernünftiger Alternativen wie auch der Nullvariante in der UVP-Dokumentation zu betrachten. Diesbezüglich ist die Information in der UVP-Dokumentation unzureichend.

Abgebrannte Brennelemente und radioaktive Abfälle

Die UVP-Dokumentation beinhaltet keine Information über die wichtige Frage der Entsorgung von abgebrannten Brennelementen und radioaktiven Abfällen aus den KhNPP-3&4: Es fehlt die Angabe des erwarteten Inventars an abgebranntem Brennstoff aus den KhNPP-3&4. Es fehlt die Angabe über den Status des zentralen Zwischenlagers, wo die abgebrannten Brennstäbe aus den KhNPP-3&4 gelagert werden sollen. Ebenso gibt es keine Information über die geplanten Optionen für das Back-end der Brennstoffkette (Wiederaufbereitung, Endlagerung in der Ukraine, internationales Endlager?). Abgebrannte Brennelemente und radioaktiver Abfall können negative Umweltauswirkungen haben und daher sollten ihre Entsorgung in der UVP bewertet werden.

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[2] Download unter: http://www.umweltbundesamt.at/umweltsituation/uvpsup/espooverfahren/espoo_ukraine/kkwkhmelnitsky34/

Reaktortyp

Für die Fertigstellung von der KhNPP-3&4 sollen die bereits in den 1980er Jahren errichteten Gebäude und Strukturen verwendet werden. Über den Zustand der existierenden Gebäude, Strukturen und Anlagen gibt es in der UVP keine Angaben.

Eine mehr als zehn Jahre alte Untersuchung, die zwischen 2005 und 2009 durchgeführt wurde, kam zu dem Schluss, dass sich die **bestehenden Gebäude und Konstruktionen** in einem für den Betrieb geeigneten Zustand befinden – es gibt in den UVP-Dokumenten keinen Hinweis darauf, dass eine jüngere Untersuchung durchgeführt worden wäre. Dieses Jahr soll eine Inspektion durchgeführt werden, die die Lebensdauer und Zuverlässigkeit der Gebäude und Konstruktionen von der KhNPP-3&4 bestätigt. Die UVP-Unterlagen beinhalten keine Information über die Widerstandsfähigkeit von der KhNPP-3&4 gegen externe Auswirkungen.

In Summe bedeutet dies, dass heute keine überzeugenden Nachweise vorliegen, dass die bestehenden Gebäude, Konstruktionen und Anlagen einen 50-jährigen sicheren Betrieb garantieren können. Die Gebäude und Konstruktionen waren ursprünglich für einen Betrieb von 40 Jahren ausgelegt und müssen somit 100 Jahre in Betrieb bleiben können.

Ein Programm zum Alterungsmanagement (AMP) ist nicht genannt, obwohl die Alterung der über 30 Jahre alten Konstruktionen, Gebäude und Anlagen bereits ohne Betriebslast eine offene Frage darstellt. Der negative Effekt der Alterung ist von der Inspektion, Erneuerung und den getätigten Schutzmaßnahmen (AMP) abhängig. Die erste Topical Peer Review (TPR) basierend auf Artikel 8e der Richtlinie 2014/87/EURATOM war auf das Alterungsmanagement ausgerichtet. Für die Ukraine hat diese Prüfung einige schwere Abweichungen von den Erwartungen gezeigt, die in Europa an ein akzeptables Alterungssicherheitsmanagement gestellt werden. Besonders ernst zu bewerten ist ein von der TPR angesetzter Maßstab, welcher von den KhNPP-3&4 nicht erfüllt wurde: „*Während der langen Bauzeiten von KKWs werden relevante Alterungsmechanismen identifiziert und angemessene Maßnahmen durchgeführt, um einsetzende Alterungseffekte oder andere Effekte zu beherrschen.*“ (ENSREG 2018)

Das verbesserte Sicherheitskonzept des WWER-1000/V-392B (mit passiven Sicherheitssystemen) für die Fertigstellung von der KhNPP-3&4 wurde 2008 ausgewählt und genehmigt, wohingegen das Design WWER-1000/V-320 moderne Sicherheitsstandards nicht einhält.

Zu einem gewissen Grad ist es nachvollziehbar, wenn für die Fertigstellung der KhNPP-3&4 ein Reaktor der WWER-1000 Reaktorfamilie gewählt wird, da nahezu alle Reaktoren in der Ukraine WWER-1000 sind. Allerdings gibt es bereits seit einigen Jahren weiterentwickelte WWER-1000 mit verbessertem Sicherheitsdesign, die bereits errichtet wurden.

Die UVP-Dokumentation befasst sich mit keinem der bekannten Sicherheitsprobleme der WWER-1000/V-320 Reaktoren. Von besonderem Interesse ist, wie für die Blöcke 3 und 4 die diversen Sicherheitsprobleme der WWER-1000/V-320 Reaktoren allgemein und konkret in der Ukraine gelöst werden.

Eine im Rahmen der EU-Beitrittshilfe für die Blöcke 5 und 6 des KKW Kosloduj in Bulgarien durchgeführte Analyse (PHARE-Projekt) deckte ein Problem des Designs der WWER-1000/V-320 auf. Es handelt sich dabei um ein frühes Durchschmelzen des Containments über die Kanäle der Ionisierungskammern, die sich um den Reaktorschacht befinden. Die bulgarische Aufsichtsbehörde forderte eine spezifische technische Lösung als Bedingungen für die Lizensierung von Kosloduj. In den UVP-Dokumenten wird nicht angeführt, ob das Abdichten der Kanäle der Ionisierungskammern für die KhNPP-3&4 geplant ist.

Die hochenergetischen Rohrleitungen des KKW Temelín (WWER 1000/V-320) befinden sich zwischen dem Containment und der Turbinenhalle auf der 28,8m-Ebene, ohne Trennwände und ohne Schutz. Die UVP-Dokumentation enthält keine Erklärung, wie die Frage der hochenergetischen Rohrleitungen bei KhNPP-3&4 behandelt werden wird.

Das wichtigste Sicherheitsmerkmal des für KhNPP-3&4 gewählten Reaktors ist die externe Kühlung des Kern bei einem Kernschmelzunfall. Die Entwicklung dieser Funktion für "In Vessel Melt Retention" (IVMR), das Auffangen der Kernschmelze im Reaktordruckbehälter, ist z. B. bei den Referenzanlagen des KKW Temelín noch nicht abgeschlossen.

Die UVP-Dokumentation beinhaltet keine detaillierte Beschreibung der sicherheitsrelevanten Systeme. Die meisten werden nur aufgelistet, ohne Beschreibung der Kapazitäten, Redundanzen und der physischen Trennung. Die in den 1980er entwickelten Reaktordesigns – wie der WWER-1000/V-320 – erfüllen die modernen Auslegungsprinzipien bei der Redundanz, bei der Diversifizierung und physischen Trennung der redundanten Subsysteme oder der Bevorzugung von passiven gegenüber aktiven Systeme nur teilweise (siehe IAEA 2016a, WENRA 2013).

Laut WENRA (2013) sollen die WENRA-Sicherheitsziele für neue KKW auch als Referenz für die vernünftigerweise durchführbaren Sicherheitsverbesserungen für "verzögerte" KKW, wie die KhNPP-3&4 angewendet werden. Doch die UVP-Dokumentation nannte dieses WENRA-Sicherheitsziel nicht.

Laut ENERGOATOM (2017a) ist eine Erhöhung auf 104 % der Auslegungsleistung und Betrieb in Lastfolge für die KhNPP-3&4 vorgesehen. Der Lastfolgebetrieb verursacht eine Reihe von negativen technischen Effekten, da die Kraftwerkskomponenten zahlreichen thermischen Stresszyklen unterworfen werden. Das führt zu einer verstärkten Alterung und erfordert anspruchsvollere Systeme für Reaktorüberwachung und Reaktorsteuerung. Die erhöhte Reaktorleistung verringert die Sicherheitsreserven des Reaktors und beschleunigt die Alterungsprozesse.

Störfälle und Unfälle ohne Beteiligung Dritter

Eine systematische Analyse der Auslegungsstörfälle (DBA) und auslegungsstörfallüberschreitenden Unfälle (BDBA) wird in den UVP-Unterlagen nicht präsentiert, sondern behandelt werden nur die Strahlenfolgen eines DBA und eines BDBA. Der betrachtete BDBA ist ein Kühlmittelverlustunfall mit dem Versagen der aktiven Systeme für die Kernnotkühlung und das Sprinklersystem. Die berechnete Wahrscheinlichkeit für diesen BDBA liegt bei 4,29*E-7 pro Jahr. Dieser BDBA stellt nicht das Worst-Case Szenario dar, um die möglichen (grenzüberschreitenden) Folgen dieses BDBA zu berechnen, denn es wird angenommen, dass die Kernschmelze im Reaktordruckbehälter (RDB) zurückgehalten würde. Diese Annahme ist nicht hinreichend begründet, weil die Einrichtung zur Rückhaltung des Coriums im RDB (In-Vessel Melt retention – IVMR) noch nicht zur Verfügung steht. Außerdem würde diese Einrichtung das Risiko der radioaktiven Freisetzung zwar beim Großteil, aber nicht bei allen Unfallszenarien reduzieren.

Um die Folgen von BDBA zu bewerten, ist es notwendig, eine Reihe von schweren Unfällen zu untersuchen, einschließlich derer mit Containment-Versagen und mit Cointainment-Bypass. Beim Reaktortyp WWER 1000/V-320 sind schwere Unfälle dieser Art möglich. Auch wenn die Wahrscheinlichkeit un-ter einem bestimmten Wert liegt, können derartige schwere Unfälle nicht aus-geschlossen werden. Ein Bericht der norwegischen Strahlenschutzbehörde be-rechnete 2012 die möglichen Folgen bei einem WWER-1000/V-320 Reaktor mit einem deutlich höheren Quellterm, als er in den UVP-Dokumenten verwendet wurde.

Die Ergebnisse der EU-Stresstests zeigten auf, dass das Management schwerer Unfälle (SAM), d. h. die Prävention von schweren Unfällen und die Minderung von deren Konsequenzen, bei ukrainischen KKW noch eine Reihe von Schwächen aufweist. Umfassende Verbesserungen werden von der Aufsichtsbehörde gefordert, allerdings empfahl das ENSREG Peer Review Team noch weitere Verbesserungen. Dabei handelt es sich um eines der Beispiele für die Kluft zwischen den Sicherheitsstandards und Sicherheitsanforderungen von Ukraine und EU.

Die aktuell geltenden internationalen Anforderungen an neue Kernkraftwerke (IAEA 2012 und WENRA 2013) fordern den praktischen Ausschluss von Unfallabfolgen mit frühen oder großen Freisetzungen. Das Konzept des „praktischen Ausschlusses“ von frühen oder großen Freisetzungen wird in den UVP-Unterlagen für die KhNPP-3&4 nicht genannt. Im Gegenteil: ENERGOATOM (2017a) hält fest, dass die Wahrscheinlichkeit schwerer Unfälle (z. B. mit Containment-Versagen) mit größeren Freisetzungen vernachlässigbar sei. Diese Zugangsweise entspricht nicht dem Stand der Technik. Ziele für Wahrscheinlichkeiten können festgelegt werden, doch kann der „praktische Ausschluss“ nicht nachgewiesen werden, indem das Erreichen eines allgemeinen Wahrscheinlichkeitswerts nachgewiesen wird. Laut IAEA (2016a) stellt eine geringe Eintrittswahrscheinlichkeit für einen Kernschmelzunfall keinen Grund dafür dar, das Containment nicht gegen die durch einen solchen Unfall erzeugten Bedingungen zu schützen.

Externe Gefährdungen

Die UVP-Unterlagen zeigen auf, dass die Standortprüfung den aktuellen **internationalen Anforderungen** nicht entspricht, weil die zitierten internationalen Anforderungen veraltet sind. Laut SNRIU (2017) ist die seismische Gefährdung neu zu bewerten, die Machbarkeitsstudie wurde unter der Bedingung akzeptiert, dass die Berechnungen zur maximalen Bodenbeschleunigung (PGA) ausgearbeitet und/oder präzisiert werden. Der Standort Khmelnitsky liegt in einem **tornadogefährdeten Gebiet.** Aus diesem Grund kann der Standort für neue Reaktoren nur dann verwendet werden, wenn angemessene technische Maßnahmen ergriffen werden.

Die Machbarkeitsstudie von 2011 wurde unter der Bedingung genehmigt, dass eine vertiefte Prüfung der Auswirkungen von extremen externen Ereignissen – natürlichen und vom Menschen verursachten – wie auch deren Kombination im Vorläufigen Sicherheitsbericht (SNRIU 2012b) eingeschlossen wird. Diese Bedingung fehlt in der Aufzählung der Bedingungen, die die Genehmigung der aktuellen Machbarkeitsstudie SNRIU (2017) auflistet.

Laut WENRA (2013) sollen die Sicherheitsanalysen für neue Kernkraftwerke nachweisen, dass externe Gefährdungen, so weit wie vernünftigerweise durchführbar entweder beseitigt oder minimiert werden. Die UVP-Unterlagen erwähnen nicht, ob diese WENRA-Empfehlung auch für KhNPP-3&4 anzuwenden ist.

Störfälle und Unfälle mit Beteiligung Dritter

Die Einwirkungen Dritter (Terrorangriffe oder Sabotageakte) können starke Auswirkungen auf Nuklearanlagen haben, natürlich auch auf die KhNPP-3&4 in der Ukraine. Dennoch werden diese in den UVP-Unterlagen nicht erwähnt. In vergleichbaren UVP-Unterlagen wurden diese Ereignisse bis zu einem gewissen Grad behandelt.

Auch wenn Vorkehrungen gegen die Einwirkungen Dritter aufgrund der notwendigen Vertraulichkeit nicht im Detail im UVP-Verfahren behandelt werden können, so sollten die notwendigen rechtlichen Anforderungen in den UVP-Unterlagen dargestellt werden. Vor allem sollten die UVP-Dokumente detaillierte Informationen über die Anforderungen an das Design betreffend einen gezielten Absturz eines kommerziellen Verkehrsflugzeugs beinhalten. Dieses Thema ist von besonderer Bedeutung, da die Wanddicke des Reaktorgebäudes/Containments bei den KhNPP-3&4 nur etwa 1.000–1.200 mm beträgt. Daher könnten diese Blöcke gegenüber Terrorangriffen verwundbar sein (einschließlich Flugzeugabstürzen). Im Jahre 2013 wurde von der ukrainischen Aufsichtsbehörde keine Widerstandsfähigkeit für die KhNPP-3&4 gegenüber zufälligen oder beabsichtigten Flugzeugabstürzen (großer Passagierflieger) gefordert.

Eine jüngst durchgeführte Bewertung der nuklearen Sicherung in der Ukraine verwies auf Schwachstellen gegenüber den benötigten Anforderungen: Der 2018 NTI Index bewertet die Schutzbedingungen der nuklearen Sicherung bei den Nuklearanlagen gegenüber Sabotageakten. Die Ukraine kam mit einer Gesamtpunkteanzahl von 70 von 100 nur auf Platz 30 von 45 in der Länderreihung, was auf ein geringes Schutzniveau hinweist. Ebenso ist anzuführen, dass die niedrige Bewertung beim „Schutz vor Insiderbedrohung“ und „Cybersicherheit“ Defizite in diesen Bereichen aufzeigt.

Grenzüberschreitende Auswirkungen

Schwere Unfälle mit deutlich höheren Freisetzungen als in den UVP-Unterlagen angenommen können für die KhNPP-3&4 nicht ausgeschlossen werden, auch wenn deren Wahrscheinlichkeiten unter einem bestimmten spezifischen Wert zu bleiben haben. Solche schwersten Unfälle sollten in der UVP berücksichtigt werden, da deren Auswirkungen weitreichend und langfristig sein können und selbst Länder betreffen, die nicht an die Ukraine angrenzen, wie etwa Österreich.

Da keine Analysen zu den schwersten Unfallszenarien vorgelegt wurden, ist die Schlussfolgerung der UVP-Dokumente betreffend grenzüberschreitender Folgen nicht angemessen.

Die Berechnungen des Österreichischen Ökologie-Instituts (1998) zeigten, dass ein schwerer Unfall (Worst Case Szenario) in den KhNPP-3&4 mehrere Regionen Europas kontaminieren würde. Für die Ostregion Österreichs würden laut Berechnungen ca. 1.000 kBq/m² Cäsium-137 erreicht werden (das entspricht etwa dem Fünffachen des im Jahre 1986 gemessenen höchsten Wertes).

Auch zeigten die Berechnungen des flexRISK-Projekts, dass nach einem schweren Unfall die durchschnittliche Bodenkontamination mit Cäsium-137 in den meisten Gebieten Österreich das Interventionsniveau für landwirtschaftliche Maßnahmen erreichen würde (d. h. vorgezogene Ernte, Schließen von Gewächshäusern). Somit wäre Österreich von schweren Unfällen in den KhNPP-3&4 betroffen.

РЕЗЮМЕ

Державне підприємство «Національна атомна енергогенеруюча компанія «Енергоатом» веде підготовку до завершення будівництва 3 і 4 атомних блоків (ХАЕС № 3 та 4) на Хмельницькому майданчику в Україні. На майданчику вже діють дві реакторні установки типу ВВЕР-1000/В-320.

Будівництво енергоблоків ХАЕС № 3 та 4 розпочалося у 1985-1986 роках. У зв'язку з введенням в 1990 році в СРСР мораторію на спорудження нових енергоблоків АЕС будівництво енергоблоків № 3 та 4 Хмельницької АЕС було припинено.

У 2005 році Кабінет Міністрів України вирішив, відновити будівництво. Було вибрано реакторну установку типу ВВЕР-1000/В-392 (Атомстройекспорт), що було закріплено на рівні закону в 2012 році. У зв'язку з погіршенням відносин між Україною та Росією, цей закон було скасовано в 2015 році.

Відповідно до положень Конвенції Еспо, у 2010 році було розпочато оцінку впливу на навколишнє середовище (ОВНС). Австрія бере участь у цій процедурі з 2011 року та у 2013 році подала експертну заяву (UMWELTBUNDESAMT 2013[3]); у серпні 2013 року відбулися двосторонні консультації з українською стороною. Метою участі австрійської сторони в процедурі Еспо є надання рекомендацій щодо мінімізації або навіть усунення можливого значного негативного впливу на Австрію.

Загальні та процедурні аспекти

Більшість документів ОВНС, наданих у 2013 році, залишаються незмінними, за винятком документів, в яких обговорюється нещодавно вибраний реактор типу ВВЕР1000/В-320. Нової оцінки можливого транскордонного впливу надано не було.

Згідно з Конвенцією Еспо, в документацію з оцінки впливу на навколишнє середовище має бути включений обґрунтований опис альтернатив технологічного характеру планової діяльності, а також опис «нульового варіанту» (варіант без проекту). Таким чином інформація, представлена у документації з ОВНС не є достатньою.

Відпрацьоване паливо та радіоактивні відходи

Документи ОВНС не містять важливої інформації про поводження з відпрацьованим паливом та радіоактивними відходами з енергоблоків ХАЕС № 3 та 4. Не наведена очікувана облікова інформація щодо відпрацьованого палива з енергоблоків ХАЕС № 3 та 4. Інформація про стан централізованого тимчасового сховища, де зберігатиметься відпрацьоване паливо з енергоблоків ХАЕС № 3 та 4, відсутня. Немає інформації про заключну стадію життєвого циклу палива (переробка, остаточне захоронення в Україні, захоронення на території інших країн?).

[3] Доступне за посиланням: http://www.umweltbundesamt.at/umweltsituation/uvpsup/espooverfahren/espoo_ukraine/kkwkhmelnitsky34/

Відпрацьоване паливо та радіоактивні відходи можуть спричинити несприятливий вплив на навколишнє середовище, тому питання поводження з ними має бути оцінене в ОВНС.

Тип реактора

Для завершення будівництва енергоблоків ХАЕС № 3 та 4 планується використати будівлі та споруди, що були побудовані в 1980-х роках. В документах ОВНС не наведено інформацію про стан існуючих будівель, споруд та обладнання. Згідно висновків обстеження, що було проведене більше ніж 10 років тому, в період з 2005 по 2009 рр, **існуючі будівлі та споруди** перебувають у справному стані. Документи ОВНС не містять більш актуальної інформації. Перевірка для підтвердження довговічності та надійності будівель та споруд енергоблоків ХАЕС № 3 та 4 має бути проведена в цьому році. В документах ОВНС не міститься інформація про стійкість енергоблоків ХАЕС № 3 та 4 до зовнішніх впливів.

Загалом, на сьогодні немає переконливих доказів того, що існуючі будівлі, споруди та обладнання в змозі забезпечити безпечну експлуатацію протягом 50 років. Будівлі та споруди, розраховані на експлуатацію протягом 40 років, повинні залишатися працездатними близько 100 років.

Програма управління старіння (AMP) не згадується, незважаючи на те, що старіння будівель та обладнання, що старші за 30 років, становить проблему навіть без експлуатаційного навантаження. Негативний вплив старіння залежить також від заходів з інспектування, відновлення та захисту (AMP). У відповідності до статті 8e Директиви 2014/87/EURATOM в першій Тематичній експертній оцінці (TPR) розглядалось питання управління старінням. Оцінка показала, що в Україні існує ряд відхилень від очікуваного рівня безпеки пов'язаного з управлінням старінням в Європі. Одне з відхилень від очікуваного рівня виконання ТЕО, викликає особливе занепокоєння у випадку енергоблоків ХАЕС № 3 та 4: *«У випадку тривалого процесу будівництва АЕС, мають бути визначені відповідні механізми старіння та вжито відповідних заходів для контролю будь-якого початкового старіння або інших наслідків».* (ENSREG 2018)

У 2008 році була обрана та затверджена вдосконалена концепція безпеки ВВЕР-1000/В-392Б (з пасивними системами безпеки) для завершення будівництва ХАЕС № 3 та 4, а конструкція ВВЕР1000/В-320 не відповідає сучасним стандартам безпеки.

Вибір реакторної установки типу ВВЕР-1000 для добудови ХАЕС № 3 та 4 є певною мірою прийнятним, зважаючи на те, що майже всі діючі реактори в Україні є реакторами ВВЕР-1000. Проте вже протягом декількох років доступні і вже експлуатуються удосконалені реактори ВВЕР-1000 з покращеними характеристиками безпеки.

В документації ОВНС не освітлено жодну з відомих проблем безпеки реакторів ВВЕР-1000/В-320. Особливо важливим є питання того, як на енергоблоках ХАЕС № 3 та 4 буде подолано різні недоліки реакторів ВВЕР1000/В-320 загалом та в Україні зокрема.

Аналіз, проведений під час підготовки до вступу до ЄС (проект PHARE) в Болгарії на 5 і 6 енергоблоках АЕС Козлодуй, виявив уразливість конструкції ВВЕР-1000/В-320, що полягає в ранньому проплавленні захисної оболонки через канали іонізаційної камери (ionization chamber) навколо шахти реактора. Болгарський регулятор поставив реалізацію конкретного інженерного рішення, як умову для отримання ліцензії на АЕС Козлодуй. У документах з ОВНС не зазначено, чи передбачається підключення каналів іонізаційної камери на енергоблоках ХАЕС № 3 та 4.

Трубопроводи високої потужності АЕС Темелін (ВВЕР-1000/В-320) знаходяться між захисною оболонкою і турбінним залом на рівні платформи 28,8 м без перегородок і без захисту. У наданій документації з ОВНС немає інформації про те, яким чином на енергоблоках ХАЕС № 3 і 4 буде вирішено питання трубопроводів високої потужності.

Основною характеристикою безпеки у реакторних установках, вибраних для ХАЕС № 3 та 4, є зовнішнє охолодження розплавленого ядра у випадку аварії з розплавленням активної зони. Розробка системи для "Утримання розплаву в корпусі реактора» (IVMR) досі продовжується, наприклад, на референтних блоках АЕС «Темелін».

Документи з ОВНС не містять детального опису систем, що стосуються безпеки, більшість з них лише перераховані, а інформація про потужності, резервування та фізичне розділення не наводиться. Конструкція АЕС, розроблених в 1980-х роках, таких як ВВЕР-1000/В-320, відповідає сучасним принципам проектування в плані резервування, різноманітності і фізичного розділення резервних підсистем, переваги пасивних систем над активними системами безпеки, лише частково. (див. IAEA 2016a, WENRA 2013).

Згідно з положеннями WENRA (2013), цілі безпеки WENRA для нових АЕС також мають слугувати еталоном, для визначення обґрунтовано можливого підвищення безпеки на "відкладених станціях", таких як ХАЕС № 3 та 4. Проте в документах з ОВНС такі цілі безпеки WENRA не згадуються .

За даними ЕНЕРГОАТОМУ (2017a) для енергоблоків ХАЕС № 3 і 4 заплановано збільшення потужності до 104% від проектної потужності та введення маневрового режиму. Маневровий режим призводить до технічних недоліків, оскільки компоненти станції піддаються численним циклам термічного навантаження; це призводить до більш швидкого старіння і вимагає більш складних систем моніторингу та контролю реакторів. Збільшення потужності реактора знижує межі безпеки і в той же час прискорює процеси старіння.

Інциденти та аварії без участі третіх осіб

В документах з ОВНС немає систематичного аналізу проектних аварій (DBA) та надпроектних аварій (BDBA); описано лише радіологічні наслідки однієї проектної аварії і однієї надпроектної аварії. Розглянута надпроектна аварія передбачає протікання теплоносія з відмовою активних систем аварійного охолодження активної зоні і спринклерної системи.

Розрахована ймовірність такої BDBA становить 4,29 * E-7 на реактор у рік. Ця BDBA не є найгіршим сценарієм. При розрахунку можливих (транскордонних) наслідків такої BDBA передбачається, що розплав ядра залишатиметься в корпусі реактора високого тиску (RPV). Це припущення не обґрунтовано належним чином, оскільки системи, що забезпечили б утримання розплавленого ядра в корпусі реактора (утримання розплаву в корпусі реактора - IVMR), поки що недоступні. Крім того, якщо цю систему можна було б реалізувати, це лише зменшить ризик викиду радіоактивних речовин при більшості, але не при всіх сценаріях аварії.

Для того, щоб оцінити наслідки BDBA, необхідно проаналізувати цілий ряд важких аварій, у тому числі при руйнуванні захисної оболонки, та при **байпасуванні** захисної оболонки. Для реактора типу ВВЕР1000/В-320 існує ймовірність виникнення таких важких аварій. Ці серйозні випадки не можна виключати, хоча їхня ймовірність є нижчою від зазначеної величини. У доповіді, опублікованій у 2012 році Норвезьким агентством радіаційного захисту (NRPA), було розраховано можливі наслідки для реактора ВВЕР-1000/В-320, у яких характеристики радіоактивного викиду були значно вищими, ніж ті, що наведено в документах з ОВНС.

Результати стрес-тестів ЄС показали, що управління важкими аваріями (SAM) (тобто запобігання важким аваріям та пом'якшення їх наслідків) на українських АЕС має багато недоліків. Регулятор вимагає комплексних покращень; однак, група експертів ENSREG рекомендує подальші вдосконалення. Це один з прикладів невідповідності української сторони стандартам та вимогам безпеки ЄС.

Відповідно до сучасних міжнародних вимог до нових атомних електростанцій (МАГАТЕ 2012 та WENRA 2013), аварійні послідовності з ранніми або великими викидами мають бути практично усунутими. Концепція «практичного усунення» ранніх або великих викидів не згадується документах з ОВНС енергоблоків ХАЕС № 3 та 4. Навпаки, ЕНЕРГОАТОМ (2017a) стверджує, що ймовірність виникнення важких аварій (наприклад, з руйнуванням захисної оболонки), при яких можуть статись великі викиди, є незначною. Такий підхід не відповідає рівню технологічного розвитку. Незважаючи на те, що можна встановити імовірнісні цілі, не можна декларувати «практичне усунення» основуючись на відповідності загальному імовірнісному значенню. Згідно МАГАТЕ (2016): низька ймовірність виникнення аварії з розплавом активної зони не є причиною не вживати заходів для захисту від наслідків такої аварії.

Зовнішні небезпеки

Інформація, наведена в документах ОВНС, показує, що оцінка майданчику не відповідає сучасним **міжнародним вимогам**, оскільки використані міжнародні рекомендації застаріли. За даними Держатомрегулювання (2017), необхідно заново оцінити сейсмічний ризик, ТЕО було схвалене з умовою розробки та/або уточнення розрахунку пікового значення прискорення на рівні грунту майданчика. Ділянка ХАЕС розташована в **зоні ймовірності ураганів.** Таким чином, місце розташування може бути використано лише як місце для нових реакторів, якщо будуть прийняті відповідні технічні запобіжні заходи.

Старе техніко-економічне обґрунтування 2011 року було схвалено за умови, що буде проведено і включено в Попередній звіт з безпеки (SNRIU 2012b) поглиблену оцінку впливу зовнішніх екстремальних подій природної і техногенної природи, а також їх комбінацій. Цю умову не включено в умови затвердження чинного ТЕО (Держатомрегулювання (2017).

Згідно з WENRA (2013), оцінка безпеки для нових атомних електростанцій повинна демонструвати, що загрози від зовнішніх небезпек або усунені, або мінімізовані, наскільки це практично можливо. В документах ОВНС не зазначено, чи буде ця рекомендація WENRA застосована для енергоблоків ХАЕС № 3 та 4.

Інциденти та аварії з залученням третіх осіб

Вплив третіх сторін (терористичні напади або диверсії) може мати значний вплив на ядерні об'єкти, а отже, і на енергоблоки ХАЕС № 3 та 4 в Україні. Проте, в документах ОВНС для енергоблоків ХАЕС № 3 та 4 про них не згадується. У аналогічних документах з ОВНС подібні проблеми були вирішені в деякій мірі.

Хоча запобіжні заходи проти втручання третіх сторін не можуть бути детально обговорені в процесі ОВНС з міркувань конфіденційності, проте в ОВНС мають бути встановлені відповідні законодавчі вимоги. Зокрема, в документах ОВНС має міститись детальна інформація про вимоги до проекту у випадку терористичної атаки з падінням пасажирського літака. Ця тема особливо важлива, оскільки товщина стінок будівлі реактора/захисної оболонки енергоблоків ХАЕС № 3 і 4 становить лише близько 1000-1200 мм. Таким чином, енергоблоки можуть бути вразливими до терористичних атак (включаючи падіння літака). У 2013 році український регулятор не вимагав стійкості енергоблоків ХАЕС № 3 та 4 проти випадкового або навмисного падіння великого пасажирського літака.

Нещодавня оцінка ядерної безпеки в Україні вказує на недоліки у порівнянні з відповідними стандартами ядерної безпеки: Індекс ядерної безпеки, розроблений Глобальною ініціативою зі зменшення ядерної загрози в 2018 році, оцінює рівень безпеки ядерних об’єктів в контексті їх захисту від диверсій.

Україна набрала 70 балів зі 100 можливих і посіла лише 30 місце з 45 країн, що свідчить про низький рівень захисту. Слід зазначити, що низькі бали в категоріях “Запобігання внутрішнім небезпекам” та „Кібербезпека” вказують на недоліки в цих сферах.

Транскордонний вплив

Важкі аварії з викидами, що значно перевищують передбачені в документах з ОВНС, не можуть бути виключені для енергоблоків ХАЕС № 3 та 4, навіть якщо їхня ймовірність повинна бути нижче встановленої величини. В оцінку мають бути включені найгірші сценарії, оскільки їхні наслідки можуть бути настільки широкомасштабними і тривалими, що навіть країни, які безпосередньо не межують з Україною, такі як Австрія, можуть постраждати.

Через відсутність аналізу найгірших сценаріїв, висновок документів ОВНС про транскордонний вплив не є доречним.

Результати розрахунків Австрійського інституту екології (1998) свідчать про те, що важка аварія (найгірший сценарій) на ХАЕС призведе до забруднення деяких регіонів Європи. Для східної частини Австрії розрахунок показав забруднення цезієм-137 на рівні приблизно 1000 кБк/м2 (що майже в 5 разів перевищує найвищі значення зафіксовані в Австрії в 1986 році).

Крім того, результати проекту flexRISK вказують на те, що у випадку важкої аварії середній вміст цезію-137 на більшості районів території Австрії перевищить поріг для проведення сільськогосподарських робіт (наприклад, ранній збір врожаю, закриття теплиць). Таким чином, Австрія постраждає від важкої аварії на енергоблоках ХАЕС № 3 та 4.

1 INTRODUCTION

In Ukraine, the state enterprise "National Nuclear Energy Generating Company Energoatom" is preparing the completion of the construction of the nuclear power plant units 3 and 4 (KhNPP-3&4) at the Khmelnitsky site. At this site, two units VVER-1000/V-320 are already in operation.

The project has a long history and the document prepared by the State Nuclear Regulatory Inspectorate of Ukraine (SNRIU 2017) provides an overview: The construction of KhNPP-3&4 started in September 1985 and June 1986, respectively. Due to the 1990 moratorium on the construction of nuclear power units in the former USSR, the construction of KhNPP-3&4 was ceased. In 2005, the Cabinet of Ministers of Ukraine decided to renew the construction. A tender for the reactor model was opened in 2008, resulting in selecting the Russian reactor VVER-1000/V-392, which was approved in 2009. In 2011, the feasibility study was submitted and approved after SNRIU has completed a "state expert review of nuclear and radiation safety" in March 2012, followed by the adoption of a corresponding law in September 2012.

Due to the deteriorating relations between Ukraine and Russia, this law ceased to be in force in 2015. Energoatom replaced the reactor vendor with a European supplier, Škoda JS a.s. (EXPLANATION n.d.) An updated and revised feasibility study was submitted, again assessed by SNRIU during another "state expert review of nuclear and radiation safety" in 2017 and approved in April 2017. On July 5, a Ukrainian government committee approved the adapted feasibility study for the KhNPP-3&4; on July 26, the feasibility study was approved by the Cabinet of Ministers of Ukraine. (ECOACTION 2018) The competent authority is the Ministry of Energy and Coal Industry of Ukraine.

An environmental impact assessment (EIA) under the Espoo Convention (1991) started in 2010. Austria has participated in this procedure since 2011. An expert statement was commissioned by the former Austrian Ministry of Agriculture, Forestry, Environment and Water Management (UMWELTBUNDESAMT 2013[4]), expert consultations between the Ukrainian and the Austrian side were conducted in August 2013. The procedure was halted in 2015 due to the political developments in Ukraine. In spring 2019 the Ukrainian side informed the Austrian side about the continuation of the transboundary environmental impact assessment under the Espoo Convention, several documents in English were notified, the Austrian side had additional parts of the Environmental Report translated into German.

The Austrian Ministry for Sustainability and Tourism commissioned the Environment Agency Austria to provide the expert statement at hand assessing the recently submitted documents.

The objective of the Austrian participation in the Espoo procedure remains the same as in the first phase: to give recommendations to minimise or even eliminate possible significant adverse impacts on Austria resulting from the project.

[4] http://www.umweltbundesamt.at/umweltsituation/uvpsup/espooverfahren/espoo_ukraine/kkwkhmelnitsky34/

2 OVERALL AND PROCEDURAL ASPECTS OF THE ENVIRONMENTAL IMPACT ASSESSMENT (EIA)

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

2.1 Provided documents

The following documents were provided by the Ukrainian side and are quoted in this expert statement as follows:

- ENERGOATOM (2017a): Ministry of Energy and Coal Industry of Ukraine, State Enterprise National Nuclear Generating Company ENERGOATOM SE Atomproektinzhiniring: Updated Information Khmelnytskyi NPP Construction of NPP Units No. 3 and No. 4.
- EXPLANATION (n.d.): Explanation of the continuation of the procedure for implementing the Espoo Convention provisions to the construction of power units No. 3 and No. 4 of Khmelnitsky NPP.
- OVOS (2016): OJSC "Kiev Scientific and Research Design-and-Engineering Institute "ENERGOPROEKT", State Enterprise National Nuclear Generating Company ENERGOATOM SE Atomproektinzhiniring: Khmelnytska NPP. Feasibility Study of the Power Units 3,4 Construction, Volume 13 Environmental Impact Assessment Report (OVOS), Part 14 Assessment of the transboundary transfer consequences under normal and emergency conditions.

Additionally, a list of (sub)chapters of volume 13 of the EIA Report (OVOS 2019a) were submitted to the Austrian side (see http://www.umweltbundesamt.at/umweltsituation/uvpsup/espooverfahren/espoo_ukraine/kkwkhmelnitsky34/k3_4_uve2019_ukrainisch/) Several parts of those files the Austrian Environmental Agency had translated into German[5].

- OVOS (2019b): Gründe für die Durchführung einer technisch-wirtschaftlichen Begründung [PDF, 2.0 MB], (= OVOS 2019a, chapter 13_18_2, p. 17ff)
- OVOS (2019c): 1.6 Verzeichnis und Kurzanalyse der vorangegangenen Abstimmungen und Expertisen, einschließlich öffentlicher Prüfung [PDF, 508 KB], (= OVOS 2019a, chapter 13_1_1, p. 23ff.)
- OVOS (2019d): Technische Daten des Kraftwerksblocks [PDF, 1.7 MB], (= OVOS 2019a, chapter 13_03_3, p. 17ff.)
- OVOS (2019e): 2.2.9 Systeme zur Sammlung, Verarbeitung und Lagerung von RAA [PDF, 424 KB], (= OVOS 2019a, chapter 13_03_3, p.50ff.)

[5] The German titles of the files do not refer to the whole content, they display only the first relevant header where translation started.

- OVOS (2019f): 2.9 Bewertung der radiologischen Bedeutung grenzüberschreitender Übertragungen [PDF, 286 KB], (= OVOS 2019a, chapter 13_17_02, p. 25ff.)
- OVOS (2019g): 3.1. Strahlungsquellen bei Normalbetrieb und ihre Eigenschaften [PDF, 816 KB], (= OVOS 2019a, chapter 13_03_3, p. 75ff.)
- OVOS (2019h): 3.5. Mögliche Störfälle und Havarien mit Umweltbelastung [PDF, 803 KB], (= OVOS 201a9, chapter 13_03_3, p. 104ff.)
- OVOS (2019i): Grundschema des Reaktorbereiches für die Kraftwerksblöcke Nr. 3 und 4 des Kernkraftwerks Khmelnitsky [PDF, 420 KB], (= OVOS 2019a, chapter 13_03_3, p. 34f.)
- OVOS (2019j): Längsquerschnitt des Turbinen- und Entlüftungsbereiches [PDF, 286 KB], (= OVOS 2019a, chapter 13_03_3, p. 30)
- OVOS (2019k): Bildlegenden zu Kapitel 13.18 [PDF, 88 KB], (= OVOS 2019a, in: chapter 13)

The above mentioned notified document OVOS (2016) is also included in the list of chapters of volume 13, it is identical in content with chapter 13_14_2.pdf.

2.2 Treatment in the EIA documents

The revision of the feasibility study is explained in ENERGOATOM (2017a), the recent step of the EIA procedure in EXPLANATION (n.d.).

The document EXPLANATION (n.d.) explains the changes made until now and revises the original feasibility study from 2011. The table on page 2f. lists “performance indicators” that have been changed between 2011 and 2016. These changes include:

- The design capacity increased from 2,094 to 2,178 MW(e).
- The time the NPP will be connected to the grid with at least one main generator has been increased from 7,185 to 7,450 hours per year.
- The reactor type from VVER-1000 (JSC Atomstroyexport) was replaced by VVER-1000 (Manufacturing: Škoda JS a.s.).
- The parameter for the annual electricity production has been increased from 15.044 to 16.226 billion kWh.
- The parameter for the annual electricity output to consumers has been increased from 14.300 to 15.420 billion kWh.

On top of the technical solutions and planned power output, the scope of documents for the updated EIA Report underwent some changes. (EXPLANATION n.d.) Sections of the EIA Report volumes have been updated and brought in line with legal documents that have been amended or put into force in the meantime. Assessments of climate and microclimate, geology, physiography, groundwater, soil, air, surface water, flora and fauna and environmental impacts resulting from construction have remained unchanged.

Alternatives

The EIA Report explains why this area was selected and how the Khmelnitsky site is justified. OVOS (2019b, p. 18) At the time of the construction stage of unit 1, the existing Khmelnitsky site was approved for NPPs with a total of 4,000 MW in accordance with the requirements of the current regulatory documents. It is explained that the Khmelnitsky site fulfils all regulatory requirements. No other sites are discussed and compared in the provided EIA documents. Furthermore this chapter stated that once the decision of the Ukrainian Government to build KhNPP-3&4 had been taken, no alternative options for the site and the production method of electricity and thermal energy were assessed. The reactor type of Škoda JS a.s., was selected by Energoatom after the agreement with Russia ceased in 2015. (EXPLANATION n.d.)

2.3 Discussion

During bilateral consultations the procedure was explained by the Ukrainian side as follows (MINUTES 2014):

1. In the **feasibility study stage**, a draft law is issued on location, design and construction of KhNPP-3&4. In this draft law the site and the reactor type are decided upon. It is not a final decision in the meaning of the Espoo Convention because the draft law does not approve all environmental aspects of the project. The EIA procedure is conducted during this feasibility study stage, therefore the received comments can already be considered at the next stage, the project stage.
2. In the **project stage**, all deterministic and probabilistic safety analyses of design basis accidents (DBA) and beyond design basis accidents (BDBA) will be performed. A preliminary safety report (PSR) will be prepared. The project stage will be approved by a resolution of the Cabinet of Ministers of Ukraine. This decision will be **the final decision according to the Espoo Convention**. It approves the basic design and the ecological benchmarks and considers comments received during the first stage.
3. The **construction license** will be issued.
4. The **final safety report** will be prepared which is necessary for the **operation license**.

Austria will be informed about the final decision of the EIA procedure and how the submitted comments were taken into account.

During the bilateral consultations in August 2013, the Ukrainian side offered to answer the open questions of the Austrian side in writing, but did not do so until today. Moreover, the Ukrainian side promised to send those parts of the Preliminary Safety Report that concern environmental and transboundary issues as soon as they were available, and to answer questions of the Austrian side that might occur after evaluating these parts of the safety analyses. (MINUTES 2014, topic 15, p. 8) The Austrian side has not received those parts.

The timetable for the next steps in the procedure is unclear, both when the project stage will start and when the final decision can be expected. ENERGOATOM (2017b, p. 14) informs that unit 3 shall be completed in 2024, and unit 4 in 2026. But the timetable is already behind schedule – the Parliament of Ukraine should have passed the law “On siting, designing, and construction of KhNPP units 3 and 4” already in 2018.

On 4 April 2019 Petro Poroshenko instructed the Cabinet of Ministers to submit to Parliament a new draft law on the design and construction of power units Nos. 3 and 4 at Khmelnytsky nuclear power plant as soon as possible.[6]

This new draft law probably will replace the draft law from 2012 and again will not constitute the final decision; the situation remains as it was after the bilateral consultations in 2013: The procedure under the Espoo Convention can only be finalised after the Austrian side has received all information including the promised parts of the PSR and after the questions of this expert statement have been answered.

Completeness and comparison of documents

In Ukraine, an EIA Report (OVOS 2019a) was published on 15 Jan 2019 together with information on participation and hearings. (ENERGOATOM 2019) To Austria not the entire EIA Report was notified, but only the last part (pages 476-511) which is identical with the notified English document OVOS (2016).

The other (sub)chapters of volume 13 that were submitted to Austria are not included in the EIA Report published in Ukraine.

It should be questioned wether if this is in line with Art. 2 (6) of the Espoo Convention : *“The Party of origin […] shall ensure that the opportunity provided to the public of the affected Party is equivalent to that provided to the public of the Party of origin.”*

In 2013, the Ukrainian side provided an Analytical Survey (IAS) of the Feasibility Study (FS) materials, prepared for the public review, including the anticipated consequences of the construction, commissioning, operation and decommissioning of the KhNPP-3&4. (IAS 2011) Also the former version of the OVOS was submitted in English (“Khmelnytska Feasibility Study of Power Units 3,4 Construction Volume 13 Environmental Impact Assessment Report (OVOS) Part 14 Assessment of the Transboundary Transfer Consequences under Normal and Emergency Conditions”). (OVOS 2011). The complete EIA Report was provided to the Austrian side in Ukrainian language.

The comparison of OVOS (2011) with OVOS (2016) only showed that typos were removed. It can be concluded that no update of the transboundary impact assessment has been made.

Most of the EIA documents provided 2013 have remained unchanged, with the exception of documents on the recently selected reactor type and legal changes that have occurred between 2013 and today.

[6] http://www.ukrainianjournal.com/index.php?w=article&id=29221, seen 28 Apr 2019

Fulfilment of Espoo Convention

Ukraine has ratified the Espoo Convention. According to Art. 2(3) of the Espoo Convention the environmental assessment of a project should take place before a decision is made: *"The Party of origin shall ensure that in accordance with the provisions of this Convention an environmental impact assessment is undertaken prior to a decision to authorize or undertake a proposed activity listed in Appendix I that is likely to cause a significant adverse transboundary impact."*

It is questionable whether the EIA procedure of KhNPP-3&4 is fulfilling these requirements because **all relevant aspects/alternatives of the project have been decided upon before the EIA started – the decision for using nuclear energy, the decision for the site and the decision for the reactor type:**

- In OVOS (2019b) was provided the explanation that due to the decision of the Ukrainian Government to build KhNPP-3&4 no alternative options for the production method of electricity and thermal energy were assessed.
- At the bilateral consultations between the Ukrainian and the Austrian side in August 2013, Austria was informed that the site has already been decided upon in the "Energy Strategy of Ukraine up to 2030" by a decision of the Cabinet of Ministers of Ukraine from 15 March 2006. And this energy strategy is a plan/programme and therefore not subjected to the Espoo Convention, because Ukraine has not ratified the SEA protocol. (MINUTES 2014, p. 2) Austria could not participate in the development of this Energy Strategy.
- The former reactor type was decided upon in 2012, before the EIA procedure started in Austria (public participation was open from May to June 2013). And the recent reactor type was selected before the most recent EIA phase started in 2019.

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

Ukraine-EU-Energy Bridge

Of special interest is the Ukraine-EU-Energy Bridge project (ENERGOATOM 2017b) serving:

- Development of cross-border electric grids and increase of their transmission capacity
- The integration of the Ukrainian power system into ENTSOE-E (European Network of Transmission System Operators for Electricity)
- The disconnection of KhNPP 2 from Ukrainian power system for long-term export
- The long-term electricity export to raise funds for KhNPP-3&4

It is not clear whether the Energy Bridge can be realized: Under number EL-08 an upgrade and an extension of the existing transmission infrastructure (750 kV line) between Khmelnitsky and Rzeszow (Poland) was submitted to Energy Community's call for a list of projects of Energy Community interest. In 2018 it was assessed as not eligible. (REKK 2018, p. 40f.; ENERGY COMMUNITY 2018)

More information would be appreciated about the status of the Energy Bridge project and how sufficient budget will be made available for financing the necessary safety and security measures for KhNPP-3&4 if the export option fails.

2.4 Conclusions, questions and preliminary recommendations

The EIA documents that were published in Ukraine are not identical to those published in Austria for public participation, and vice-versa. It is questionable if this is in line with Art.2 (6) of the Espoo Convention requiring that the Party of Origin to ensure that the opportunity provided to the affected Party's public to participate in relevant environmental impact assessment procedures is equivalent to that provided to the public of the Party of origin.

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

Therefore, it is questionable if these requirements of the Espoo Convention are fully met.

Most of the EIA documents provided 2013 have remain unchanged, with the exception of documents discussing the new reactor type and legal changes that have occurred between 2013 and today. No new assessment of possible transboundary impacts has been provided.

The KhNPP-3&4 project shall be part of the Ukraine-EU-Energy Bridge project aiming at exporting electricity from KhNPP-2 to raise funds for KhNPP-3&4. It is not clear whether the Energy Bridge will work. More information would be appreciated how to compensate in case for the loss of funding to prove that enough budget is available to invest into safety and security measures.

However, it has been longstanding EU policy that power trading with third countries would be pre-conditioned by strict compliance with the economic and ecological principle of reciprocity.

Questions

1. *What information is included in the EIA documents that were published in Ukraine for public participation but were not submitted to Austria?*
2. *When will the promised parts of the Preliminary Safety Report be submitted to Austria?*
3. *What is the timetable for the next steps of the EIA procedure?*
4. *What is the status of the Ukraine-EU-Energy Bridge project?*
5. *If the Ukraine-EU-Energy Bridge project fails, how will the completion of KhNPP-3&4 be funded?*

Preliminary recommendation

1. 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, and to also assess a no-action alternative.

3 SPENT FUEL AND RADIOACTIVE WASTE

In this chapter the planned management of the spent fuel and radioactive waste generated by KhNPP-3&4 is assessed.*

3.1 Treatment in the EIA documents

Overall and procedural aspects

During operation of the NPP solid and liquid radioactive waste will be produced. In OVOS (2019e) the modus of collection, conditioning and storing the liquid and solid radioactive waste is explained, some information on capacity of the available facilities and possible future amounts is given.

No information is given on the expected amount of spent fuel over the operation time of KhNPP-3&4. In OVOS (2019e, p. 57) it is declared that spent fuel will be transported to the new central interim storage. This central interim storage will be built with Holtec technology.

3.2 Discussion

In the EIA documents no explanation is given about Ukraine's national nuclear waste management programme, amongst others if such a programme fulfils international standards.

Also the status of the construction of the central interim storage for spent fuel is not presented, neither the site nor the timetable or any features of safety relevance are discussed in the EIA documents. From the national report of Ukraine for the 6th review meeting of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (NATIONAL REPORT 2017) it can be concluded that the central interim storage is located in the Chernobyl exclusion zone.

The EIA documents do not inform about the entire period of nuclear waste management, information is lacking on the back-end of the fuel chain. It is unclear whether the Ukraine will opt for reprocessing or direct final disposal, where the final disposal facility will be located and which technology will be used.

The NATIONAL REPORT (2017) provides more information on nuclear waste management. Also the Energy Strategy of Ukraine until 2035, called "Safety, Energy Efficiency, Competitiveness" (Energy Strategy) is referred to as a new energy strategy and was approved by Cabinet Resolution No. 605-r of 18 August 2017. According to the NATIONAL REPORT (2017, p. 13), it contains both options for spent fuel management: transport of spent fuel for reprocessing to the Russian Federation and long-term storage of spent fuel with a delayed decision for reprocessing or direct disposal; however, no information on when the decision will be taken.

If the necessary capacity in a final disposal is not available in time, the question about safety of long-term interim storage of the spent fuel and other high level waste has to be answered.

The Ukrainian side should provide a national nuclear waste management plan is in force, and the status of its implementation, including information how the necessary resources will be made available.

3.3 Conclusions, questions and preliminary recommendations

Important information on the management of the spent fuel and radioactive waste from KhNPP-3&4 is lacking in the EIA documents: The expected inventory of spent fuel from KhNPP-3&4 is not given. Information on the status of the central interim storage where the spent fuel from KhNPP-3&4 shall be stored is lacking. No information was provided about the planned options for the back-end of the fuel chain (reprocessing, final disposal in Ukraine, international disposal?). Spent fuel and radioactive waste can cause adverse environmental impacts and therefore the EIA needs to assess the nuclear waste management.

Questions:

1. What is the expected inventory of spent fuel and radioactive waste from operation of KhNPP-3&4?
2. What is the status of the central interim storage facility for spent fuel?
3. What is planned for the back-end of the fuel cycle? Is spent fuel reprocessing in Russia still under consideration?
4. Is an international cooperation for final disposal of spent fuel and/or radioactive waste planned?
5. Which interim and final storages for radioactive waste are in operation in Ukraine, will their capacity be sufficient to dispose of all radioactive waste from operation of KhNPP-3&4?
6. How can the safe storage of spent fuel and radioactive waste be ensured if the interim storage and final disposals will not be ready in time?

Preliminary recommendation:

1. To demonstrate the safe management of nuclear waste from KhNPP-3&4 detailed information on the interim storages and final disposals should be provided; also alternative nuclear waste management solutions, if these facilities will not be operable in time.

4 REACTOR TYPE

4.1 Treatment in the EIA documents

In the IAS (2011), some general information about the previous activity in constructing the KhNPP is given: Construction of KhNPP-1,2,3,4 was initiated in 1979, 1983, 1985 and 1986. While KhNPP-1 was commissioned in 1987, unit 2 was commissioned in 2005. KhNPP-1,2 are VVER-1000/V-320 reactors. Construction of the units 3 and 4 was halted in 1990 due to the moratorium for construction of nuclear power units on the territory of Ukraine. In 2008, the preparatory works were ongoing at the units 3 and 4. (IAS 2011, p. 7)

In chapter 6 of the IAS (2011, p. 30) completion of the units 3 and 4 is specified with 28% and 10%, respectively.

According to ENERGOATOM (2017a, p. 7) the construction of the power units no. 3 and 4 is envisaged using the existing building structures of the reactor compartment, the Standby Diesel Power Plant (SDPP) and other facilities directly connected with the reactor building, which are in the unfinished construction stage. At the same time, all repair and restoration work on construction structures are performed, which are determined by the results of the survey and evaluation of their technical condition.

After the completion of the repair and restoration works, based on the results of the survey, the required parameters for durability will be achieved, which will ensure reliable operation of the power units throughout the service life of the plant. The feasibility study included the preliminary calculation taking into account additional loads and influences, which confirms the possibility of using the existing building structures for the completion of the power units. (ENERGOATOM 2017a, p. 19)

In chapter 3 of ENERGOATOM (2017a), the envisaged main technical solutions of KhNPP-3&4 are described. It is explained that as a result of negotiations with potential suppliers of reactor equipment, the decision was taken to use the VVER-1000 reactor facility manufactured by Škoda JS a.s., which complies with all established regulatory documents of Ukraine and the requirements of the International Atomic Energy Agency (IAEA).

As a reference reactor, the VVER-1000/V-320, implemented at the Temelín NPP, is considered.[7] At the same time, in the project of the KhNPP-3&4 all measures to improve safety and reliability should be implemented in accordance with the "Integrated (consolidated) program to improve the safety level of NPP power units" (ENERGOATOM 2017a, p. 7)

Basic data of VVER-1000 type manufactured by Škoda JS are:

- nominal thermal capacity of the reactor facility is 3012 MW;
- temperature of generated steam at rated load – 278.5 °C;
- possibility of increasing the power to 104%.

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[7] The National Nuclear Generating Company Energoatom approved the turbine unit on the basis of the project K-1000-60/1500-2M produced by Turboatom JSC.

The planned operating time of the power units KhNPP-3&4 is 50 years. The units are aimed at the electric power generation in base load operation with the possibility of load following.

Safety systems

In ENERGOATOM (2017a, p.14) the safety systems of KhNPP-3&4 similar to the ones at the operating power KhNPP-1,2 are only listed (see also IAS 2011, p. 21):

- protection of the primary circuit against overpressure;
- emergency gas removal;
- passive part of emergency core cooling system;
- emergency cooling of high-pressure core;
- emergency cooling of low-pressure core;
- protection of the secondary circuit against overpressure, including steam valve blocks on steam lines;
- supply emergency feed water to the steam generators.

According to ENERGOATOM (2017a, p. 8), the VVER-1000 project of Škoda JS a.s. will also provide additional systems and means for control of beyond design basis accidents (BDBA), including severe accidents. The project provides for the implementation of a number of fundamental technical solutions related to:

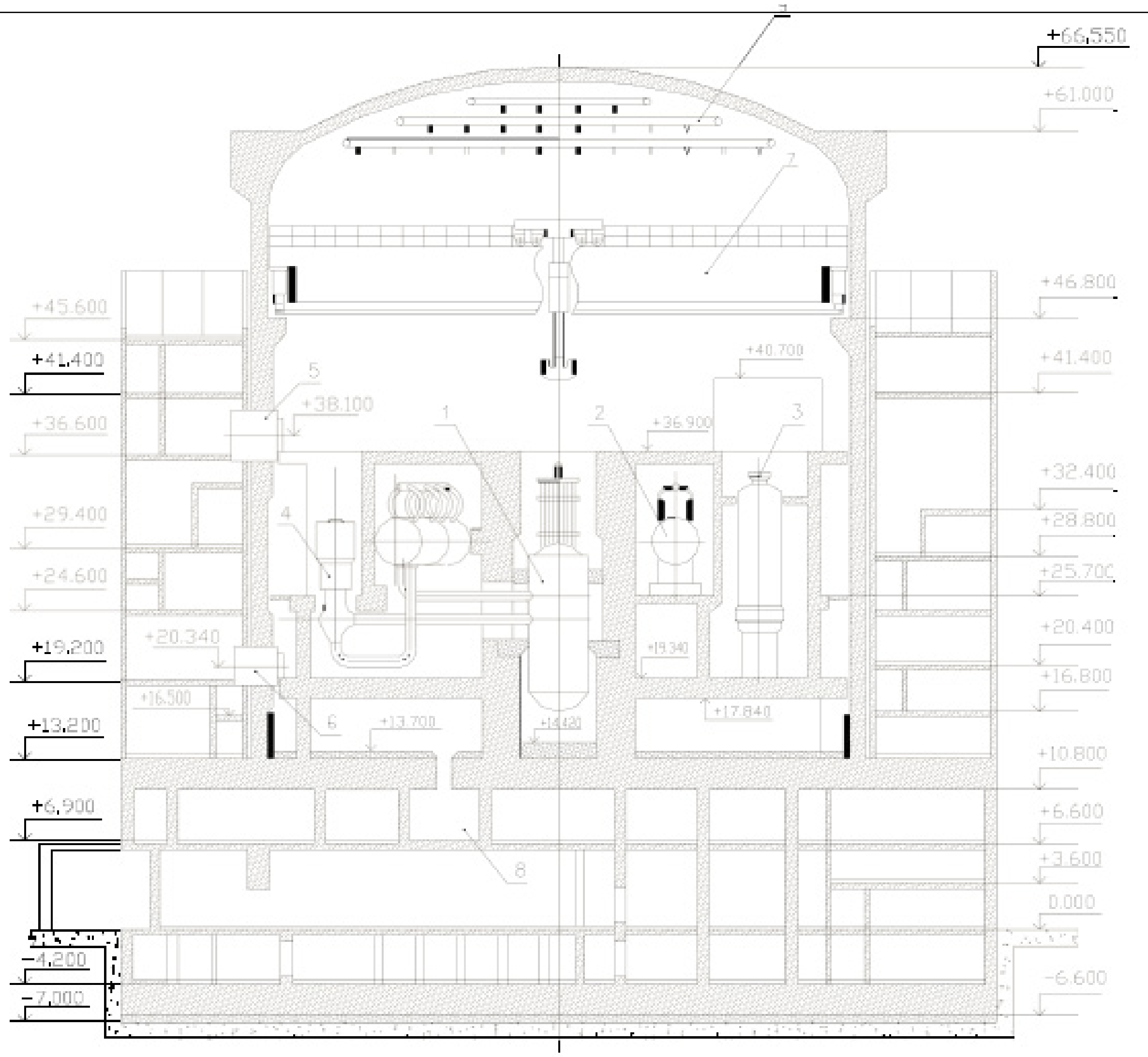
- The introduction of additional systems and equipment for the BDBA control, such as:
  - hydrogen control and removal systems;
  - systems of forced (filtered) release of pressure from under the containment;
  - systems for external cooling of the reactor pressure vessel during severe accidents;
- The introduction of in-depth diagnostics of process equipment, hardware and software and digital safety control systems;
- Increasing the technical level of the systems by increasing the volume of automation, optimizing control and management algorithms.

Reactor compartment

When completing the construction of the KhNPP-3&4, it is planned to maintain a unified approach for the layout of the reactor compartment. The reactor compartment consists of the foundation part, the containment and auxiliary building with concrete dome. The sealed cylindrical containment with an internal diameter of 45.0 m, starting at elevation 13.200, is centrally symmetric in the construction with dimensions of 66.0 × 66.0 m.

The basic layout solutions of the reactor compartment are similar to those existing at the power units no. 1, 2 of KhNPP. The section of the main building is shown in figure 1.

Reactor building of unit 3 and 4 of KhNPP



Source: ENERGOATOM (2017a)

Figure 1: Reactor building of unit 3 and 4 of KhNPP (ENERGOATOM 2017a, p.10)

In addition to the basic project, the reactor compartment design will include the following equipment:

- tanks of the external cooling system of the reactor vessel during severe accidents;
- Venturi scrubber with aerosol filter of the forced (filtered) release of pressure from the containment.

External cooling system of the reactor vessel

According to ENERGOATOM (2017a, p. 14) the system is designed to minimize the consequences of severe accidents, to prevent the core melt from draining out of the reactor pressure vessel and, as a result, damage to the last protective barrier, the containment and the spread of radioactive substances into the environment.

This system makes it possible to prevent reactor vessel damage caused by the high-temperature core-melt, and to substantially reduce the volume of hydrogen that is formed by the interaction of corium with concrete in the out-of-the-vessel stage of a severe accident.

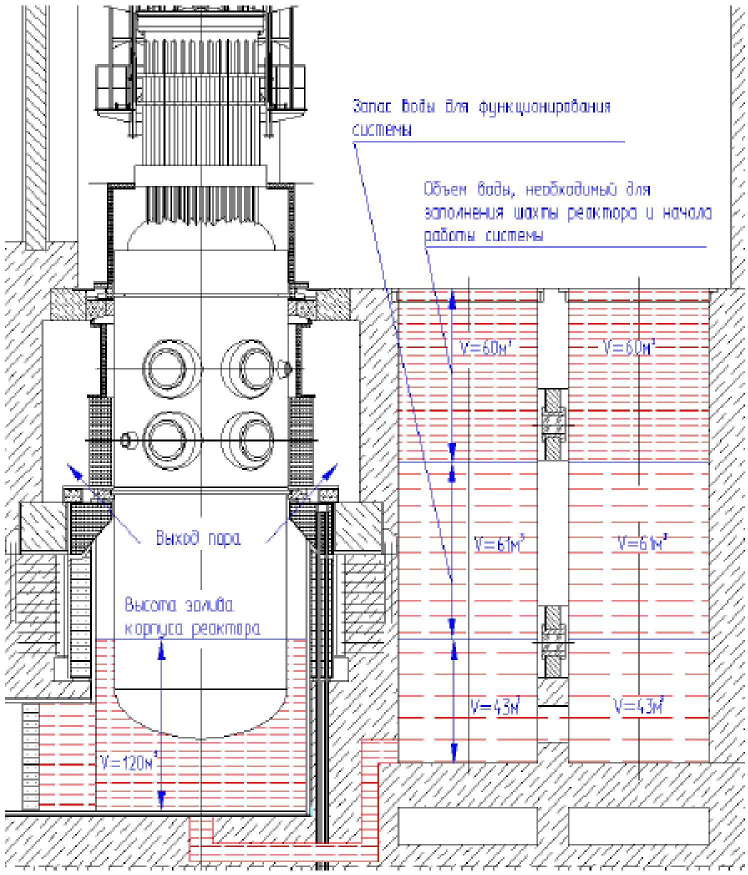
The strategy of retaining the core melt in the reactor vessel was accepted and implemented in modern NPP projects (AP-1000). For the VVER-1000 power unit (Škoda JS a.s.), the calculation and experimental justification for this capability and design developments for the equipment have been carried out, which makes it possible to consider the possibility of implementing the external cooling system of the reactor vessel of KhNPP-3&4.

Shafts for the revision of vessel internals and protective tube block are used as the basic stock of the coolant. Tanks of the external cooling system of the reactor vessel are planned to be placed at elevation 36.600 m and on the roof of the superstructure at elevation 45.600 m the reactor compartment (nine tanks with additional supply of coolant with total volume of 648 m^3).

For long-term heat removal from the reactor facility, it is proposed to use unlimited supply of water from the channel of the circulating water supply system. A schematic diagram of the initial filling of the reactor shaft is shown in figure 2.

Figure 2: Schematic diagram of initial filling of the reactor shaft (ENERGOATOM 2017a, p. 16)

Schematic diagram of initial filling of the reactor shaft



Source: ENERGOATOM (2017a)

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Hydrogen monitoring and removal system

The hydrogen monitoring and removal system is designed to detect and reduce the concentration of hydrogen released during accidents to values below the explosive limit. The Emergency Hydrogen Removal System (EHRS) is a set of autocatalytic hydrogen recombiners located at various elevations of the pressurized volume. Westinghouse Electric Germany GmbH has estimated that 53 NIS PAR (Passive Analytic Recombiner) modules are needed to perform their functions of ensuring hydrogen safety in the sealed containment (SC) in case of beyond design basis and "severe" accidents. (ENERGOATOM 2017, p. 17)

System of forced (filtered) pressure venting

The system is designed to protect the containment and to reduce radioactive releases into the environment, excluding damage to the containment caused by an increase of internal pressure in the event of a severe accident with the melting of fuel. The system simultaneously performs the function of gas cleaning and provides the process for smooth controlled change in pressure. The Filtered Containment Venting System (FCVS) comprises the Venturi scrubber and the aerosol filter. (ENERGOATOM 2017, p. 17)

Mobile means and sources of power supply

In case of the loss of power supply and the loss of the ultimate heat sink, additional mobile pumping units with a diesel drive are provided for:

- filling the spray cooling pool;
- make-up of steam generators;
- make-up of the cooling pool.

The mobile diesel generator set (MDGS) should provide power supply to consumers with 6 and 0.4 kV at the same time due to the design of the generator or the addition MDGS delivery of additional equipment. (ENERGOATOM 2017, p. 18)

Assurance of nuclear and radiation safety

Chapter 4.2 of ENERGOATOM (2017a, p. 22) provides a short overview about the “assurance of nuclear and radiation safety”. Radiation safety is provided by the following engineering, organizational means and activities:

- High reliability of equipment, including improved taking into account the operational experience of NPPs with VVER reactors;
- low frequency of initial events that disrupt normal operation;
- maximum reduction of the probability of "severe" damage to the core CDF), including the case when the reactor is shutdown, to the value of at least 10^{-5} per year (the aim is to ensure that the probability of such an event does not exceed $5*10^{-6}$ per year);
- maximum reduction of the probability of emergence of the limiting accidental release (if the emission is exceeded, measures should be taken to evacuate the population beyond the selected zone) to a value of at least 10^{-6} per year (the aim is to ensure that the probability of such an event does not exceed 10^{-7} per year by accidents);
- protection against common cause failures and personnel errors;

- negligible probability of occurrences of such events as:
  - re-criticality of the melt;
  - severe accident with a bypass of the containment;
  - severe accident at high pressure in the reactor installation;
  - severe accident with failure of the containment after the emergency process has been reduced to low pressure scenarios.

4.2 Discussion

Existing building, structures and equipment

According to ENERGOATOM (2017a), the planned construction of the KhNPP-3&4 counts on using the existing structures of the reactor compartment and other facilities built in the 1980s.

ENERGOATOM (2012) states that it has developed a detailed comprehensive programme of preparatory activities related to the inspection of structures and corrosion prevention works. Based on findings of the inspection of structures, buildings and constructions, the repair-and-renewal works are underway. In Annex B of the IAS (2011) it is mentioned that “a part of the equipment, delivered to the site, is in use”.

According to ENERGOATOM (2017b), the construction availability of the power units is assessed at the level:

- 75% for unit 3 (85 items of equipment were installed, including tanks, heat exchangers, filters, etc.)
- 28% for unit 4

Furthermore, the use of the equipment stored in a warehouse facility at the KhNPP site (containing about 20,000 components of equipment for KhNPP-3&4) is mentioned.

Information about the conditions of the existing buildings, structures and equipment is lacking in the EIA documents.

During the consultation in 2013 the Ukrainian side stated that all structures can be used for the completion of units 3 and 4, all the existing structures are in an operable condition. This was the result of a survey done before the preparation of the FS. The only safety relevant building, which has already been completed, is the building of the back-up diesel generator of unit 3. (MINUTES 2014, topic 20-21)

According to OVOS (2019b, p. 24f.) this survey was performed between 2005 and 2009, no reference to a more recent survey has been made during the consultation in 2013 or in the EIA documents.

The objective of the survey was to justify the possibility of reliable operation during the planned project period with development of proposals on performance of repair and rehabilitation works. It is stated that the works will be carried out to achieve the required lifespan, which will ensure reliable operation of the power units throughout their entire service life. (ENERGOATOM 2019)

However, this calculation was based on a service life of 75 years (including construction age: 20 years for unit 3; 17 years for unit 4; completion period: 5 years for unit 3; 8 years for unit 4; design service life: 40 years; decommissioning period: 10 years. But today's service life-time is considerably longer, it is about 100 years (construction age and completion period: 38 years, operation time: 50 years, decommissioning period: 10 years, totalling 98 years).

The Austrian expert team has a critical view about the condition of the existing structures and building, because there is no convincing evidence that they have not been sufficiently protected against weather impacts.[8]

In 2017, SNRIU conducted a state expert review of nuclear and radiation safety (NRS) of the updated/revised feasibility study (FS) of "Construction of Khmelnitsky NPP units No. 3 and 4. According to SNRIU (2017), the FS was approved upon several conditions, amongst others: carrying out compulsory research at project stage and providing relevant justifications in the Preliminary Safety Report regarding the use of existing buildings and structures of units 3 and 4.

Recently ordered was the update of the inspection and confirmation of the durability and reliability of the KhNPP-3&4 building and structures. It shall be performed until 20 December 2019.[9]

The 2011 feasibility study has been approved with the following conditions, amongst others: Increase robustness of existing buildings and construction elements of KhNPP-3&4 to withstand additional loads from security systems and safety relevant systems (including new ones and upgraded ones) during the life time. (SNRIU 2012b)

In SNRIU (2017) this condition is not mentioned again. The reason is not known.

All in all, it is not proven today that the original structures are still in a usable condition.

SNRIU (2012b) stated: In addition, the decision on the site, design and construction of KhNPP-3&4 should take into consideration, that the completion of the project with the use of existing structures will be impossible.

Ageing Management Programme

An ageing management programme (AMP) is also not mentioned in the EIA documents, despite the fact that ageing of more than 30 years old structures is an issue. Ageing is considered as a process which changes the physical characteristics and attributes of a structure, system and component (SSC) in time or due to usage. As the structures are more than 30 years old, adverse ageing effects are already an issue. The extent of the damage caused by ageing depends on the protective measures taken.

The first Topical Peer Review (TPR) based on Article 8e of Directive 2014/87/EURATOM focused on ageing management. In the course of the TPR, national results have been evaluated through the peer review process, complementing the national assessments. In this context a TPR expected level of

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[8] Pictures show that some structures have been standing in water and were unprotected over the last years, see https://bellona.ru/2015/10/05/khaes-cancelled/ (seen 02 May 2019).

[9] https://smarttender.biz/publichni-zakupivli-prozorro/4960404/

performance for ageing management is the level of performance that should be reached to ensure consistent and acceptable management of ageing throughout Europe. The AMP of all countries are assessed against the TPR expected level of performance. For Ukraine, this assessment revealed that there are several deviations from these safety expectations.

One of the issues assessed is of particular concern for KhNPP-3&4 because it refers to delayed NPP projects: "*During long construction periods or extended shutdown of NPPs, relevant ageing mechanisms are identified, and appropriate measures are implemented to control any incipient ageing or other effects*". According to ENSREG (2018), this "TPR expected level of performance" is not performed in the Ukraine.

Another important shortcoming concerns the methodology applied for setting up the scope of the structures, systems and components (SSCs) which are subject to ageing management. In Ukraine, the scope of the overall ageing management programme is not reviewed and, if necessary, updated, in line with the new IAEA Safety Standard.

Further improvements are also necessary in the other areas that were assessed during the TPR. (ENSREG 2018)

Protection against external hazards

The EIA documents do not provide information about the external impacts on KhNPP-3&4. In this context it is of interest against which external impacts the existing buildings are originally designed, which requirements had to be applied for the original design, what loads were taken into account and whether the structures and buildings still comply with today's requirements and will continue doing so for 50 years operation time. Even more important is the question whether the old requirements are the same as the current requirements for the resistance against external hazards. Another open question concerns the external hazards which the ongoing task for updating the inspection and confirming the durability and reliability of the building and structures of KhNPP-3&4 are based on.

The (cancelled) reactor type V-392B

In 2008, the Ministry of Energy and Coal Industry of Ukraine ran a tender to select a reactor for the KhNPP-3&4, the results – the choice of reactor type VVER-1000/V-392 – was approved by the Cabinet of Ministers of Ukraine. (SNRIU 2012b)

The existing situation of the Russian-Ukrainian relations made it impossible to construct power units using the VVER-1000/V-392 reactor, which the approved feasibility study used. According to the results of the negotiations conducted by Energoatom with potential participants in the construction of KhNPP-3&4, it was decided to switch the supplier of the reactor technology and equipment and use a consortium of Czech companies headed by Škoda JS a.s..

The main difference between the reactor units V-320 and its improved variant V-392B[10] consists in additional safety systems, which provide a significant safety level increase. Design V-392B is the adaption of the conceptual design AES-92 to the power unit 5 of the Balakovskaya NPP. The design offers a number of improvements based on the analysis of the operating experience and IAEA recommendations for operating NPPs with VVER-1000. The highlights of this reactor type compared with the VVER-1000/V-320 are passive safety systems[11].

Having considered the results of the state expertise of nuclear and radiation safety of FS of 2011, the SNRIU Board states (SNRIU 2012a): the FS is not substantiated, and therefore remains open the question of possibility to use existing building structures designed for VVER-1000/V-320 type reactor for the construction of power units with technical characteristics of VVER-1000/V-392 type reactor. According to explanations provided by Energoatom, detailed justification of the possibility of integrating existing building structures into a new project of power units is not feasible at the "feasibility study stage", and therefore will be carried out at the "project stage". Reaching a solution to this problem has been postponed to the next stage of designing. (SNRIU 2012b).

The improved safety concept of the VVER1000/V-392B for the completion of unit 3 and 4 of the KhNPP was selected and approved in 2008. The design of the VVER 1000/V-320 does not comply with modern safety standards.

Design weaknesses of the VVER-1000/V-320

The units 3 and 4 of the KhNPP will be identical to a relatively large extent to the design of the VVER-1000/V-320 reactor type.

A considerable number of safety issues of the VVER-1000/V-320 is known, e.g. embrittlement of the reactor pressure vessel, steam generator integrity or lack of physical separation of the feed water lines and steam lines, as discussed for example in IAEA (1999). This report also discussed improvements which had already been performed at this time or had been envisaged. It can be assumed that today, the safety of the Ukrainian VVER 1000/V-320 reactors is significantly enhanced.

Nevertheless, according to a 2012 performed safety assessment there are still deficiencies: In November 2007, the EC-IAEA-Ukraine Project "Safety Evaluation of Ukrainian Nuclear Power Plants" was launched to perform an overall safety assessment of all operational Ukrainian nuclear power plants. The assessment was aimed at verifying the compliance of nuclear safety in the Ukraine with current IAEA Safety Standards, taking into account the improvements that were carried out so far or scheduled to be implemented under the ongoing Ukrainian safety upgrading programmes (IAEA 2012). Under the framework of the "design safety assessment", Ukrainian NPPs are found to be compliant with only 172 out of 194 requirements of IAEA NS-R-1 "Safety of Nuclear Power Plants: Design", already published in 2000. Issues that were found to be

[10] The reactor models V-392 and V-392B are different reactor types, however - although it is clear that V-392B has been selected - the names of the reactor types are used synonymously in the IAS (2011).

[11] Details on the passive safety systems (high-pressure boron injection system, passive system for heat removal, passive core flooding system) have not been provided. Their functionality under severe accident conditions id not proven yet.

not fully compliant included: equipment qualification, consideration of severe accidents, NPP seismic resistance, completeness of probabilistic and deterministic safety analysis, and post-accident monitoring (ENSREG UCR 2012).

According to SNRIU (2016), the work on two issues (equipment qualification; qualification of steam generator pilot-operated relief valves and BRU-A valves) is still in progress. It is planned to eliminate the incompliance within the Comprehensive (Integrated) Safety Improvement Programme for Nuclear Power Plants.

Not only the long time until international safety requirements are implemented in Ukraine is a problem, but also the fact that not all design-related safety deficits can be remedied: The VVER-1000/V320 has a basic shortcoming not encountered in western Pressurized Water Reactors (PWR). 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 about 48 hours. The containment atmosphere will then blow down into parts of the reactor building that are not leak-tight resulting in high radioactive releases. (HIRSCH et al. 2005).

How the KhNPP-3&4 units will overcome the various shortcomings of the VVER1000/V-320 reactors in general and in Ukraine in particular is of high interest, but it is not addressed in the EIA documents.

Selection of a reactor from the VVER-1000 reactor family for the completion of KhNPP-3&4 is comprehensible to some extent, given the fact that nearly all of the operating reactors in Ukraine are VVER-1000. However, it is planned to build two units of the reactor type V-320 that belong to Generation II of the VVER-1000, although advanced VVER-1000 with different reactor types and enhanced safety features have been available for several years; and have already been built.

The design of the reactor type VVER 1000/V-320 dates back to the 1980s. A later version of the V-320 designed for export is the reactor type V-392, with enhanced safety and seismic features. In the 1980s and 1990s, on the basis of the VVER 1000 Rosatom developed in several steps a third generation nuclear reactor, the VVER1200. It is currently marketed in two forms, one designed by its Moscow/Nizhny Novgorod based department (the VVER 1200/392M) and one by its St. Petersburg based department (the VVER 1200/491). The first unit started up in 2016 in Novovoronezh, the latter in 2018 at the Leningradskaya NPP at Sosnovy Bor near St. Petersburg. (HAVERKAMP 2019)

Ex-vessel coolability and In Vessel Melt Retention (IVMR)

Key safety feature of the envisaged reactor units of KhNPP-3&4 is the external cooling of the molten core in case of a core melt accident. The development of this feature is still ongoing.

According to SNRIU (2017), the FS was approved with several conditions, among others: carrying out compulsory research at the “project stage” and provide relevant justifications in the preliminary Safety Analysis Report regarding application of new systems, in particular, of external cooling systems of the reactor vessel, and modernized systems and equipment.

With the current design and severe accident management measure of the reactor type VVER-1000/V-320 the retention of the molten core inside the RPV in case of a severe accident is not possible.

As part of the outcome of the EU Stress Tests in 2012, several areas for further research in the field of Severe Accident Management have been identified. One of these areas concerns the feasibility of In Vessel Melt Retention (IVMR) for VVER 1000 reactors. The in-vessel coolability and retention is based on the idea of flooding the PWR vessel cavity with water to either submerge the vessel completely or at least submerge the lower head. The PWR lower head containing the melt pool is cooled from outside, which keeps the outer surface of the reactor pressure vessel (RPV) wall cool enough to prevent vessel failure. Ensuring that the corium could stay in the RPV during a severe accident would reduce significantly the risk of release of radioactive substances to the environment for most of the severe accident scenarios. (JRC 2016)

This type of severe accident management strategy has already been incorporated in several operating small size Light Water Reactors (such as the VVER 440). The concept is also deployed in the generation-III designs such as the AP-1000. However, for existing units with higher power it was for long time assumed the IVRM strategy is not possible. This assumption is slowly changing. (ZDAREK 2017)

Starting from 2012, several research institutes and utilities in Europe (and also in the Russian Federation) started some work on this topic- JRC-IET organized an international benchmark on computer code calculations for “In Vessel Retention for VVER 1000” with the target of providing preliminary results on the feasibility of this mitigation strategy. The main findings of this benchmark are amongst others (JRC 2016):

- There are no experimental data available regarding critical heat fluxes (CHF) for RPV geometry of VVER-1000;
- There are still uncertainties regarding the behaviour of the corium in the lower head until it reaches a more stable state;
- The way the accident evolves will lead to different degrees of corium oxidation and material relocation and that has a big impact on the heat flux in the lower head;
- A detailed analysis of core degradation and early core meltdown phases is desirable and even necessary for further refinement of the initial conditions for modelling transient phase of IVMR.

A larger project on the topic was prepared in 2014. At present the EC project HORIZON 2020 IVMR is continuing to provide more findings for this topic. (JRC 2016, ZDAREK 2017)

New large experimental facilities are designed to measure critical heat flux (CHF) at the outer surface of the RPV lower head under more realistic configurations and flow conditions. One of the two success criteria of the IVMR strategy is ‘thermal criterion’ to make sure the heat flux from in-vessel molten pool is less than the CHF at the outer surface of the RPV lower head that is determined by external cooling conditions with water flooded in the reactor cavity. Based on the results from small-scale experiments, the most effective measures to increase CHF might be optimization of the flow path and the outer RPV surface conditions of the lower head. Full height experimental facilities are necessary for validation data, and they should be designed as closely as possible to the real conditions. (ZDAREK 2017)

Plugging of ionization chamber (IC) channel

An analysis performed during a EU pre-accession instrument (PHARE project) in Bulgaria at units 5&6 of the VVER-1000/V-320 Kozloduy NPP discovered a vulnerability of this design consisting in early containment melt-through[12] via ionization chamber (IC) channels situated around the reactor pit. If vessel failure is not prevented, the melt will discharge and spread over the cavity floor. The melt would ablate the side concrete wall of 145 mm thickness in about 45 minutes after the melt release from RPV and would penetrate into IC channels. After that the melt very fast goes out of the containment through the concrete bottom of IC channels (POPOV 2012).

In 2011 it was proposed to plug the bottom of IC channels by plugs made from the high-temperature-resistant materials (Titanium Carbide: melting point of 3,170 °C). It was assessed, within PSA Level-2 for units 5&6 of the Kozloduy NPP that the implemented plugs would rise the time for retention of the melt from one hour to 36 hours.

The Bulgarian regulator made the realization of the proposed specific engineering solution design for prevention of early containment melt-through during severe accident a condition in the licenses of the units 5&6 of Kozloduy NPP. The overall implementation process of mounting of the plugs lasted two years (performed during the annual outages) on Units 5&6 in 2013-2014 respectively. According to POPOV (2017), it could be useful for all other VVER-1000 reactors.

It is not mentioned in the EIA documents whether plugging of the IC channels for KhNPP-3&4 is foreseen.

High-energy pipelines of the secondary circuit at NPP Temelín

The high-energy pipelines at the Temelín NPP (VVER 1000/V-320) are between the containment and the turbine hall at the level of the 28.8 m platform without partition walls and without protection. In the case of break of a pipeline, it may be consequential damage to other lines and components, and thus to an accident that can no longer be controlled. In 2000, both the German company for reactor safety GRS and WENRA have assessed this issue as unsolved. An analysis of all conceivable incidents with consequential damages up to the multiple failure of pipelines, as well as constructive and structural measures to avoid them are necessary. (UMWELTBUNDESAMT 2001)

In the course of the Melk Process follow-up, which concerned Temelín 1 and 2, a number of issues were discussed extensively between Czech and Austrian experts in a series of expert workshops. Most of these issues have been resolved so that no more open questions remained. However, regarding the issue of high energy pipelines of the secondary circuit, some questions remained. Dedicated expert workshops took place in 2008 and 2009. Information regarding the following points would be required by the Austrian experts for complete clarification.

Further information concerning this issue was provided at the regular bilateral meeting between Czech Republic and Austria in 2014. Realized technical measures and analyses from 1998 to 2009 were listed. It was concluded in the

[12] It is also called “early containment bypass”

presentation at the bilateral meeting that many analyses, assessments and calculations had been performed, and many modifications had been implemented that improved the technical condition of high-energy pipelines of the secondary circuit at Temelín NPP. It was stated that the status of these pipelines is continuously monitored during operation, inspections at designated points are also conducted at specified periods and measured values are evaluated according to established criteria in accordance with the operational documentation. However, the four points concerning the safety case are still not clarified.[13] (BMLFUW 2016)

There is no information provided within the EIA documentation, how the issue of high-energy pipelines will be dealt with at KhNPP-3&4.

Project targets and international requirements

It was explained during the bilateral consultations that the project was based on national regulatory documents and IAEA recommendations that were in force respectively published at the time of the preparation of the feasibility study (2011). Only in case new national regulations have to be applied which take newer international requirements into account, the safety requirements for KhNPP-3&4 will be increased.

According to SNRIU (2017) the updating of the 2011 FS was carried out also due to the necessity to implement the provisions of legislative and normative documents, amended or put into effect after the approval of the FS. (SNRIU 2017) The feasibility study foresees safety principles in line with the “defence-in-depth” strategy protection (point 5.3 of the NR 306.2.141-2008), the provisions of WENRA, the basic safety principles SF-1, as well as international requirements for new NPP units (SSR-2/1 and WENRA documents).

Concerning the new safety systems, it is stated that in accordance with the Resolution of the Board of SNRIU No. 15 of 20.11.2012 and the provisions/requirements of international regulations (Council Directive 2014/87/EURATOM of July 8, 2014, IAEA and WENRA regulations on new power units) the FS provides new systems compared to the basic project of the VVER-1000 reactor.

These systems should ensure implementation of the requirements of point 5.3 of the NR 306.2.141-2008 for level 4 of the defence-in-depth strategy for the management of beyond design basis accidents (BDBA). The system must also meet the requirements of the NR 306.2.204-2016, as well as those of point 2.1.7 of the Rules and Norms in Nuclear Power Industry Point 2.1.7 specifies the necessity of availability of technical means for preventing the damage to leak-tight enclosure and its reinforced concrete structures in case of increase of pressure and temperature beyond design basis, keeping the molten core within accident zone (in-vessel molten fuel retention), prevention of hydrogen explosions, limitation of radioactive release into the environment.

SNRIU (2017) concludes that the FS largely adhere to the requirements of NRS norms, rules and standards, requirements of the SNRIU and the provisions of

[13] Catalogue of load cases which were considered; details regarding the selection of possible locations of pipe breaks; details regarding the methodology and results of new stress calculations; requirements for the application of the “No Break Zone” concept and justification of the application of this concept to the whole pipe system.

international organizations' documents regarding new NPPs. According to the preliminary assessments provided by the FS, the use of new and upgraded systems and the implementation of planned technical solutions in the project of power unit based on Škoda VVER-1000 type reactor will allow compliance with the established criteria of nuclear and radiation safety. However, a detailed analysis of the implementation of safety criteria will be carried out at the "project stage" when preparing a preliminary Safety Analysis Report (SNRIU 2017).

In the EIA documents project targets to ensure the radiation safety are only provided in a very general manner; however, they are of utmost interest to assess the safety level of KhNPP-3&4.

According to WENRA (2010), the units KhNPP-3&4 are so-called deferred plants – "plants projects originally based on design similar to currently operating plants, the construction of which halted at some point in the past and is now being completed with more modern technology." In 2009, the reactor harmonization working group (RHWG) of the Western European Nuclear Regulator's Association (WENRA) published the "Safety Objectives for New Power Reactors" (WENRA 2009). These safety objectives should be also used as a reference for identifying reasonably practicable safety improvements for deferred plants (WENRA 2010). WENRA´s RHWG was outlining more explicit positions implied by the new safety objectives for some selected important topics. These positions were published by March 2013 (WENRA 2013).

Safety objectives 1 to 3 of WENRA (2013) aim at strengthening each of the levels of the defence-in-depth concept separately. In addition, the aim of safety objective 4 is an overall reinforcement of the defence-in-depth concept by enhancing the effectiveness of independence between all levels[14].

In the EIA documents it is not mentioned that the WENRA safety objectives shall be applied for KhNPP-3&4. All in all, it is not clear to which extent the current requirements/recommendations of WENRA will be applied for the power unit KhNPP-3&4.

In 2014, WENRA published a revised version of the Safety Reference Levels (RLs) for existing reactors developed by the Reactor Harmonisation Working Group (RHWG). The objective of the revision was to take into account lessons learned of the TEPCO Fukushima Daiichi accident. (WENRA 2014) 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 DEC has been introduced to achieve consistency with the IAEA SSR-2/1 safety standard (IAEA 2016b).

[14] Safety objectives 5 to 7 deal with safety and security interfaces, radioactive waste management and safety management.

According to WENRA (2014) as part of the defence-in-depth, analysis of Design Extension Conditions (DEC)[15] shall be undertaken with the purpose of further improving the safety of the nuclear power plant by:

- enhancing the plant's capability to withstand more challenging events or conditions than those considered in the design basis
- minimising radioactive releases harmful to the public and the environment as far as reasonably practicable, in such events and conditions.

There are 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;
- DEC B with postulated severe fuel damage.

The analysis shall identify reasonably practicable provisions that can be implemented for the prevention of severe accidents. Additional efforts to this end shall be implemented for spent fuel storage with the goal that a severe accident in such storage becomes extremely unlikely to occur with a high degree of confidence. In addition to these provisions, severe accidents shall be postulated for fuel in the core and, if not extremely unlikely to occur with a high degree of confidence, for spent fuel in storage, and the analysis shall identify reasonably practicable provisions to mitigate their consequences. (WENRA 2014)

Application of the defence-in-depth principles, as recognized in international standards and guidance and by WENRA, ensures that safety activities are subject to, as far as reasonably practicable, independent layers of provisions, so that in the event that a failure was to occur, it would be detected, compensated or corrected by appropriate measures.

Defence-in-depth is generally structured in five levels. Should one level fail, the subsequent level comes into play. The objective of the first level of protection is the prevention of abnormal operation and system failures. If the first level fails, abnormal operation is controlled or failures are detected by the second level of protection. Should the second level fail, the third level ensures that safety functions are further performed by activating specific safety systems and other safety features. Should the third level fail, the fourth level limits accident progression through accident management, so as to prevent or mitigate severe accident conditions with external releases of radioactive materials. The last objective (the fifth level of protection) is the mitigation of the radiological consequences of significant external releases through the off-site emergency response.

The effectiveness of each of the different layers is an essential element of defence-in-depth to prevent accidents and mitigate the consequences should they occur.

Current safety requirements (see IAEA 2016b, WENRA 2014) have to be applied to ensure sufficient reliability of the equipment of the third level of defence, the following design principles: a) redundancy; b) diversity and physical separation of redundant subsystems, preference of passive over active safety equipment.

[15] Conditions more complex and/or more severe than those postulated as design basis accidents (DBAs) can occur. These conditions shall be investigated as Design Extension Conditions (DEC) so that any reasonably practicable measures to improve the level of safety of a plant, compared to the level reached with the design basis, are identified and implemented.

However, the EIA documents do not provide a detailed description of the safety relevant systems, most of them are only listed, and information about the capacities, redundancies and physical separation are not given.

NPP design developed in the 1980s, like the VVER-1000/V-320, only partly fulfil these design principles.

Power uprate and load-following

According to ENERGOATOM (2017a) a power uprate to 104% of the design power and load-following operation is planned for KhNPP-3&4.

According to SNRIU (2017), the FS approved upon several conditions, amongst others: Carry out compulsory research at the "project stage" and provide relevant justifications in the preliminary Safety Analysis Report regarding the use of existing building constructions of power units 3 and 4.

NPPs in Europe are mainly used in base load operation. Their flexibility is limited to a few percentages of nominal power. For new plants (under construction and planned) load following is supposed to be fully implemented. But there is very little experience from operation practice. Controlling the reactor core during load-following operation is challenging and difficult in particular for reactors with large cores. The reactor has to perform the load changes while maintaining the core limitations for local power peaking and safety margins. Load-following mode causes technical disadvantages, because plant components are exposed to numerous thermal stress cycles; this leads to faster ageing and requires more sophisticated systems for reactor monitoring and control.

Power uprating is an option to increase the profitability of NPPs. An increase of thermal power implies more nuclear fissions (and so more fission products). Also, higher loads to the reactor materials are unavoidable. An increase of reactor power reduces safety margins and at the same time accelerates ageing processes. An IAEA-Report highlighted that changing the thermal power affects many systems and analyses, thus there are numerous “opportunities” to overlook potential problems. Experience shows: Higher excitation/vibration of steam lines leads to accelerated wear of supporting structures and studs. Increased flow will have an impact on flow-induced vibration in the steam/feedwater path; non-linear effects might occur. Higher steam flows can also result in valves not performing as they did before the power uprate. (IAEA 2011)

4.3 Conclusions, questions and preliminary recommendations

For the completion of KhNPP-3&4, it is planned to use the buildings and structures already built in the 1980s. Information about the conditions of the existing buildings, structures and equipment is not provided in the EIA documents.

An over 10-year-old survey performed between 2005 and 2009 concluded that the **existing buildings and structures** are in an operable condition – no reference to a more recent survey is made in the EIA documents. Furthermore, the scope of the survey was not sufficient. In this year, an inspection and confirming the durability and reliability of the building and structures of KhNPP-3&4 shall be performed. The EIA documents to not provide information about the resistance against external impacts of the KhNPP-3&4.

All in all, there is no convincing evidence today that the existing building, structures and equipment are in a condition to ensure 50 years of safe operation. Buildings and structures originally designed for operation of 40 years have to be kept operable for about 100 years.

An ageing management programme (AMP) is not mentioned, despite the fact that ageing of the more than 30 year old structures, buildings and equipment is an issue even without operational loads. The adverse effect of ageing depends also on the inspection, restoration and protection measures taken (AMP). The first Topical Peer Review (TPR) based on Article 8e of Directive 2014/87/EURATOM focused on Ageing Management. For Ukraine, this assessment revealed several deviations from the safety expectations for an acceptable ageing management in Europe. At KhNPP-3&4, one of the expected TPR levels of performance, which is not met, is of particular concern: "*During long construction periods of NPPs, relevant ageing mechanisms are identified, and appropriate measures are implemented to control any incipient ageing or other effects*". (ENSREG 2018)

The improved VVER-1000/V-392B safety concept of the (with passive safety systems) for the completion of KhNPP-3&4 was selected and approved in 2008, whereas the VVER 1000/V-320 design does not comply with modern safety standards.

To choose from the VVER-1000 reactor family for the completion of KhNPP-3&4 is comprehensible to some extent, given the fact that nearly all of the operating reactors in Ukraine are VVER-1000 reactors. However, advanced VVER-1000 reactors with enhanced safety features have been available for several years and have already been built.

The EIA documentation does not deal with any of the known safety issues of the VVER-1000/V-320 reactors. It is very important to understand how the KhNPP-3&4 units will overcome the various shortcomings of the VVER1000/V-320 reactors in general and more concretely in this project in Ukraine.

An analysis performed in the framework of the EU pre-accession instrument (PHARE project) in Bulgaria at units 5&6 of the Kozloduy NPP discovered a vulnerability of the VVER-1000/V-320 design consisting in early containment melt-through via the ionization chamber (IC) channels situated around the reactor pit. The Bulgarian regulator demanded the realization of a specific engineering solution as a pre-condition for licensing Kozloduy. It is not mentioned in the EIA documents whether plugging the IC channels at KhNPP-3&4 is foreseen.

The high-energy pipelines at the Temelín NPP (VVER 1000/V-320) are situated without partition walls and without protection between the containment and the turbine hall at the level of the 28.8 m platform. The EIA documentation does not explain how the issue of high-energy pipelines will be dealt with at the KhNPP-3&4.

Key safety feature of the envisaged KhNPP-3&4 reactor units is the external cooling of the molten core in case of a core melt accident. The development of this feature for the "In Vessel Melt Retention" (IVMR) is still underway, for example at the reference units at the Temelín NPP.

The EIA documents do not provide a detailed description of the safety-relevant systems, most of them are only listed without any information about the capacities, redundancies and physical separation. NPP design developed in the 1980s, like the VVER-1000/V-320, only partly meet modern design principles concerning redundancy, diversity and physical separation of redundant subsystems or the preference of passive over active safety systems. (See IAEA 2016b, WENRA 2013)

According to WENRA (2013), the WENRA Safety Objectives for new NPPs shall also be used as a reference for identifying reasonably practicable safety improvements for "deferred plants" like KhNPP-3&4. However, the EIA documents don't mention this WENRA safety objectives.

According to ENERGOATOM (2017a) a power uprate to 104% of the design power and load-following operation are planned for KhNPP-3&4. The load-following mode causes technical disadvantages, because plant components are exposed to numerous thermal stress cycles; this leads to faster ageing and requires more sophisticated systems for reactor monitoring and control. An increase of reactor power reduces safety margins and accelerates ageing processes at the same time.

Questions

1. *Against which external impacts were the existing buildings originally designed, which requirements for the original design has to be applied, what loads were taken in account?*
2. *Do the structures and buildings still comply with these requirements and will they continue to do so for the operation time of 50 years?*
3. *What are the differences of the previous requirements in the 1980s years and the current requirements concerning the resistance against external hazards?*
4. *Which external loads shall the ongoing survey of the buildings and structures of KhNPP-3&4 take into account?*
5. *What is the time schedule for the necessary improvement of the ageing management programme (AMP) based on the findings of the Topical Peer Review (TPR) based on Article 8e of EU Directive 2014/87/EURATOM?*
6. *Are the existing buildings, structures and equipment for KhNPP3&4 included in the AMP?*
7. *Please provide information about the ongoing restoration programme.*
8. *Please provide information about the condition of the existing buildings, structures and equipment of the units 3 and 4 (including pictures).*
9. *Does the design of units 3 and 4 differ from the design of units 1 and 2 of the KhNPP? If so, in which areas?*
10. *Is there a systematic evaluation of the KhNPP-3&4 design deviations from the current international safety standards and requirements envisaged?*
11. *Is it planned to plug the IC channels like in Kozloduy 5&6 or will this shortcoming be prevented by design changes?*
12. *Will the WENRA safety objectives for new nuclear power plant be applied for units KhNPP-3&4? Will the concept of defence-in-depth be implemented according to this WENRA safety objectives?*

13. *Which are the improvements of the design, material etc. of the reactor pressure vessel (RPV) and steam generator (SG) compared with these components used at the reactor type V-320? In general, how will the safety requirements according to IAEA NS-R-1 “Safety of Nuclear Power Plants: Design”, (2000) be dealt with at the KhNPP-3&4?*
14. *Is it foreseen to include all improvements of NPP Temelín regarding the issue of high energy pipelines to KhNPP-3&4? Or is an adequate physical separation of the feed water and steam lines ensured by design?*
15. *What is the current status of research for the feature of ex-vessel cooling of the reactor pressure vessel for the VVER 1000/V-320? When will this safety feature be ready for implementation at the reference reactor in Temelín? Is this feature also intended for implementation at the other reactors in Ukraine or other countries?*
16. *Are there different legal requirements for new and operating reactors in Ukraine?*

Preliminary Recommendations

1. It is recommended to repeat the survey of the conditions of the building, structures and equipment before taking any decision regarding the specific project completion. The survey should take into account the protection against external hazards (natural and man- made) according to current international requirements. The prediction should include the current service life time. The results of the investigation are to be subjected to an international review.
2. It is recommended to implement all available design improvements of VVER-1000/V320 reactor for the KhNPP-3&4.
3. It is recommended to apply the WENRA Safety Objectives for new NPP to assess the nuclear safety of KhNPP-3&4. According to WENRA, this document shall be used as a reference for identifying reasonably practicable safety improvements for ´deferred plants` like KhNPP-3&4.
4. The parts of the Preliminary Safety Report that will be provided to the Austrian side shall include the following information concerning the project[16]:
   a. Information about the applied national requirements and international recommendations
   b. Updated justification on the condition of the existing structures, buildings and equipment
   c. Information about (new) safety requirements for the KhNPP-3&4 concerning the protection against terror attacks including a deliberate crash of a commercial airplane.

[16] During the bilateral consultations, it was agreed to provide relevant parts of the Preliminary Safety Report as soon as it becomes available.

5 INCIDENTS AND ACCIDENTS WITHOUT INVOLVEMENT OF THIRD PARTIES

5.1 Treatment in the EIA documents

For the analysis of the possible radiological consequences of accidents, two accidents were considered in the EIA documents:

- Maximum Design Basis Accident (MDBA), a scenario with a guillotine rupture of the main circulation pipeline, which leads to a leak equivalent diameter of 2x850mm (this accident is postulated as the DBA in the regulations);
- Beyond Design Basis Accident (BDBA), a scenario with a guillotine rupture of the DN 2 × 850 mm conditioned by the guillotine rupture of the main circulation pipeline with the failure of the active systems of the emergency cooling of the core (ECCS) and operating sprinkler system. (ENERGOATOM 2017, p. 33; see also IAS 2011, p. 43)

In annex F of the IAS (2011) it is pointed out that in reviewing the MDBA, the following conservative assumptions are adopted:

- damage of all fuel rod claddings;
- functioning of only one (of three) line/s of the sprinkler systems.

For the BDBA, it is assumed:

- all fuel elements of the core are melting and
- malfunction of the active emergency core cooling systems (ECCS).

In ENERGOATOM (2017a, p. 33), it is explained that during MDBA and BDBA, the release into the atmosphere shall be defined by a containment leakage and by the period of high pressure on it. The release into the air comprises noble gases, radioisotopes of iodine, aerosols (Cesium-137 and Strontium-90) and other radio-nuclides (see also IAS 2011, p. 53).

The activities of several radionuclides calculated for the releases of the considered accidents are listed in ENERGOATOM (2017a, p. 7 and p. 18). The releases of the radiological relevant radionuclide iodine (I-131) and caesium (Cs-137) are as follows[17]:

MDBA:	I-131: $1.1 \cdot 10^{12}$ Bq	Cs-137: $2.3 \cdot 10^{10}$ Bq
BDBA:	I-131: $8.8 \cdot 10^{13}$ Bq (88 TBq)	Cs-137: $4.5 \cdot 10^{11}$ Bq (0.45 TBq)

The calculated probability of the considered BDBA is $4*29 \cdot 10^{-7}$ per reactor and per year. (ENERGOATOM 2017, p. 33; see also IAS 2011, annex E).

The radiation doses for the population, and the release of radioactive substances in the environment during normal operation and accidents shall be in accordance with the standards of the radiological safety of the Ukraine (NRBU-97), which was introduced by order of the Ministry of Public Health of Ukraine in 1997 (no. 208 of 07/14/1997) (OVOS 2016, p. 3).

[17] All releases are calculated for an average fuel burnup of 60 MWd/kg.

Results

Individual effective doses for the population as a result of MDBA were estimated. Conducted conservative estimates of doses on the population, taking into account all pathways of exposure showed that for MDBA (in accordance with the norms) no urgent countermeasures (including iodine prophylaxis) are required.

Radioactive contamination of agricultural products as a result of MDBA may exceed the criteria established in the norms for taking decisions of the use of such products at distances up to 30 km. There is a possibility of imposing a ban on the consumption of grain products and meat grown in the immediate vicinity of the site (up to 6 km). The duration of the ban on the consumption of grain products and meat grown in this territory may reach two years. (ENERGOATOM 2017, p. 33)

Individual effective doses to the population as a result of BDBA were also estimated. Based on the maximum effective dose estimates, it is necessary to introduce a restriction on the stay of the population in the open air at a distance of up to 4 km from the source of the release. In the case of this countermeasure, individual risks of occurrence of stochastic effects do not exceed the limit of individual risk for the population. (ENERGOATOM 2017, p. 34)

In case of the considered BDBA, the limits for Cs-137 in milk, cattle meat, food grains and leafy vegetables for more than 25 km, cabbage up to 20 km, fruit up to 10 km from KhNPP would be exceeded. According to the conservative estimates received, the duration of the ban on the consumption of grain products and meat grown in this territory may reach two years.

The conducted calculations showed that outside the KhNPP site the individual risks for the population as a result of radioactive release during MDBA, both during protective measures (countermeasures) and without them (less than $2.0*10^{-6}$ and $3.8*10^{-6}$, respectively) are even below the acceptable level of the individual risk ($5*10^{-5}$ year^{-1}.) (ENERGOATOM 2017, p. 33)

The calculations showed that outside the KhNPP site, individual risks for the population due to radioactive release of nuclear power plants in the event of protective measures (countermeasures) will be below $1.3*10^{-5}$ per year and will not exceed the acceptable level of the individual risk ($5*10^{-5}$ per year^{-} according to the norms). In the absence of protective measures at several hundred meters away from the worst conditions (contamination during the harvest period under the worst weather conditions), in a very limited area, there may be an excess of the mortality risk for the population at the level of $5 \cdot 10^{-5}$ per year. The introduction of restrictions on the consumption of food from this site can reduce the dose. (ENERGOATOM 2017, p. 37)

External hazards

The EIA documents do not provide sufficient information about the evaluation of external hazards for the KhNPP-3&4. According to seismic characteristics, the operating base earthquake (OBE) = 5 points, the safe shutdown event (SSE) = 6 points. In accordance with IAEA recommendations, the level of seismicity for the KhNPP site is assumed at the ground level PGA = 0.1g (ENERGOATOM 2017, p. 6)

According to the IAS (2011, p. 16), natural conditions limiting the NPP site include the fact that the site is located in the **tornado** hazardous area. The factor (Kr = 2.75) is unfavourable, but the site is "allowed with the implementation of engineering activities" according to IAS (2011) meaning it can be used as a site for new reactors if appropriate technical provisions are taken.

5.2 Discussion

A systematic analysis of design basis accidents (DBA) and beyond design basis accidents (BDBA) is not presented in the EIA documentation. Both, the IAS and the updated EIA documents, only discuss the radiological impact of one DBA and one BDBA.

During the consultation in Kiev on August 28 2013, it was confirmed that in the framework of the EIA procedure, only one DBA and one BDBA are considered to calculate the possible (transboundary) consequences. The DBA and the BDBA treated in the EIA procedure are based on safety analyses of the KhNPP-1,2. The higher fuel burn-up of KhNPP-3&4 is taken into account. To calculate the possible consequences of the BDBA, it was assumed that during the accident the core will melt, but the corium is contained within the reactor pressure vessel.

Furthermore, it was also explained that according to the regulatory requirements, deterministic and probabilistic safety analyses of all DBAs and BDBAs will be performed at the project stage. The core damage frequencies (CDF) as well as the large release frequencies (LRF) will be calculated in the framework of the probabilistic safety analyses (PSA) level 1 and 2. These analyses will consider recommendation of the IAEA and the EUR, and will be used to prepare the Preliminary Safety Report (PSR), which is the document necessary to get the construction licence. (MINUTES 2014, topic 37)

During the consultation, the Ukrainian side promised to provide the parts of the PSR that deal with transboundary consequences. It was pointed out that the delivery of the PSR would exceed the requirements of the Espoo Convention. On top the PSR is the property of the operator, thus it cannot be promised to deliver the whole report. (MINUTES 2014, topic 13-15; 37)

As mentioned above, for the calculation of the possible transboundary consequences of the BDBA, it was assumed that during the core melt accident, the corium is contained within the RPV. This BDBA does not constitute a worst case scenario. The assumption is not duly justified, because measures to ensure the retention of the corium in the reactor pressure vessel are not yet available for this reactor type (IVMR see chapter 4). Furthermore, if the ex-vessel-coolability could be realized and corium could stay in the RPV during a severe accident this would reduce significantly the risk of release of radioactive substances for most but not for all of the severe accident scenarios.

In order to assess the consequences of BDBAs, it is necessary to analyse a range of severe accidents, including those with early and late containment failure relating to the time of the core damage, and severe accidents where the containment is bypassed. For the reactor type VVER 1000/V-320 these kinds of severe accidents are possible.

Such severe accidents with considerably higher releases than assumed in the EIA documents cannot be excluded for the considered reactor type even though their calculated probability is below a specific value. This applies also for the KhNPP-3&4, and in addition it is possible that the condition of existing structures, buildings and systems could further increase the probability of severe accidents.

Only results of detailed safety assessments for the reactor would permit to exclude a larger source term – in case it can be proven with a high degree of confidence that such a larger source term is practically excluded. Such safety assessments, however, do not exist for the KhNPP-3&4

A report published in 2012 by the Norwegian Radiation Protection Authority (NRPA) calculated the potential consequences in Norway after a hypothetical accident at the new nuclear power plant Leningrad II. The severe accident scenario was selected by Enconet based on a Level 2 PSA for a VVER-1000/V-320 model It is stated that the calculation was based on the most severe radiological consequences that could occur as a result of a "credible" accident scenario. (NRPA 2012).

The accident scenario (containment bypass) is initiated by a large break in the steam generator (40 mm). The emergency core cooling systems and the auxiliary feed water systems are assumed to be operable, the operator is successfully preventing steam generator (SG) overfilling, and the SG relief valve is operating normally. However, the fast cool-down and stabilization of the unit fails, leading to core melt. This is an accident sequence with bypass of the containment that involves early and late releases directly to the environment. Nevertheless, the source term is limited due to the retention in the primary system caused by a high flow in intact legs and intensive heat exchange and condensation in the SG.

The radionuclide inventory of the core was based on Russian data derived for the original fuel. The source term of this scenario was calculated to 2,800 TBq (0.85% of core inventory) for Cs-137 and 26,700 TBq (0.85% of core inventory) for I-131 (NRPA 2012).

These source terms are considerably higher compared to those used in the EIA-documents.

Severe Accident Management (SAM)

In the Ukrainian National Report of the EU stress tests, the results of analyses to identify cliff edge effects of VVER-1000/V-320 reactors as well as spent fuel pools (SFP) were presented. The analysis of station blackout (SBO) accidents has shown that the time margin before fuel damage in the reactor in the worst case is only 2-2.5 hours. For SFP of Ukrainian NPPs it was stated that the time margin to fuel heat-up above the design limits established for the most unfavourable conditions, with the reactor core unloaded to SFP, is about 6.5-7 hours. (UNR 2011)

The results of the EU stress tests in 2011 have revealed that the severe accident management (SAM), i.e. the prevention of severe accidents and the mitigation of its consequences, at Ukrainian NPPs shows a lot of shortcomings. According to the ENSREG Peer Review Country Report "*SAM provisions (SAMG, dedicated hardware means and equipment qualification in severe accident con-*

ditions) have not yet been implemented for the Ukrainian NPPs and it is an area for improvement." (ENSREG UCR 2012) The peer review team highlighted that this implementation must have a high level of priority due to the possibility of cliff-edge effects in the case of a severe accident.

The measures identified from stress tests have been incorporated into the "Comprehensive (Integrated) Safety Improvement Program" (C(I)SIP). It is intended to accelerate the following measures (ENSREG UCR 2012):

- SAMGs development and implementation;
- Implementation of hydrogen concentration reduction measures in the containment for BDBA situations;
- Installation of hydrogen monitoring system in the containment for BDBA scenarios;
- Preservation of the containment integrity if there is interaction with corium at the ex-vessel phase of severe accident;
- Enhancement of systems that aim to ensure Main Control Room (MCR) and Emergency Control Room (ECR) habitability and accessibility;
- Development and implementation of measures for diagnostics in case of a severe accident.

In addition to the envisaged improvements, the ENSREG peer review recommends the following topics (ENSREG UCR 2012):

- It should be demonstrated, with a high degree of confidence, that the key functions needed for SAM can be achieved. In particular, provisions against cliff-edge effects on accident progression should be addressed as a priority (hydrogen management, control, reliability of reactor coolant system (RCS) depressurization function in severe accident condition);
- A strategy and programme for the qualification of equipment needed in severe accident conditions should be implemented;
- The risk induced simultaneously by reactor and SFP in case of a severe accident should be assessed;
- The analysis of SFP accident in various configurations in order to underwrite Emergency Operation Procedures (EOP) and SAMGs;
- The robustness of the means to cool the SFP even after core melt should be improved. If SFP is inside the containment, a means to cool the SFP should be ensured even if some internal structures (pipes) in the containment have been damaged by a hydrogen combustion;
- Further investigation of the habitability of MCRs and ECRs in case of a severe accident;
- Consideration of the protection of population with regard to the SAM provisions;
- For sites with several units, the feasibility of immediate actions required to avoid core melt, prevent large release, and avoid site evacuation for a disaster affecting more than one unit at a particular site should be verified in detail;
- Enhanced seismic capabilities for the building hosting the crisis centre should be assessed.

Several measures to enhance the safety of the existing NPPs are part of the Comprehensive (Integrated) Safety Improvement Program (C(I)SIP). According to SNRIU (2016), all C(I)SIP measures were to be implemented in 2012–2017, but the programme was extended to 2020 by the Resolution of the Cabinet of Ministers of Ukraine 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.

Several measures, mainly the use of mobile generators and pumps, are required to enhance the safety of the operating NPPs in Ukraine. During the consultation, it was explained that those measures will be also included in the project KhNPP-3&4. However, it was also stated that the KhNPP-3&4 will be designed in a way that these safety improvements will not be necessary. This statement was related to the implementation of a reactor type V392B. It should be clarified which of the required safety improvements are currently included by the design of the KhNPP-3&4.

The information given during the consultation indicates that the KhNPP-3&4 spent fuel pools will have the same safety level as those of operating VVER-1000 reactors. As additional measure, only the use of mobile pumps for emergency cooling of the spent fuel pool is planned.

Demonstration of practical elimination

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. (JPEE 2018)

The concept of "practical elimination" of early or large releases is defined in details in IAEA (2012) and WENRA (2013). Accident sequences with early or large releases could be considered to have been practically eliminated if it is physically impossible for the accident sequence to occur or if the accident sequence can be considered with a high degree of confidence to be extremely unlikely to arise.

The demonstration of "practical elimination" has to be achieved by deterministic considerations supported by probabilistic considerations, taking into account the uncertainties due to the limited knowledge of some physical phenomena.

IAEA (2016a) recommends to pay attention of practical eliminating of the following severe accident conditions which could:

- damage the containment in an early phase as a result of direct containment heating, some steam explosions or large hydrogen detonation;
- damage the containment in a late phase as a result of basemat melt-through or containment excessive pressure;
- occur during an open containment – notably in shutdown states;
- bypass the containment (e.g. Steam Generator (SG) tube rupture or an Interfacing System Loss of Coolant Accident (ISLOCA).

IAEA (2016a) proposes the following categories of accident conditions that should be addressed for "practical elimination":

- Events that could lead to prompt reactor core damage and consequent early containment failure:
  - failure of a large component in the reactor coolant system;
  - uncontrolled reactivity accidents.

- Severe accident phenomena which could lead to early containment failure:
  - direct containment heating;
  - large steam explosion;
  - Hydrogen detonation.
- Severe accident phenomena which could lead to late containment failure:
  - molten core concrete interaction (MCCI);
  - loss of containment heat removal.
- Severe accident with containment bypass;
- Significant fuel degradation in a storage pool.

None of the phenomena mentioned above can be ignored by putting forward the argument of low likelihood. To support the safety claims it is necessary to deliver credible research results and dedicated means to eliminate the identified risks.

JPEE (2018) provided an overview how these phenomena could be addressed for VVER 1000/V320 reactors. The summarized design features and preventing and mitigation measures were already implemented at Kozloduy NPP. It was pointed out, that issues related to external steam explosion are underlined for further study.

Table 1: Measures for severe accident management of the VVER 1000/V320 at Kozloduy NPP (JPEE 2018)

Phenomena	Design features	Additional prevention and mitigation measures
Core melt	• Active medium and low-pressure safety injection; • Passive Hydro Accumulators; • Emergency boron injection.	• Additional diesel generators; • Qualification of some systems to operate as safety systems; • Water injection in reactor core or SG by mobile fire protection equipment in extreme conditions.
Core melt under high pressure	• Primary depressurization system; • Safety valves; • Spray system.	• Qualification of some systems operates as safety systems
Pressure vessel failure	• In-vessel retention (by in-vessel injection of water).	• By external vessel cooling with water
External steam explosion	• None. The cavity is dry.	• Need additional investigation in case of flooding of cavity for In-Vessel Melt Retention (IVMR).
Basemat melt-through	• In-vessel melt retention by water injection.	• Plugging all ionization chamber channels located in the walls of the reactor vessel cavity; • Ex-vessel measures
Containment overpressure	• Containment spray (earlier phase); • Larger containment free volume.	• Containment venting system (scrubber).
Hydrogen detonation	• Larger containment free volume.	• Hydrogen recombiners; • Long term containment management (risk for late phase release).
Containment bypass	• Accident management (for Primary to Secondary (PRISE) events using appropriate procedures).	• Ex-vessel measures (corium spreading, corium cooling by water supplying); • Long term cooldown of corium.
Accident in spent fuel pool (SFP)	• Water level and temperature monitoring; • Emergency water supply system.	• Even SFP heat distribution; • Water injection in SFP by mobile fire protection equipment in extreme conditions.

According to ENERGOATOM (2017a, p. 22) the probability of occurrences of following events for the KhNPP-3&4 which could result in a major release are negligible as:

- re-criticality of the melt;
- "severe" accident with a bypass of the containment;
- "severe" accident at high pressure in the reactor installation;
- "severe" accident with failure of the containment after the emergency process has been reduced to "low pressure scenarios".

However, this approach of Energoatom for the KhNPP-3&4 does not comply with the state of the art**:** 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. According to IAEA (2016a) 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.

External hazards

The information provided in the IAS (2011) shows that the **site evaluation is not in compliance with current international requirements** because the quoted international recommendations are outdated. The site was selected and approved for a NPP with a capacity of 4,000 MW in line with the legal requirements in 1975.

Regarding **earthquakes**, the quoted international recommendation is also outdated as it was published nearly 20 years ago. However, according to the results of the EU stress tests, a re-assessment of the seismic hazard was carried out at Ukrainian NPPs from 1999 until 2010, taking IAEA recommendations into account.

In SNRIU (2017) it is stated the FS should be supplemented and/or specified by the necessary requirements in order to ensure that the FS fulfils the norms, rules and standards, as well as with reactor specifications approved by SNRIU. One of the identified shortcomings is as follows: Specifications for the calculation of the peak ground acceleration for the project location (PGA=0,1g) given in the Feasibility Study do not correspond to the information specified in technical specifications. According to SNRIU (2017), the FS is approved amongst others upon the following condition: the calculation of the site's peak ground acceleration is to be elaborated and/or clarified.

The feasibility study of 2011 has been approved based upon the several following conditions, amongst others the in-depth assessment of the impact of extreme external events of natural and man-made nature as well as their combinations is to be included in the preliminary Safety Analysis Report (SNRIU 2012b). These requirements are not repeated in SNRIU (2017).

The KhNPP site is located in the **tornado hazardous area**. Thus, the location can only be used as a site for new reactors if appropriate technical provisions are taken. According to the EU stress tests, especially the essential service water system (ESWS) is vulnerable to the impact of tornadoes.

The information provided so far is not sufficient to evaluate the risk of external hazards for the KhNPP-3&4. External events are of particular concern for the KhNPP site at which (after commissioning KhNPP-3&4) four reactors will be operated. A comprehensive site analysis can contribute to minimize the probability of a severe accident with significant adverse environmental impacts.

External hazards may simultaneously affect all units, including back up safety systems. For multi-facility sites this makes the generation of safety cases more complex and requires appropriate interface arrangements to deal with common equipment or services as well as potential domino effects.

In the current WENRA document concerning the design of new nuclear power plants (WENRA 2013) it is stated**:** **"**The safety assessment for new reactors should demonstrate that threats from external hazards are either removed or minimized as far as reasonably practicable." More specifically:

- External Hazards considered in the *general design basis* of the plant should not lead to a core melt accident (Objective O2 i.e. level 3 DiD).
- Accident sequences with core melt resulting from external hazards which would lead to early or large releases should be practically eliminated (Objective O3 i.e. level 4 DiD). For that reason*, rare and severe external hazards*, which may be additional to the *general design basis*, unless screened out, need to be taken into account in the overall safety analysis.

In WENRA (2014) it is required that nuclear power plant against impacts like earthquakes or flooding with an exceedance probability of 10^{-4}/year have to be designed. Where it is not possible to calculate these probabilities with an acceptable degree of certainty, an event shall be chosen and justified to reach an equivalent level of safety.

The basic requirements for the consideration of natural hazards regarding the safety of nuclear power plants are described in the IAEA Specific Safety Guides SSG-9 for earthquake and in SSG-18 for flooding (IAEA 2010a, b). In IAEA (2010b) it is pointed out that possible climatic changes in the site of the nuclear plant, which can have an impact on safety, have to be taken into account.

The EIA documents do not provide information about the WENRA requirement/recommendations to be applied for the KhNPP-3&4.

5.3 Conclusions, questions and preliminary recommendations

Incidents and accidents without involvement of third parties

A systematic analysis of design basis accidents (DBA) and beyond design basis accidents (BDBA) is not presented in the EIA documents; only the radiological consequences of one DBA and one BDBA are discussed. The considered BDBA is a loss of coolant accident with the failure of the active systems of the emergency core cooling and the sprinkler system. The calculated probability of this BDBA is 4.29*E-7 per reactor year. This BDBA does not constitute a worst case scenario. To calculate the possible (transboundary) consequences of this BDBA, it was assumed that the core melt will remain within the reactor pressure vessel (RPV). This assumption is not justified, because features to ensure the retention of the corium in the RPV (In-Vessel Melt retention -IVMR) are not available yet. Furthermore, if this feature could be realized it would only reduce the risk of radioactive release in most but not in all severe accident scenarios.

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/V-320 reactor type. Although their probability is below a specific value this type of such severe accidents cannot be excluded. A report published in 2012 by the Norwegian Radiation Protection Authority (NRPA) calculated the possible consequences for a VVER-1000/V-320 reactor with source terms considerably higher compared to those used in the EIA documents.

The results of the EU stress tests have revealed that the severe accident management (SAM) (i.e. the prevention of severe accidents and the mitigation of its consequences) at the Ukrainian NPPs shows a lot of shortcomings. 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.

According to current international requirements for new nuclear power plants (IAEA 2012 and WENRA 2013), accident sequences with early or large releases have to be practically eliminated. The concept of “practical elimination” of early or large releases is not mentioned for KhNPP-3&4 in the EIA documents. Quite the opposite: ENERGOATOM (2017a) states the probability of severe accidents (e.g. with containment failure) that could have a major release are negligible. This approach does not comply with the state of the art. Although probabilistic targets can be set, “practical elimination” cannot be demonstrated by showing the compliance with a general probabilistic value. According to IAEA (2016a) 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.

External hazards

The information provided in the EIA documents shows that the site evaluation is not complying with current **international requirements**, because the quoted international recommendations are outdated. According to SNRIU (2017), the seismic hazards have to be re-evaluated, the FS was approved with the condition to elaborate and/or clarify the calculation of the site’s peak ground acceleration (PGA). The KhNPP site is located in a **tornado hazardous area**. Thus, the location can only be used as a site for new reactors if appropriate technical provisions are taken.

The 2011 feasibility study has been approved with the condition that an in-depth assessment of the impact of extreme external events of natural and man-made nature as well as their combinations will be included in the Preliminary Safety Report (SNRIU 2012b). This condition is not included in conditions for the approval of the current FS (SNRIU 2017).

According to WENRA (2013), the safety assessment for new nuclear power plants should demonstrate that threats from external hazards are either removed or minimized as far as reasonably practicable. Information whether this WENRA recommendation is to be applied for KhNPP-3&4 is not provided in the EIA documents.

Questions

1. *Which of the design features and additional prevention and mitigation measures for severe accident management of the Kozloduy NPP (JPEE 2018) have to be applied for KhNPP-3&4 (see table 1)?*
2. *Have all of the recommendations by the ENSREG peer review team listed in the Country Report of the EU stress tests to further improve the SAM be considered for KhNPP-3&4?*
3. *Which measures of the "Comprehensive (Integrated) Safety Improvement Program for Ukrainian NPPs (C(I)SIP) have to be implemented for KhNPP-3&4? Which of the measures are not necessary because of design improvements of the VVER-1000/V-320 for KhNPP-3&4?*
4. *Which requirements have the filtered venting systems to fulfil, particularly regarding earthquake resistance?*
5. *What is the time schedule for the implementation of all required SAM features, and has the implementation of all SAM features including the ex-vessel cooling to be finished before commissioning KhNPP-3&4?*
6. *Which initiating events (external and internal) will be considered for the accident analyses?*
7. *Is the KhNPP site today in compliance with current IAEA requirements?*
8. *Please provide more details regarding the calculation of the seismic hazard. When will the seismic PSA for KhNPP-3&4 be developed? What are the results of the seismic PSA for KhNPP 1&2?*
9. *Please provide more information about the protection measures against tornadoes and time schedule for implementation.*
10. *What are the parameters of the maximum aircraft crash (plane mass and speed) the buildings of the KhNPP-3&4 can withstand? Regarding external explosions, what are the maximum shockwave overpressures the buildings can withstand?*
11. *Why is the condition of SNRIU (2012b) to include an in-depth assessment of the impact of extreme external events of natural and man-made nature as well as their combination in the Preliminary Safety Report not included in the conditions for the approval of the current FS by SNRIU (2017)?*

Preliminary Recommendations

1. It is recommended that the concept of practical elimination is applied consistently in the safety requirements for the new nuclear power plants. For KhNPP-3&4, practical elimination of accident sequences has to be demonstrated with state-of-the-art probabilistic and deterministic methods, fully taking into account the corresponding publications of WENRA.
2. It is recommended to demonstrate that for KhNPP-3&4 threats from external hazards are either eliminated or minimized as far as reasonably practicable using the method according to the WENRA Safety Objectives for new Nuclear Power Plants (Position 6).

3. It is recommended to use current IAEA and WENRA safety guides and requirements for the evaluation of the external hazards.
4. The parts of **Preliminary Safety Report** that will be provided to the Austrian side shall include the following information concerning accident analyses and the results of the PSA (Level 1, 2 und 3):
   a. Core damage frequency (CDF) and severe accidents with (early) large releases (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 design basis accidents (DBA) and beyond design basis accidents (BDBA)
   d. Source terms of the most important release categories 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
   f. Justification of the BDBA(s) that is/are chosen to calculate possible transboundary consequences
5. The parts of **Preliminary Safety Report** that will be provided shall include the following information concerning site evaluation:
   a. Presentation of the results of current studies on natural hazards (in particular earthquakes, floods and extreme weather conditions)
   b. Description of the method used to determine the relevant external events
   c. List of external events to be considered (including their justification) and their characteristics
   d. Information on the combination of external events taken into consideration
   e. Data on the required safety margins for the NPP design basis (in particular for earthquakes)
   f. Consideration of multi-unit accidents and accidents in the spent fuel pools.

6 INCIDENTS AND ACCIDENTS WITH INVOLVEMENT OF THIRD PARTIES

6.1 Treatment in the EIA documents

Chapter 5.6 of the IAS (2011) provides some basic information about the physical protection. (IAS 2011, p. 30) It is pointed out that the physical protection is in line with the Ukraine law "on physical protection of nuclear facilities, nuclear materials radioactive waste, other sources of ionizing irradiation" (No 2064-II of 19.10.2000) and other regulatory and legal documents. It is mentioned that for KhNPP-3&4, the current system of physical protection at KhNPP site will be extended.

ENERGOATOM (2017a) does not provide any information about this topic.

6.2 Discussion

Interference by third parties (terrorist attacks or acts of sabotage) on nuclear power plants may have significant impacts. Nevertheless, they are not mentioned in the EIA documents for KhNPP-3&4. In comparable EIA procedures such events were addressed to some extent.

The EIA report on the planned Bohunice-3 nuclear power plant in the Slovak Republic discussed the possible risks of a terrorist attack. It is explained that this kind of hazard for the new nuclear power plant cannot be completely excluded. In accordance with the valid legislation of the Slovak Republic, the license holder is therefore obliged to monitor and eliminate the risk of a terrorist attack in cooperation with the respective state authorities. A deliberate crash of a large passenger aircraft is considered to be a covering terrorist attack, i.e. a terrorist attack with the potentially most serious consequences. It is required that Bohunice-3 will be adequately protected against the impact of a large commercial aircraft (JESS 2015).

It was explained during the bilateral consultations in Kiev on the 28 August 2013, that the part of the reactor buildings of KhNPP-3&4 which has already been built is similar to those of units 1 and 2. The wall thickness of the containment is 1,000-1,200 mm. A possible crash of an airplane was evaluated within the EIA. But because the calculated probability of accidental crashes of civil and military airplanes is very low, the possibility of such airplane crashes is considered as negligible – and therefore a wall thickness of 1000 mm is considered to be sufficient. Furthermore, it was stated neither national legislation nor international recommendations include requirements concerning the stability of the containment building against acts of terror (including airplane crash). The requirement is only at a draft stage in the WENRA document. In case this draft document passes and is also included in the Ukrainian legislation, or if the IAEA adopts such a requirement before the final decision of the KhNPP-3&4, then this requirement will be adopted and acts of terror including deliberate airplane crashes will be taken into account. (MINUTES 2014, topic 22 and 23)

In August 2013, the resistance of KhNPP-3&4 against the accidental or deliberate crash of a large (commercial) airplane is not required. However, the specific WENRA document was published in 2013. It does not contain requirements, but safety expectations which are supplementing the WENRA Safety Objectives for new NPP. They should be taken into account in the Ukrainian legislation before the final decision of the KhNPP-3&4 is taken.

The reactor buildings of the reactor type VVER-1000 are not sufficiently protected against external hazards. The KhNPP-3&4 design does not reflect current standards in science and technology. New reactor designs are protected against a deliberate attack with a commercial airplane.

It is likely that the reactor building will be the primary target in case of an attack. If the reactor is in operation as the attack occurs, and if the cooling is interrupted, a core melt can result within a very short time. Such an accident can also occur when the reactor is shut down, although somewhat slower in this case (HIRSCH et al. 2005).

If the impact of an airplane crash causes a major damage of the reactor building, it has to be assumed that the reactor's cooling circuit will be damaged and that safety and control systems because of debris and fire will also suffer major damage. If the pipelines of the cooling system or the reactor pressure vessel itself are damaged, it would be irrelevant if the emergency cooling system still functioned, since it would no longer be able to be effectively fed in. Such a case would thus in a short time – within a few hours – lead to the meltdown of the reactor core. Radioactive substances will be released from the melted fuel and, since the containment will have been destroyed, they can get into the atmosphere with practically no delay or retention inside the building.[18]

By combining different measures, a certain protection against terrorist attacks and sabotage can be attempted. Even if, for reasonable reasons of secrecy, precautions against serious third-party interference cannot be publicly discussed in detail in the EIA procedure, the EIA should at least set out the requirements to a certain extent. It should be borne in mind that in general an existing sufficient structural protection against external impacts such as a deliberate aircraft crash can be presented to the public.

Nuclear Security

Nuclear facilities are designed with safety provisions such as thick concrete walls, containment and independent and diverse systems providing multiple backups in case of an emergency. These provide some protection against terrorist attacks. However, new possible means to support attacks are emerging: Unmanned flying objects, drones, can – like in military application – be used for the preparation or support of terror attacks. In autumn 2014, drones had flown over French nuclear facilities over 30 times without their originators being identified, are an additional security threat to nuclear installations. Not only the drone overflights themselves but also the inability of security officials to explain and prevent such activity are issues for concern. (BECKER 2017)

[18] In all studies on risks such a scenario – a core meltdown with open containment – is regarded as the worst conceivable scenario. It leads to particularly large and – even worse – to particularly early releases of radioactivity. The time available for taking protective measures against the disaster is very short.

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

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

However, the assessment of the protection against sabotage recognized shortcomings compared to necessary requirements: The Nuclear Threat Initiative (NTI) 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 2018 NTI Index assesses nuclear security conditions related to the protection of nuclear facilities against acts of sabotage. This ranking includes 45 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 2018)

In the NTI Index scores of 100 represent the highest possible score. Ukraine with a total score of 70 points only ranked 30 out of 45 countries, which indicates a low protection level.

Table 2 shows some details about the Nuclear Security Index for Ukraine. It has to be pointed out that the low scores for “Insider Threat Prevention” and “Cybersecurity” indicate deficiencies in these issues.[19]

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”.

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

Table 2: The 2018 Nuclear Security Index for Ukraine. (NTI 2018)

	Scores	Scores
1) NUMBER OF SITES		**60**
2) SECURITY AND CONTROL MEASURES		**61**
2.1) On-site Physical Protection	80	
2.2) Control and Accounting Procedures	86	
2.3) Insider Threat Prevention	22	
2.4) Response Capabilities	100	
2.5) Cybersecurity	20	
3) GLOBAL NORMS		**85**
4) DOMESTIC COMMITMENTS AND CAPACITY		**100**
5) RISK ENVIRONMENT		37
5.1) Political Stability	15	
5.2) Effective Governance	25	
5.3) Pervasiveness of Corruption	0	
5.4) Group(s) Interested in Committing Acts of Nuclear Terrorism		100
Overall score		**70**

Physical protection

Regarding **physical protection** of the KhNPP-3&4, it is questionable whether the physical protection relies on requirements which are fully up to date, because as mentioned above, it is in line with the Ukraine law of the year 2000, the provisions in question are therefore outdated. (UMWELTBUNDESAMT 2013)

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**) and International Nuclear Security Service. 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 2014a) Until now, an International Physical Protection Advisory Service (IPPAS) in the Ukraine was neither performed nor envisaged. (IAEA 2019)

6.3 Conclusions, questions and preliminary recommendations

The effects of third parties (terrorist attacks or acts of sabotage) can have a considerable impact on nuclear facilities and thus also on the KhNPP-3&4 in Ukraine. Nevertheless, they are not mentioned in the EIA documents for the KhNPP-3&4. In comparable EIA documents such events were addressed to some extent.

Although precautions against interference by third parties cannot be discussed in detail in the EIA process for reasons of confidentiality, the necessary legal requirements should be set out in the EIA documents. 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, as the wall thickness of the reactor building/containment of KhNPP-3&4 is only about 1000 - 1200 mm, therefore, the units will be vulnerable against terror attacks (including airplane crash). In 2013, the resistance of KhNPP-3&4 against the accidental or deliberate crash of a large (commercial) airplane was not required by the Ukrainian regulator.

A recent assessment of the nuclear security in Ukraine points to shortcomings compared to necessary requirements for nuclear security: The 2018 NTI Index assesses nuclear security conditions related to the protection of nuclear facilities against acts of sabotage. With a total score of 70 out of 100 points, Ukraine ranked only 30 out of 45 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.

Questions

1. *What are the requirements with respect to the planned NPP design against the deliberate crash of a commercial aircraft?*
2. *Is the protection of KhNPP-3&4 against the crash of a commercial aircraft required by the Ukrainian regulation? Or is such a requirement provided for?*
3. *Have the recommendations of WENRA 2013 (Position 7: Intentional crash of a commercial airplane) been or will they be fully incorporated into the Ukrainian regulations?*
4. *Have the requirements with respect to the protection against cyberattacks and insiders improved since the survey of the Nuclear Security Index 2018 or is such an increase/update of the requirements planned?*
5. *Against which external attacks must the reactor building, and other safety relevant buildings be designed, especially the already completed building (back-up diesel generator of unit 3)? Is this protection still guaranteed despite adverse ageing effects? On the basis of which studies and conducted in which years can such a statement be made or will it be made in the future?*
6. *Is a peer-review mission of the IAEA International Physical Protection Advisory Service (IPPAS) planned before commissioning of KhNPP-3&4?*

Preliminary recommendations

1. It is recommended to apply the requirements of WENRA 2013 (Position 7: Intentional crash of a commercial airplane) for the KhNPP-3&4.
2. In light of the special situation in Ukraine, the effects of third parties (terrorist attacks or acts of sabotage of the plant) should be given high priority. Protection against cyber-attacks and insiders should be improved. The IAEA's International Physical Protection Advisory Service (IPPAS) should be used to improve the security.

7 TRANSBOUNDARY IMPACTS

7.1 Treatment in the EIA documents

Chapter 5.9.3 of ENERGOATOM (2017a, p. 35) summarized the “assessment of the consequences of accidents on the territory of neighbouring countries”. It is explained that KhNPP is located at a distance of 160 km from the border with Belarus and about 190 km from the border with Poland. Taking this into account, a mesoscale Lagrangian Euler diffusion model is used to simulate the transboundary transfer in case of an accident at the KhNPP-3&4.

Annex C of the IAS (2011) provided some information about the used methods, assumptions etc. used to calculate the transboundary impact. The used Lagrangian-Eulerian diffusion model LEDI was developed for calculations of the contamination transfer to the distances up to 1,000 km from the source with the effective altitude of the emission from 0 to 1,500 m. The model was used for the reconstruction of the radioactive contamination with radionuclides caesium-137 and iodine-131 of the territory of Ukraine in the initial period after the Chernobyl accident.

For the simulation of transboundary consequences, three typical **meteorological situations** were chosen with a possible intensive transboundary transfer in the direction of Poland and Belarus. For that purpose, real atmospheric data[20] of three different time periods[21] were used. The data of these scenarios were also modified: it was assumed, while precipitation was absent on the whole territory of Ukraine, precipitation (0.5 mm/h) started after the radioactive cloud is passing the border of Poland or Belarus. (OVOS 2016 p.8f, see also IAS 2011, annex C).

In annex F of the IAS, it is pointed out, that for the BDBA the following conservative assumption is adopted: the radioactive release occurs with zero height and shielding at the nearby buildings are not taken into account (IAS 2011, annex F).

The basic criteria of the radiation limitation of the population in Europe through anthropogenic sources is the limit of the annual individual effective dose at the level of 1 mSv per year. It coincides with the dose limit for population in Ukraine. (OVOS 2016, p. 10)

For the evaluation of the **annual individual effective dose**, relevant exposure ways are considered (inhalation, ingestion, radiation from radioactive cloud, radiation from radionuclides deposited on the ground). The assessment of the dose was made for two age groups – adults and 1-2-year-old children. Calculations were made using the set of application programme RadEnvir3.1, which was developed jointly by IAEA and Scientific and Research Institute of the Radiation Protection of the Academy of Technical Science of Ukraine (OVOS 2016, p. 9; see also IAS 2011, annex C).

Figure 2.1 to 2.6 of OVOS (2016) depicts the isolines of the density field of the release I-131 during the MDBA for the different meteorological scenarios. In annex A of OVOS (2016) the results of the calculation of transboundary transfer of the radionuclides after the MDBA and BDBA are given. The calculated values of

[20] Data of the Hydro-Meteorological Service of Ukraine were used.

[21] 10-12 February, 1984; 26-27 November, 1982 and 6-9 May, 1986

the fallout density and of the time integral of the volumetric activity in the surface air and effective annual doses for the critical groups of population on the border of Belarus and Poland respectively (in the centre of trail) for the meteorological scenario 1 are listed.

The critical scenario is the scenario 3A, according to which the fallouts happen during the vegetation period of plants. Maximum levels of density of the fallouts on the territory of Poland will make about 4,350 Bq*m^{-2} for I-131 and 119 Bq*m^{-2} for Cs-137. (OVOS 2016 p. 19 and p. 35)

It is highlighted in ENERGOATOM (2017a, p. 35) that findings of the assessment of the **transboundary impact** indicate that during none of the both accidents the level of the individual annual effective dose for the individuals of the critical group in the neighbouring countries will be exceeded. Furthermore, it is mentioned, children are the critical group, main contribution to the radiation dose comes from ingestion, and main dose-forming radionuclide is iodine-131.

7.2 Discussion

The updated EIA document OVOS (2016) provides the same approach and results of the transboundary impact assessment as the EIA document OVOS (2011), a new calculation was obviously not performed by Energoatom.

The described **approach** to calculate the transboundary impacts is comprehensible**.** The reasons for selecting the meteorological situations used are not explained in detail; thus it is not possible to assess whether worst case meteorological conditions were applied. The general assumption regarding the precipitation is conservative, but the used precipitation intensity is very low (i.e. it is not conservative, because higher precipitation intensity results in higher contaminations). Also, the reason of the emission height of zero meters is not explained; in general, higher emission heights result in a wider spread of released radionuclides and in higher ground contamination in larger distances.

However, in particular the conclusion regarding possible transboundary impacts is not comprehensible because of the considered BDBA does not constitute a worst case accident scenario at the units KhNPP-3&4 (see chapters “accident analysis”). Because of the lack of such analysis, the conclusion of the transboundary impact is not sufficient.

As the EIA documents **do not provide possible consequences of a severe accident with containment failure or containment-bypass,** the results of a study performed by the Austrian Institute of Ecology in the framework of the review of the Environmental Impact Assessment (EIA) of the completion of Khmelnitsky 2/Rovno 4 (1998) are presented below (WENISCH et al. 1998). In order to assess the consequences of a severe accident at Khmelnitsky 2 (KhNPP-2), results of source term calculations for the Kozloduy NPP in Bulgaria (also VVER-1000/V-320) were used.

It was not intended to predict the exposure of the population in the affected areas; therefore only **caesium-137** was considered. The releases for caesium-137 in severe accidents are estimated between 4% and 50% of the total core inventory (the different scenarios and releases are: core-melt followed by steam explosion: 40%; failure of core cooling systems, containment spray and residual heat removal: 50%; overpressure failure of the containment heat removal: 20%; LOCA, failure of containment spray and containment isolation: 4%; containment bypass: 10%)

To investigate the possible impact following a severe accident at Khmelnitsky-2 (KhNPP-2), a release of 20% of the total core inventory of caesium-137 was assumed (5*5 x 10^{16} Bq). To account for plume rise due to associated release of energy (heat), an equal source distribution was assumed at the height of 76 m (roof height) to 200 m. Furthermore, a release duration of one hour was assumed.

The transport and deposition of aerosol-bound radionuclides were simulated with the validated **Lagrangian particle dispersion model** FLEXPART. Because the major contribution to doses in Austria arises from deposition (resulting in groundshine and ingestion), only deposition was evaluated.

The **meteorological input** to the model was taken from model output of the European Centre for Medium Range Weather Forecasting (ECMWF). A meteorological situation was selected that did occur in reality. Releases were simulated twice a day for the entire year 1995. It turned out that an accident on December 3 would have had the worst impact on Austria.

The simulations were carried out for seven days; however, already after about two days the cloud had crossed Austria and most of its activity had been washed out and deposited to the ground. The meteorological situation during the relevant period was characterized by a strong and stable high-pressure system over Scandinavia and a low-pressure system over the Mediterranean. Figure 3 shows the resulting deposition pattern. In addition to the main maximum in Austria, there are secondary maxima in southern Poland and close to the NPP[22].

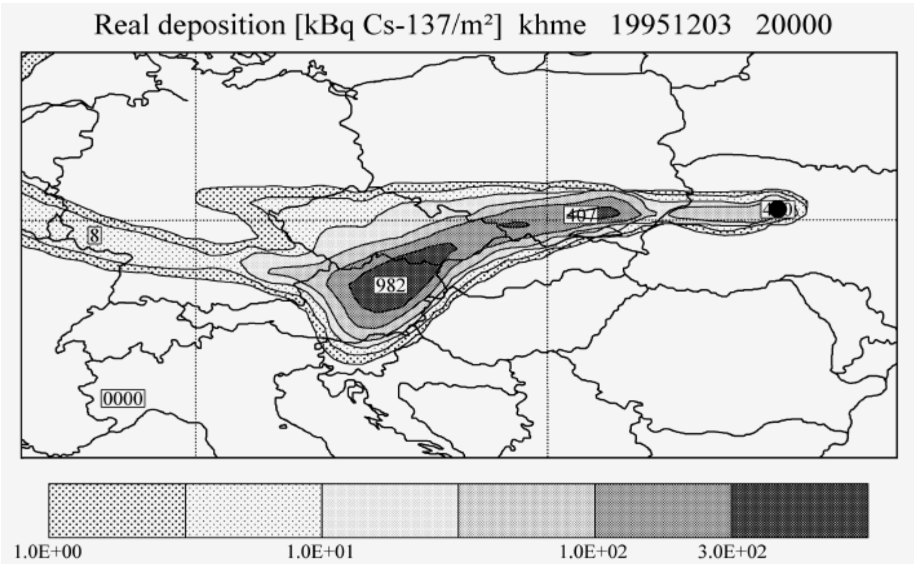


Figure 3: Deposition of caesium-137 from a hypothetical BDBA in KhNPP-2 (WENISCH et al. 1998).

Source: WENISCH et al. (1998)

[22] The size of the grid does not allow for a realistic resolution of the maximum near the site. In reality, it will be smaller but with higher values.

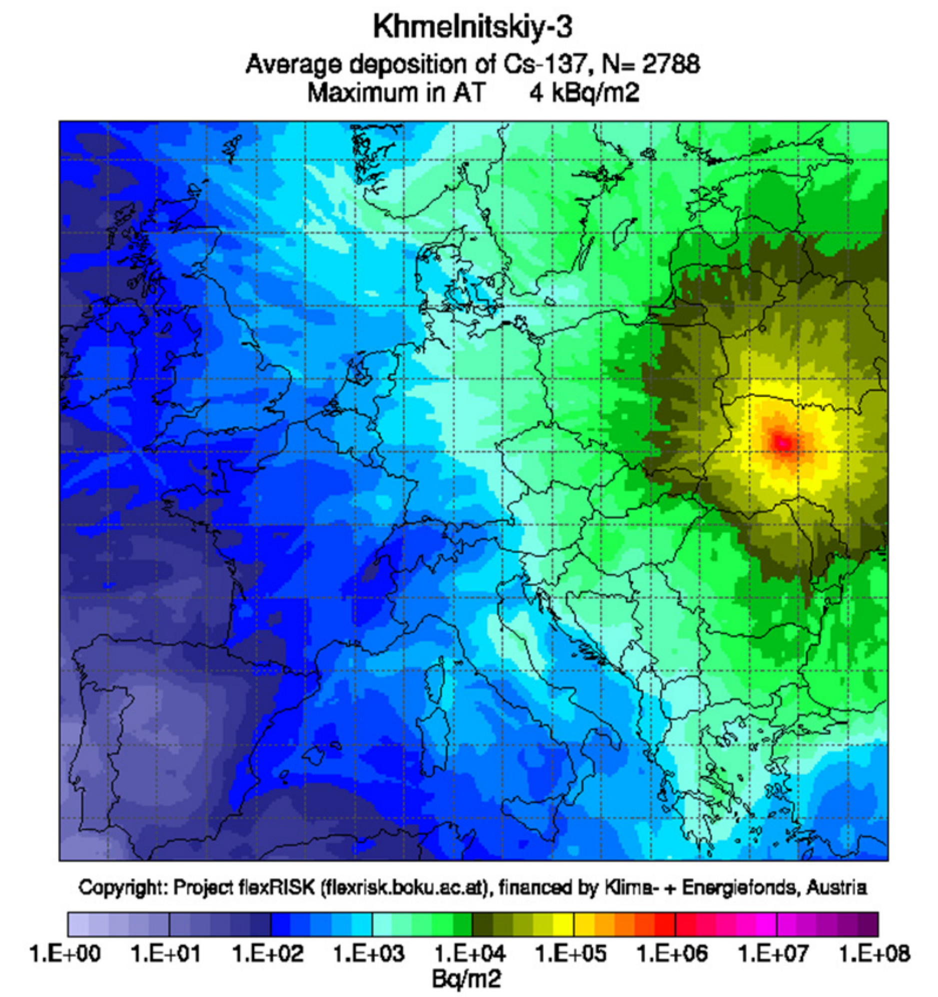
The **results** of the presented calculation indicate that there is the possibility that an accident at the KhNPP would contaminate not only regions in Ukraine, but also several regions in Europe, as in May 1986 after the Chernobyl accident. For the Eastern part of Austria, the calculation resulted in values up to approx. 1,000 kBq/m² contamination with caesium-137 (which is about 5 times the highest values measured in Austria in 1986).

If a deposition above a certain threshold can be expected, a set of agricultural intervention measures is triggered. The measures include earlier harvesting, closing of greenhouses and covering of plants, putting livestock in stables etc. Austrian authorities defined a threshold for caesium-137 ground deposition of 650 Bq/m² and for iodine-131 ground deposition of 700 Bq/m² (BMLFUW 2014).

Additionally, calculations of the **flexRISK project** can be used for the estimation of possible impacts of transboundary emission of KhNPP-3&4 (FLEXRISK 2013). The flexRISK project modelled the geographical distribution of severe accident risk arising from nuclear facilities, in particular nuclear power plants in Europe. Using source terms and accident frequencies as input, for about 1,000 meteorological situations the large-scale dispersion of radionuclides in the atmosphere was simulated.

Using the Lagrangian particle dispersion model FLEXPART, both, radionuclide concentrations in the air and their deposition on the ground, were calculated and visualized in graphs. The total caesium-137 deposition per square-meter (Cs-137 Bq/m²) is used as the contamination indicator.

Figure 4 illustrates the **average deposition** of Cs-137 after a severe accident at KhNPP-3 with the Cs-137 release of 74, 000 TBq. An accident could result in a considerable contamination of the Austrian territory; the average deposition of Cs-137 in the simulation is between 500- 4,000 Bq/m². Most parts of Austria could show depositions of 800 Bq/m² or more. As within the simulation the average ground depositions of most areas are higher than the threshold for agricultural countermeasures (650 Bq/m²), Austria would be most likely significantly affected from a severe accident at KhNPP-3&4.



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

Figure 4 Average deposition of Cs--137 after a hypothetical BDBA in KhNPP-3

The **probability of a severe accident** with a large release (core damage frequency (CDF) and large release frequency (LRF)) may be different at KhNPP-3&4 compared to KhNPP-2. But, reactor core inventory and other reactor characteristics of the reactor types of KhNPP-2 and KhNPP-3&4 that determinate the release of such an accident (source term) are comparable. Thus, the presented results of an accident at KhNPP-2 illustrate the consequences of a potential severe accident at KhNPP-3 or KhNPP-4.

The distance of the KhNPP site to the Austrian border is about 730 km. There are no results presented in the EIA documents for this distance to the KhNPP-3&4.

7.3 Conclusions, questions and preliminary recommendations

Severe accidents with releases considerably higher than assumed in the EIA documents cannot be excluded for the KhNPP-3&4, even if their probability is required to be below a specific value. Such worst case accidents should be included in the assessment since their effects can be widespread and long-lasting and even countries not directly bordering Ukraine, like Austria, can be affected.

Because of the lack of analysis of the worst case scenarios, the conclusion of the EIA documents concerning transboundary effects is not appropriate.

The results of the calculations made by the Austrian Institute of Ecology (1998) indicated that a severe accident (worst case scenario) at KhNPP would contaminate several regions in Europe. For the Eastern part of Austria, the calculation resulted in values up to approx. 1,000 kBq/m² of caesium-137 contamination (which is about 5 times the highest values measured in Austria in 1986).

Furthermore, the results of the flexRISK project indicated that after a severe accident, the average caesium-137 ground depositions at most areas of the Austrian territory would be higher than the threshold for agricultural intervention measures (e.g. earlier harvesting, closing of greenhouses). Therefore, Austria would be significantly affected by a severe accident at the KhNPP-3&4.

Questions:

1. *Please provide the quantitative results of the calculated ground deposition of I-131 and Cs-137 for the distance to Austria.*
2. *Please explain the reasons for the selection of the meteorological situations in more detail. Have analyses been performed using different meteorological assumptions? Please explain the choice of the emission height? Have simulations with other emissions heights been performed?*

Preliminary recommendations

1. It is recommended to perform a conservative worst case release scenario which is based on specific severe accident analyses of the KhNPP-3&4.
2. It is assumed that the dispersion calculations to evaluate possible transboundary consequences of a severe accident will be updated in the framework of the preparation of the Preliminary Safety Report. It would be appreciated if the following PSR information would be provided to the Austrian side:
   a. Description of the methodology of dispersion calculation and of the calculation of the radiation doses,
   b. Input data used for the dispersion calculation (source terms, emission height and duration, meteorological data) and their justification,
   c. Results of the dispersion calculation (the ground deposition, air concentrations and effective doses), in particular results for large distances including the Austrian territory.

8 QUESTIONS AND PRELIMINARY RECOMMENDATIONS

8.1 Overall and Procedural Aspects of the Environmental Impact Assessment (EIA)

Questions

1. *What information is included in the EIA documents that were published in Ukraine for public participation but were not submitted to Austria?*
2. *When will the promised parts of the Preliminary Safety Report be submitted to Austria?*
3. *What is the timetable for the next steps of the EIA procedure?*
4. *What is the status of the Ukraine-EU-Energy Bridge project?*
5. *If the Ukraine-EU-Energy Bridge project fails, how will the completion of KhNPP-3&4 be funded?*

Preliminary recommendation

1. 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, and to also assess a no-action alternative.

8.2 Spent fuel and radioactive waste

Questions

1. *What is the expected inventory of spent fuel and radioactive waste from operation of KhNPP-3&4?*
2. *What is the status of the central interim storage facility for spent fuel?*
3. *What is planned for the back-end of the fuel cycle? Is spent fuel reprocessing in Russia still under consideration?*
4. *Is an international cooperation for final disposal of spent fuel and/or radioactive waste planned?*
5. *Which interim and final storages for radioactive waste are in operation in Ukraine, will their capacity be sufficient to dispose of all radioactive waste from operation of KhNPP-3&4?*
6. *How can the safe storage of spent fuel and radioactive waste be ensured if the interim storage and final disposals will not be ready in time?*

Preliminary recommendation

1. To demonstrate the safe management of nuclear waste from KhNPP-3&4 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 Reactor type

Questions

1. *Against which external impacts were the existing buildings originally designed, which requirements for the original design has to be applied, what loads were taken in account?*
2. *Do the structures and buildings still comply with these requirements and will they continue to do so for the operation time of 50 years?*
3. *What are the differences of the previous requirements in the 1980s years and the current requirements concerning the resistance against external hazards?*
4. *Which external loads shall the ongoing survey of the buildings and structures of KhNPP-3&4 take into account?*
5. *What is the time schedule for the necessary improvement of the ageing management programme (AMP) based on the findings of the Topical Peer Review (TPR) based on Article 8e of EU Directive 2014/87/EURATOM?*
6. *Are the existing buildings, structures and equipment for KhNPP3&4 included in the AMP?*
7. *Please provide information about the ongoing restoration programme.*
8. *Please provide information about the condition of the existing buildings, structures and equipment of the units 3 and 4 (including pictures).*
9. *Does the design of units 3 and 4 differ from the design of units 1 and 2 of the KhNPP? If so, in which areas?*
10. *Is there a systematic evaluation of the KhNPP-3&4 design deviations from the current international safety standards and requirements envisaged?*
11. *Is it planned to plug the IC channels like in Kozloduy 5&6 or will this shortcoming be prevented by design changes?*
12. *Will the WENRA safety objectives for new nuclear power plant be applied for units KhNPP-3&4? Will the concept of defence-in-depth be implemented according to this WENRA safety objectives?*
13. *Which are the improvements of the design, material etc. of the reactor pressure vessel (RPV) and steam generator (SG) compared with these components used at the reactor type V-320? In general, how will the safety requirements according to IAEA NS-R-1 “Safety of Nuclear Power Plants: Design”, (2000) be dealt with at the KhNPP-3&4?*
14. *Is it foreseen to include all improvements of NPP Temelín regarding the issue of high energy pipelines to KhNPP-3&4? Or is an adequate physical separation of the feed water and steam lines ensured by design?*
15. *What is the current status of research for the feature of ex-vessel cooling of the reactor pressure vessel for the VVER 1000/V-320? When will this safety feature be ready for implementation at the reference reactor in Temelín? Is this feature also intended for implementation at the other reactors in Ukraine or other countries?*
16. *Are there different legal requirements for new and operating reactors in Ukraine?*

Preliminary Recommendations

1. It is recommended to repeat the survey of the conditions of the building, structures and equipment before taking any decision regarding the specific project completion. The survey should take into account the protection against external hazards (natural and man- made) according to current international requirements. The prediction should include the current service life time. The results of the investigation are to be subjected to an international review.
2. It is recommended to implement all available design improvements of VVER-1000/V320 reactor for the KhNPP-3&4.
3. It is recommended to apply the WENRA Safety Objectives for new NPP to assess the nuclear safety of KhNPP-3&4. According to WENRA, this document shall be used as a reference for identifying reasonably practicable safety improvements for ´deferred plants` like KhNPP-3&4.
4. The parts of the Preliminary Safety Report that will be provided to the Austrian side shall include the following information concerning the project[23]:
   a. Information about the applied national requirements and international recommendations
   b. Updated justification on the condition of the existing structures, buildings and equipment
   c. Information about (new) safety requirements for the KhNPP-3&4 concerning the protection against terror attacks including a deliberate crash of a commercial airplane.

8.4 Incidents and accidents without involvement of third parties

Questions

1. *Which of the design features and additional prevention and mitigation measures for severe accident management of the Kozloduy NPP (JPEE 2018) have to be applied for KhNPP-3&4 (see table 4)?*
2. *Have all of the recommendations by the ENSREG peer review team listed in the Country Report of the EU stress tests to further improve the SAM be considered for KhNPP-3&4?*
3. *Which measures of the "Comprehensive (Integrated) Safety Improvement Program for Ukrainian NPPs (C(I)SIP) have to be implemented for KhNPP-3&4? Which of the measures are not necessary because of design improvements of the VVER-1000/V-320 for KhNPP-3&4?*
4. *Which requirements have the filtered venting systems to fulfil, particularly regarding earthquake resistance?*

[23] During the bilateral consultations, it was agreed to provide relevant parts of the Preliminary Safety Report as soon as it becomes available.

5. *What is the time schedule for the implementation of all required SAM features, and has the implementation of all SAM features including the ex-vessel cooling to be finished before commissioning KhNPP-3&4?*
6. *Which initiating events (external and internal) will be considered for the accident analyses?*
7. *Is the KhNPP site today in compliance with current IAEA requirements?*
8. *Please provide more details regarding the calculation of the seismic hazard. When will the seismic PSA for KhNPP-3&4 be developed? What are the results of the seismic PSA for KhNPP 1&2?*
9. *Please provide more information about the protection measures against tornadoes and time schedule for implementation.*
10. *What are the parameters of the maximum aircraft crash (plane mass and speed) the buildings of the KhNPP-3&4 can withstand? Regarding external explosions, what are the maximum shockwave overpressures the buildings can withstand?*
11. *Why is the condition of SNRIU (2012b) to include an in-depth assessment of the impact of extreme external events of natural and man-made nature as well as their combination in the Preliminary Safety Report not included in the conditions for the approval of the current FS by SNRIU (2017)?*

Preliminary Recommendations

1. It is recommended that the concept of practical elimination is applied consistently in the safety requirements for the new nuclear power plants. For KhNPP-3&4, practical elimination of accident sequences has to be demonstrated with state-of-the-art probabilistic and deterministic methods, fully taking into account the corresponding publications of WENRA.
2. It is recommended to demonstrate that for KhNPP-3&4 threats from external hazards are either eliminated or minimized as far as reasonably practicable using the method according to the WENRA Safety Objectives for new Nuclear Power Plants (Position 6).
3. It is recommended to use current IAEA and WENRA safety guides and requirements for the evaluation of the external hazards.
4. The parts of **Preliminary Safety Report** that will be provided to the Austrian side shall include the following information concerning accident analyses and the results of the PSA (Level 1, 2 und 3):
   a. Core damage frequency (CDF) and severe accidents with (early) large releases (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 design basis accidents (DBA) and beyond design basis accidents (BDBA)
   d. Source terms of the most important release categories 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
   f. Justification of the BDBA(s) that is/are chosen to calculate possible transboundary consequences

5. The parts of **Preliminary Safety Report** that will be provided shall include the following information concerning site evaluation:
   a. Presentation of the results of current studies on natural hazards (in particular earthquakes, floods and extreme weather conditions)
   b. Description of the method used to determine the relevant external events
   c. List of external events to be considered (including their justification) and their characteristics
   d. Information on the combination of external events taken into consideration
   e. Data on the required safety margins for the NPP design basis (in particular for earthquakes)
   f. Consideration of multi-unit accidents and accidents in the spent fuel pools.

8.5 Incidents and accidents with involvement of third parties

Questions

1. *What are the requirements with respect to the planned NPP design against the deliberate crash of a commercial aircraft?*
2. *Is the protection of KhNPP-3&4 against the crash of a commercial aircraft required by the Ukrainian regulation? Or is such a requirement provided for?*
3. *Have the recommendations of WENRA 2013 (Position 7: Intentional crash of a commercial airplane) been or will they be fully incorporated into the Ukrainian regulations?*
4. *Have the requirements with respect to the protection against cyberattacks and insiders improved since the survey of the Nuclear Security Index 2018 or is such an increase/update of the requirements planned?*
5. *Against which external attacks must the reactor building, and other safety relevant buildings be designed, especially the already completed building (back-up diesel generator of unit 3)? Is this protection still guaranteed despite adverse ageing effects? On the basis of which studies and conducted in which years can such a statement be made or will it be made in the future?*
6. *Is a peer-review mission of the IAEA International Physical Protection Advisory Service (IPPAS) planned before commissioning of KhNPP-3&4?*

Preliminary recommendations

1. It is recommended to apply the requirements of WENRA 2013 (Position 7: Intentional crash of a commercial airplane) for the KhNPP-3&4.
2. In light of the special situation in Ukraine, the effects of third parties (terrorist attacks or acts of sabotage of the plant) should be given high priority. Protection against cyber-attacks and insiders should be improved. The IAEA's International Physical Protection Advisory Service (IPPAS) should be used to improve the security.

8.6 Transboundary impacts

Questions

1. *Please provide the quantitative results of the calculated ground deposition of I-131 and Cs-137 for the distance to Austria.*
2. *Please explain the reasons for the selection of the meteorological situations in more detail. Have analyses been performed using different meteorological assumptions? Please explain the choice of the emission height? Have simulations with other emissions heights been performed?*

Preliminary recommendations

1. It is recommended to perform a conservative worst case release scenario which is based on specific severe accident analyses of the KhNPP-3&4.
2. It is assumed that the dispersion calculations to evaluate possible transboundary consequences of a severe accident will be updated in the framework of the preparation of the Preliminary Safety Report. It would be appreciated if the following PSR information would be provided to the Austrian side:
   a. Description of the methodology of dispersion calculation and of the calculation of the radiation doses,
   b. Input data used for the dispersion calculation (source terms, emission height and duration, meteorological data) and their justification,
   c. Results of the dispersion calculation (the ground deposition, air concentrations and effective doses), in particular results for large distances including the Austrian territory.

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10 GLOSSARY

AMP .... Ageing Management Programme

BDBA .... Beyond Design Basis Accident

Bq....................... Becquerel

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

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

CHF.................... Critical Heat Flux

CMU .... Cabinet of Ministers of Ukraine

Cs-137................ Caesium-137

DBA.................... Design Basic Accident

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

DID .... Defence in Depth

EBRD .... European Bank for Reconstruction and Development

ECCS .... Emergency Core Cooling System

ECMWF............. European Centre for Medium Range Weather Forecasting

ECR.................... Emergency Control Room

EHRS .... Emergency Hydrogen Removal System

EIA .... Environmental Impact Assessment

ENSREG .... European Nuclear Safety Regulators Group

ENTSOE-E .... European Network of Transmission System Operators for Electricity

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

ESWS................. Essential Service Water Systems

EU .... European Union

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

FCVS.................. Filtered Containment Venting System

FS....................... Feasibility Study

g .... Gravitational Acceleration

GRS .... Gesellschaft für Anlagen- und Reaktorsicherheit, Germany

I-131 .... Iodine-131

IAEA .... International Atomic Energy Agency

IAS .... Information and Analytical Survey

IC........................ Ionization Chamber

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

ISLOCA .... Interfacing System Loss of Coolant Accident

IVMR .... In-Vessel Melt Retention

KhNPP .... Khmelnitsky nuclear power plant

LBLOCA .... Large Break Loss of Coolant Accident

LEDI .... Name of a Lagrangian-Eulerian diffusion model

LOCA .... Loss of Coolant Accident
LRF .... Large Release Frequency
MCCI .... Molten core concrete interaction
MCR .... Main Control Room
MDBA .... Maximum Design Basis Accident
MDGS .... Mobile Diesel Generator System
NIS PAR .... (NIS) Passiv Autocatalytic Recombiner
NPP .... Nuclear Power Plant
NRPA .... Norwegian Radiation Protection Authority
NRS .... Nuclear and radiation safety
NTI .... Nuclear Threat Initiative
OBE .... Operating Base Earthquake
PGA .... Peak Ground Acceleration
PSA .... Probabilistic Safety Assessment
PSR .... Preliminary Safety Report
PWR .... Pressurized Water Reactor
RCS .... Reactor Coolant System
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
SDPP .... Standby Diesel Power Plant
SEA .... Strategic Environmental Assessment
SFP .... Spent Fuel Pool
SG .... Steam Generator
SNRIU .... State Nuclear Regulatory Inspectorate of Ukraine
SSC .... Structure, Systems and Components
SSE .... Safe Shutdown Event
TBq .... Tera-Becquerel, E12 Bq
TPR .... Topical Peer Review
UNECE .... United Nations Economic Commission for Europe
VVER .... Water-Water-Power-Reactor, Pressurized Reactor originally developed by the Soviet Union
WENRA .... Western European Nuclear Regulators´ Association

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REG.NO. AT- 000484

ISBN 978-3-99004-511-4