ENVIRONMENT AGENCY AUSTRIA umweltbundesamt

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Construction of Units 3, 4

Expert Statement to the Information and Analytical Survey of the Feasibility Study and the EIA Report of the FS

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KHMELNITSKY NPP – CONSTRUCTION OF UNITS 3 & 4

Expert Statement to the Information and Analytical Survey (IAS) of the Feasibility Study (FS) and the EIA Report of the FS

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SUMMARY

Introduction

The government of Ukraine is preparing the completion of units 3 and 4 of the Khmelnitsky nuclear power plant (KNPP-3 & 4). The construction of KNPP 3 & 4 started in 1985/1986, however, the 1990 moratorium on the construction of nuclear power units in Ukraine stopped the construction.

Commissioning of KNPP 3 & 4 (WWER-1000/V-392B) is scheduled for 2016 and 2017, respectively. At the KNPP site, the units KNPP-1,2 (WWER-1000/V-320) are already in operation.

With reference to the Espoo Convention the Austrian Federal Ministry of Agriculture and Forestry, Environment and Water Management, expressed its interest to take part in the transboundary Environmental Impact Assessment (EIA). The Umweltbundesamt (Environment Agency Austria) was commissioned by the Austrian Federal Ministry of Agriculture and Forestry, Environment and Water Management to supervise the procedure concerning content and organizational matters. The Austrian Institute of Ecology (Österreichisches Ökologie-Institut) in cooperation with Oda Becker, Helmut Hirsch, Andriy Andrusevych and Adhipati-Yudhistira Indradiningrat was assigned by the Umweltbundesamt to prepare the expert statement at hand assessing the documents presented by Ukraine.

The Ukrainian side provided an English document which is **an Information and Analytical Survey (IAS) of the Feasibility Study (FS)** materials. This is the translation of the report which was prepared for the public review in Ukraine. It also contains information on the anticipated consequences of the construction, commissioning, operation and decommissioning of the KNPP-3 & 4. The IAS "*gives a short summary on the reference data and on the substantiations, describes basic technical decisions and results of the analysis, assessments and forecasts, presented in 23 volumes of the FS, including the Environmental Impact Assessment (OVOS)*." (IAS 2011, p. 6)

Chapter 14 of the OVOS was received 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"). The complete OVOS (EIA) itself was provided to the Austrian side in the original language. The Austrian side commissioned a German translation of relevant parts of the EIA section of the Feasibility Study (FS), especially the chapters of the EIA necessary to assess transboundary impacts.

The goal of this **expert statement** is to assess if the IAS in combination with the relevant information in the EIA documentation allows for making reliable conclusions about the potential impact of transboundary emissions. Therefore, particularly safety features, severe accident management and the accident analysis with a focus on airborne transboundary emissions and the potential impact to Austria are discussed.

The nuclear approval procedure in Ukraine

In Ukraine different approval procedures are applied to different nuclear activities, but they all follow the general sequence:

- approval decision to locate, design and construct a nuclear installation;
- decision to commission (start operation of) a nuclear installation;
- licensing the operation of a nuclear installation;
- approval decision for the decommissioning of a nuclear installation.

Construction of KNPP 3 & 4 is an activity which falls under the category “nuclear installations and radioactive waste handling plants of national importance”. The construction of KNPP 3 & 4 is at the preparation stage for the approval decision to locate, design and construct the nuclear installation (1st stage).

During the preparatory stage for the approval decision to locate, design and construct a nuclear installation the preparation of a **Feasibility Study** is obligatory. This Feasibility Study is a technical and economical justification of the project.

In 2009 the Government of Ukraine decided to use the WWER-1000/392B reactor type for the Feasibility Study and project for construction of KNPP 3 & 4 (on the basis of tender results).

Description of the Project

The project consists of the completion of the units 3 and 4 of the KNPP, which was stopped in 1990. The construction of these units, WWER-100/V-320 reactors, started in 1985/1986. The IAS described the **degree of completion** of the units KNPP 3 & 4 being 35–40% and 5–10% respectively, while the operator NNEGC “Energoatom” stated on his website the construction of the units 3 and 4 reaching 75% and 28% completion. No precise information was provided on which existing buildings or structures are to be used for the completion of the KNPP-3,4. However, it can be expected that the “new” units 3 and 4 will be **identical or similar** to a relatively large extent to the design of the **WWER-1000/V-320**.

Information about the **conditions of the existing buildings, structures and equipments** is missing. An aging monitoring and management program is also not mentioned, despite the fact that aging of the about 25 years old structures etc. is an issue.

Neither the wall thickness of the containment of the units KNPP 3 & 4 nor their **resistance against external impacts** are specified. Furthermore, it is questionable whether the **physical protection** relies on requirements which are fully up to date.

It is also questionable whether the **protection against fire hazards** relies on requirements according to the state-of-the-art. Generally, the documentation does not deal with any of the known **safety issues of the WWER-1000/V-320** reactors or explain how units KNPP 3 & 4 will overcome the various deficiencies. Thus – based on the available information – it has to be assumed that the safety level of the units 3 and 4 is only slightly higher than the safety level of the old WWER-1000/V-320 reactors.

Generally, a detailed **description of the safety relevant systems** is not provided, most of the safety relevant systems are only listed, information about the capacities, redundancies and spatial separation is not given. The highlights of the chosen reactor type WWER-1000/V-392B compared with the operating WWER-1000/V-320 are passive safety systems. However, the functionality of the passive core flooding and heat removal system is not described in detail. According to a publication of the designer, the **capability of the new passive safety systems** under real accident conditions could be limited, i.e. not sufficient to control those accidents

Project targets to ensure the **radiation safety** are provided in a very general manner only; although they are of utmost interest to assess the safety level of KNPP-3,4. **WENRA safety objectives** of new nuclear power plants are not mentioned at all. These safety objectives should also be used as a reference for identifying reasonably practicable safety improvements for deferred plants (plant projects originally based on a 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).

Site Evaluation

The IAS emphasizes that the construction of KNPP 3 & 4 at the existing site is based on a governmental decision and therefore alternative variants of generation or locations are not subject to the Feasibility Study (FS).

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

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.

The EU stress tests revealed that a **seismic PSA** for all Ukrainian NPPs still has to be developed. Furthermore, some questions were raised regarding seismic resistance of the containment and of the equipment for the current operating Ukrainian NPPs, thus probably for the KNPP 3 & 4 too.

The KNPP 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 IAS pointed out the necessity to improve the cooling capacity of the Reservoir-Cooler (RC).

Selection of the NPP Type

Before the Feasibility Study was prepared the NPP type for completion of the KNPP 3 & 4 was chosen. The choice was based on **tentative analysis** of possible alternatives.

The AP-1000, the APR-1400, the EPR-1600 and WWER-1000 reactors were determined as the alternative variants for completion of KNPP-3,4. The IAS highlights the significantly improved safety level of the **EPR**, especially in the mitigation of severe accidents, through double containment, which is resistant to outside impacts, including a crash of a big airliner.

Regarding the **WWER-1000** reactors, the operation experience with this type in Ukraine is highlighted. It is emphasized that the analysis did not show significant discrepancies of the WWER-1000 usage at the KNPP site in line with the criteria of the pre-selection. Furthermore, a lot of (economic) advantages of the usage for completion of KNPP 3 & 4 are listed, e.g. the possibility to use the completed parts of the construction of the power units 3 and 4 and of existing infrastructure and supplied equipment.

The main variants of the considered reactors based on WWER-1000 technology are**:** a) the **modernized WWER-1000**, analog of the NPP Temelin; b) the design V-392B and c) the design V-466. **Design V-392B** (based on V-392) is described as the adaption of the conceptual design AES-92 to the power unit 5 of the Balakovskaya NPP (integration into a new construction part of the V-320). V-392B belongs to Generation II of WWER-1000 reactors like the reactor type V-320. Regarding the **design V-466** (Generation III of the WWER-1000 reactors), improved and additional safety systems in comparison with the serial WWER-1000 were introduced but the reconstruction of the reactor compartment and the manufacturing of the new equipment will result in a significant rise in design costs.

The key difference between the reactor types V-392B and V-466 is the so-called **core catcher – V-392B not having a core catcher**. This device would have the potential to reduce the probability of large releases in case of a severe accident. However, there is no guarantee that it will indeed fulfill its purpose because a number of problems has not been sufficiently clarified so far. While the core damage frequencies (CDF) of the reactor type V-392B and possible alternatives for the completion of KNPP 3 & 4 are listed, the **large release frequencies** (LRF) are not mentioned. However, LRFs are of importance to assess possible transboundary impacts of a severe accident.

Although the EIA stated that the reactor type V-392B was selected, the names of the reactor types V-392B and V-392 are used synonymously in the IAS – even though these are two different reactor types. The differences between reactor types V-392 and V-392B are not pointed out. In general, no explanation is given on the extent to which the planned units KNPP 3 & 4 will be identical with the design of type V-392. The reactor type V-392B is highly unlikely to reach the same safety level as the type V-392 – the synonymous use of theses reactor type names in the IAS is therefore misleading.

The choice of a design based on the WWER-1000 technology for the completion of KNPP 3 & 4 is comprehensible to some extent, given the fact that nearly all of the operating reactors in Ukraine are WWER-1000 reactors. But the fact that mainly economic aspects (using the existing buildings, structures and equipment) instead of safety aspects (apart from compliance with the requirements) account for the choice of the specific reactor type is not comprehensible. It is planned to build two units which are similar to the reactor type V-320 and belong to **Generation II** of the WWER-1000, **although advanced WWER-1000** with different reactor types and enhanced safety features **have been available for several years**; and have already been built.

Accident Analysis

A systematic analysis of **design basis accidents** (DBA) and **beyond design basis accidents** (BDBA) is not presented. Only the radiological impact of one DBA and one BDBA is discussed. The considered BDBA is a LBLOCA with the failure of the active systems of the emergency cooling of the core and operating sprinkler system. The calculated probability of the reviewed BDBA is $4.29 \cdot 10^{-7}$ per reactor year.

The description of the initiating events and of the progress of the emergency situation is missing.

Furthermore, the considered BDBA does not constitute a worst-case scenario. The **source terms** of the radiological relevant nuclides cesium-137 and iodine-131 of this BDBA are relatively small (iodine-131: 88 TBq; cesium-137: 0.45 TBq).

All in all, the information contained in the IAS and the FS EIA do not allow for a meaningful assessment of the effects of conceivable accidents at the “new” units KNPP 3 & 4 on Austrian territory.

In the context of safety, **severe accidents** are the issue of utmost interest from the Austrian point of view since such accidents can potentially lead to adverse effects on Austrian territory. However, to assess the consequences of BDBAs it is necessary to analyze 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. Such severe accidents with considerably higher releases cannot be excluded for the considered reactor type; although their probability is below a specific value. They should be included in the assessment since their effects can be widespread and long-lasting and even countries not directly bordering Ukraine, like Austria, can be affected.

The consideration of a **worst-case scenario** is of utmost importance, in particular because 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 Ukrainian NPPs shows a lot of shortcomings. SAM provisions (SAMG, dedicated hardware means and equipment qualification in severe accident conditions) have not yet been implemented for the Ukrainian NPPs. The ENSREG 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 analysis of station blackout accidents without operation of the passive safety systems has shown that the **time margin** before fuel damage is 2 – 2.5 hours in the worst-case. For spent fuel pools (SFP) of Ukrainian NPPs the time margin to fuel heat-up above the design limits established for the most unfavorable conditions, with the reactor core unloaded to SFP, constitutes about 6.5–7 hours.

Regarding SAM, comprehensive improvements were required by the regulator, and some identified measures were part of the “Comprehensive (Integrated) Safety Improvement Program” (C(I)SIP). However, the ENSREG peer review team recommended to implement further improvements.

It is not mentioned whether the units KNPP 3 & 4 are included in the envisaged safety improvement program, information about the planned SAM for the “new” units KNPP 3 & 4 are also not provided.

Radioactive Waste Management

In the IAS, the provided short description of the **management of spent fuel and radioactive waste** is formulated in very general terms. Furthermore, it is not specified which national requirements and international recommendations these managements are based on. Information on the estimated amount of spent fuel and high radioactive waste of the units KNPP 3 & 4 is also not provided. The capacities of the spent fuel pools of KNPP 3 & 4 or the intended storage time is not mentioned.

According to the IAS, **scheme and technologies of storage** and transportation of the spent fuel of units KNPP 3 & 4 will be similar to the ones used at the operating units KNPP-1,2. The IAS emphasizes that the possibility of the implementation and the sufficiency of protective measures in case of severe accidents are confirmed by the substantiation of the current accidents plans at KNPP. Contrary to that statement, the EU stress tests results revealed, that the spent fuel pools of the operating WWER-1000 reactors (e.g. KNPP-1,2) show deficiencies regarding severe accidents. Moreover, the severe accident management (SAM) to cope with these potential accidents is of very limited scope.

Thus, information about the **spent fuel pool** (in particular SAM, capacity and storage time) is of utmost interest from the Austrian point of view.

After unloading the spent fuel from the fuel pool of the reactors, storing the spent fuel (SF) is foreseen to take place in a separate **centralized storage facility** outside the KNPP site until the decision on the final stage of the SF management (processing or disposal as radioactive waste) will have been taken and implemented. It is not specified to which interim storage facility the spent fuel will be transported. The site of the construction of a centralized storage facility for spent fuel from WWER type reactors of Ukrainian NPPs currently under construction lies in the “Exclusion zone” around (Chernobyl).

The current state of the **final stage of SF management** is not specified in the IAS. It is not mentioned when the decision or other important deadlines of this project are expected to take place. It is also not clarified whether reprocessing or final disposal of the spent fuel will be preferred.

Transboundary Impacts

Regarding transboundary impacts, the conclusion was drawn that during none of the studied accidents the level of the individual annual effective dose for the individuals of the critical group in the neighboring countries will be exceeded. Quantitative results are not presented. However, no analysis of the worst-case accident scenarios was provided, thus this conclusion is not credible.

While the IAS and the FS EIA do not provide possible **consequences of a worst-case scenario**, 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) indicate that a severe accident (worst-case scenario) at KNPP would contaminate several regions in Europe in the way it took place in May 1986 after the Chernobyl accident. For the Eastern part of Austria, the calculations resulted in values of up to approx.1,000 kBq/m² for cesium-137 contamination (which is about 5 times higher than the highest values measured in Austria in 1986).

The results of the recently published FlexRISK project indicate that after a severe accident, the average cesium-137 ground depositions of most areas of the Austria territory would be higher than the threshold for agricultural intervention measures (e.g. earlier harvesting, closing of greenhouses). Therefore, Austria would be most likely affected from a severe accident at KNPP-3,4.

ZUSAMMENFASSUNG

Einleitung

Die Regierung der Ukraine bereitet die Fertigstellung der Blöcke 3 und 4 des Kernkraftwerks Khmelnitsky (KNPP-3,4) vor. Die Errichtung des KNPP 3 und 4 begann 1985/1986, doch das Ausbau – Moratorium für KKW von 1990 führte zu einem Baustopp.

Die Kommissionierung der beiden Blöcke KNPP 3 und 4 (WWER-1000/V-392B) ist für 2016 bzw. 2017 vorgesehen. Am Standort selbst sind bereits die Blöcke KNPP 1 und 2 (WWER-1000/V-320) in Betrieb.

Bezugnehmend auf die ESPOO Konvention bekundete das Bundesministerium für Land – und Forstwirtschaft, Umwelt und Wasserwirtschaft das Interesse Österreichs an der grenzüberschreitenden Umweltverträglichkeitsprüfung (UVP) teilzunehmen. Das Umweltbundesamt wurde vom das Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft beauftragt dieses Verfahrens inhaltlich und organisatorisch zu betreuen. Das Österreichische Ökologieinstitut wurde vom Umweltbundesamt beauftragt in Zusammenarbeit mit Oda Becker, Helmut Hirsch, Andriy Andrusevych und Adhipati-Yudhistira Indradiningrat die vorliegende Fachstellungnahme auszuarbeiten und die von der ukrainischen Seite zur Verfügung gestellten Unterlagen zu evaluieren.

Die ukrainische Seite übermittelte ein englischsprachiges Dokument mit dem Titel „**An Information and Analytical Survey (IAS) of the Feasibility Study (FS)“**. Bei diesem Dokument, handelt es sich um die Übersetzung des Berichts, der für die öffentliche Begutachtung in der Ukraine angefertigt worden war. Darin finden sich Informationen über die angenommenen Folgen von Errichtung, Kommissionierung, Betrieb und Dekommissionierung von KNPP 3&4. Die IAS *„bietet einen kurzen Überblick über die Kenndaten der Anlage und die Begründungen bzw. Nachweise, beschreibt die technischen Entscheidungen und die Resultate der Analysen, Auswertungen und Prognosen der 23 Bände der Machbarkeitsstudie, einschließlich des UVP-Berichtes (OVOS).“ (IAS 2011, S. 6).*

Kapitel 14 der OVOS wurde in englischer Sprache übermittelt ("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"). Der Text des OVOS (UVP-Bericht) wurde der österreichischen Seite in Orginalsprache übermittelt. Die österreichische Seite ließ eine Übersetzung der wesentlichen Teile des UVP-Berichtes für die Machbarkeitsstudie (FS) ins Deutsche anfertigen, insbesondere jene Kapitel des UVP-Berichtes, die für die Bewertung der grenzüberschreitenden Folgen erforderlich sind.

Ziel dieser Fachstellungnahme ist es, zu bestimmen, ob die IAS zusammen mit der relevanten Information des UVP-Berichtes es ermöglichen, zuverlässige Schlussfolgerungen über die möglichen Folgen grenzüberschreitender Emissionen zu treffen. Daher werden insbesondere Sicherheitsmerkmale, das Management Schwerer Unfälle (SAM) und die Unfallanalyse mit dem Schwerpunkt auf über den Luftpfad übertragene Emissionen und mögliche Auswirkungen auf Österreich betrachtet.

Genehmigung von Nuklearanlagen in der Ukraine

In der Ukraine gibt es für die einzelnen Aktivitäten im Bereich der Atomenergienutzung unterschiedliche Genehmigungsverfahren, allen gleich ist dennoch der folgende Ablauf:

1. Genehmigung für Standort, Design und Errichtung einer Nuklearanlage;
2. Entscheidung über die Kommissionierung (Betriebsbeginn) einer Nuklearanlage;
3. Betriebsgenehmigung einer Nuklearanlage;
4. Entscheidung über die Genehmigung der Dekommissionierung einer Nuklearanlage.

Die Errichtung von KNPP 3 & 4 fällt in die Kategorie "Nuklearanlagen und Anlagen für die Behandlung von Atommüll von nationaler Bedeutung". Die Errichtung des KNPP 3 & 4 befindet sich in der Phase der Vorbereitung der Genehmigung für Standort, Design und Errichtung einer Nuklearanlage (1. Stufe).

Während der Vorbereitungsphase für die Genehmigung von Standort, Design und Errichtung einer Nuklearanlage ist die Ausarbeitung einer **Machbarkeitsstudie** verpflichtend. Diese **Machbarkeitsstudie** stellt die technische und wirtschaftliche Begründung des Projekts dar.

Im Jahre 2009 beschloss die Regierung der Ukraine einen Reaktor vom Typ WWER-1000/392B für die Machbarkeitsstudie und das Projekt der Errichtung KNPP 3 & 4 (basierend auf den Ergebnissen des Tenders) zu verwenden.

Projektbeschreibung

Das Projekt ist die Fertigstellung der Blöcke 3 und 4 des KKW Khmelnitsky, nachdem die Bauarbeiten im Jahre 1990 eingestellt worden waren. Die Errichtung dieser Blöcke mit WWER-1000/392B Reaktoren begann im Jahre 1985/ 1986. Die IAS beschrieb den **Fertigstellungsgrad** der Blöcke 3 und 4 mit 35–40 % bzw. 5–10 %, während der Betreiber NNEGC "Energoatom" auf seiner Webseite einen Fertigstellungsgrad von 75 % bzw. 28 % bekannt gibt. Allerdings fehlt die Information darüber, welche der bestehenden Gebäude und Strukturen für die Fertigstellung verwendet werden sollen. Anzunehmen ist, dass die „neuen" Blöcke 3 und 4 in einem relativ hohen Umfang mit dem Design der **WWER-1000/V-320 identisch oder ähnlich** sein werden.

Es fehlen Informationen über den **Zustand der bestehenden Gebäude, Strukturen und Anlagen**. Ein Programm für das Monitoring und Management der Alterung wird nicht genannt, obwohl dies bei den über 25 Jahre alten Strukturen etc. ein Problem darstellt.

Weder die Wandstärke des Containments der Blöcke KNPP 3 & 4 oder deren **Widerstandsfähigkeit gegen externe Einwirkungen** werden genau angegeben. Darüber hinaus stellt sich die Frage, ob der physische Schutz auf Anforderungen aufgebaut ist, die tatsächlich auf dem neuesten Stand sind.

Ebenso ist es fragwürdig, ob die Anforderungen an den Brandschutz den Stand der Technik erfüllen. Allgemein gilt, dass sich die Dokumentation mit keinem der bekannten „**safety issues“ der WWER-1000/V-320** Reaktoren befasst und wie bei KNPP 3 & 4 die entsprechenden einzelnen Mängel adäquat gelöst werden sollen. Daher ist basierend auf der verfügbaren Information anzunehmen, dass das Sicherheitsniveau der Blöcke 3 und 4 nur etwas über dem der alten WWER-1000/V-320 Reaktoren liegt.

Generell fehlt eine detaillierte **Beschreibung der sicherheitsrelevanten Systeme**. Der Großteil der sicherheitsrelevanten Systeme wird nur aufgezählt und Informationen zu deren Kapazitäten, Redundanzen und zur räumlichen Trennung liegen nicht vor. Der große Vorteil des ausgewählten Reaktors vom Typ WWER-1000/V-392B ist im Vergleich zu den in Betrieb befindlichen WWER-1000/V-320 die Verwendung passiver Sicherheitssysteme. Die Funktionalität der passiven Kernflutung und des Systems zur Abfuhr der Restwärme ist nicht detailliert beschrieben. Laut der Publikation des Designers könnte die **Kapazität der neuen passiven Sicherheitssysteme** unter realen Bedingungen beschränkt sein, d. h. nicht ausreichend genug, um Unfälle beherrschen zu können.

Die Projektzielwerte für die Sicherstellung des **Strahlenschutzes** werden nur auf einer sehr allgemeinen Ebene angeführt, obwohl sie von höchster Bedeutung für die Bestimmung des Sicherheitsniveaus von KNPP 3 & 4 wären. Die **WENRA Safety Objectives** für neue Kernkraftwerke werden hierbei nicht erwähnt. Diese Sicherheitszielwerte sollten jedoch als Referenzwert zur Identifizierung von sinnvollen und durchführbaren Sicherheitsverbesserungen für Atomkraftwerke herangezogen werden, deren Fertigstellung in der Vergangenheit eingestellt wurde und nun mit moderner Technologie fortgesetzt werden soll (deferred plants).

Standortevaluierung

Im IAS-Dokument wird dargestellt, dass die Errichtung von Khmelnitzky 3 und 4 auf dem bestehenden Standort von der Regierung beschlossen wurde und daher Erzeugungsalternativen oder Standortalternativen nicht Gegenstand der Machbarkeitsstudie (FS) sind.

Der Standort wurde für ein KKW mit einer Kapazität von 4000 MW ausgewählt und entsprechend den gesetzlichen Anforderungen im Jahre 1975 genehmigt. Die Information laut IAS zeigt, dass die Evaluierung des Standorts die **aktuellen internationalen Anforderungen nicht erfüllt**, zumal die zitierten internationalen Empfehlungen veraltet sind.

Betreffend Erdbeben sind die angeführten internationalen Empfehlungen ebenfalls veraltet, da sie vor 20 Jahren veröffentlicht wurden. Laut den Ergebnissen der EU Stress Tests wurde allerdings eine Neubestimmung der seismischen Gefährdungen der ukrainischen KKW zwischen 1999 und 2010 durchgeführt, wobei die IAEO Empfehlungen berücksichtigt wurden.

Die EU Stress Tests zeigten, dass eine **seismische PSA** für alle ukrainischen NPP erst zu entwickeln ist. Einige Fragen zur seismischen Widerstandsfähigkeit des Containments und der Anlagen der derzeit betriebenen ukrainischen KKW stellten sich ebenso, vermutlich auch zu KNPP 3 & 4.

Der Standort für KNPP 3 & 4 befindet sich in einem durch Tornados gefährdetem Gebiet. Daher kann dieser Standort nur dann für neue Reaktoren verwendet werden, wenn die notwendigen technischen Vorkehrungen auch getroffen werden. Laut den EU Stress Tests ist vor allem eine Gefährdung des Kühlwassersystems (ESWS – Essential Service Water System) durch Tornados gegeben. Die IAS unterstreicht die Notwendigkeit die Kühlkapazität des Kühlwasserreservoirs zu erhöhen.

Auswahl des Reaktortyps

Der Reaktortyp für die Fertigstellung von KNPP 3 & 4 wurde vor der Erstellung der Machbarkeitsstudie ausgewählt. Die Auswahl wurde auf der Grundlage einer **vorläufigen Analyse** möglicher Alternativen getroffen.

Die Reaktoren AP-1000, APR-1400, EPR-1600 und WWER-1000 Reaktoren wurden als Alternativen für die Fertigstellung von KNPP 3 & 4 bestimmt. Die IAS unterstreicht das beim EPR deutlich verbesserte Sicherheitsniveau, vor allem bei der Verhinderung von schweren Unfällen durch das Doppelschalencontainment, welches gegen externe Auswirkungen robust sei, einschließlich der Auswirkungen eines Absturzes eines großen Verkehrsflugzeugs.

Bei den **WWER-1000** Reaktoren wird die Betriebserfahrung mit diesem Reaktortyp in der Ukraine hervorgehoben und dass die Analysen keine signifikanten Abweichungen des WWER-1000 Betriebs am Standort KNPP gegenüber den Kriterien der Vorauswahl zeigten. Daneben wird auch eine ganze Reihe an (wirtschaftlichen) Vorteilen durch die Fertigstellung von KNPP 3 & 4 aufgezählt, z. B. die Möglichkeit die fertiggestellten Teile aus der Errichtung der Blöcke 3 und 4 und der existierenden Infrastruktur und gelieferten Anlagenteile zu nutzen.

Die wesentlichen Varianten für die in Betracht gezogenen Reaktoren vom WWER-1000 Typ sind: a) der **modernisierte WWER-1000**, analog zum KKW Temelin; b) das Design V-392B und c) das Design V-466. Das **Design V-392B** (basierend auf dem V-392) wird als die Adaptierung des Konzepts des AES-92 an den Block 5 des KKW Balakovskaya beschrieben (Integration in einen neuen Konstruktionsteil des V-320). Der V-392B gehört zur Generation II der WWER-1000 Reaktoren wie auch der V-320. Betreffend das Design V-466 (Generation III der WWER-1000 Reaktoren), wurden verbesserte und zusätzliche Sicherheitssysteme im Vergleich zum Serienreaktor WWER-1000 eingeführt. Doch würde die Rekonstruktion der inneren Struktur des Reaktors und die Erzeugung von neuen Anlagenteilen zu deutlichen Erhöhungen bei den Designkosten führen.

Der entscheidende Unterschied zwischen den Reaktortypen V-392B und V-466 ist der sogenannte **core catcher – der V-392B hat keinen core catcher.** Dieser hätte das Potential die Wahrscheinlichkeit großer Freisetzungen im Falle schwerer Unfälle zu reduzieren. Allerdings besteht keine Garantie dafür, dass dieser tatsächlich seinen Zweck erfüllen wird, da eine Reihe von Problemen bisher noch nicht ausreichend geklärt werden konnte. Während die Kernschmelzhäufigkeit (CDF) des Reaktortyps V-392B und möglicher Alternativen für die Fertigstellung des KNPP 3 & 4 aufgezählt werden, findet die **Häufigkeit großer Freisetzungen** (**Large Release Frequencies** -LRF) keine Erwähnung. Die LRF sind jedoch von Bedeutung bei der Bestimmung möglicher grenzüberschreitender Auswirkungen von schweren Unfällen.

Obwohl laut UVP-Bericht der Reaktortyp V-392B ausgewählt wurde, werden die Bezeichnungen V-392B und V392 als Synonyme in der IAS verwendet – wobei es sich dabei um zwei verschiedene Reaktortypen handelt. Die Unterschiede zwischen den beiden Reaktortypen V-392B und V392 werden nicht beschrieben. Generell wird nicht erläutert, in welchem Ausmaß die geplanten Blöcke des KNPP 3 & 4 mit dem Design des V-392 übereinstimmen werden. Es ist unwahrscheinlich, dass der Reaktortyp V-392B dasselbe Sicherheitsniveau wie der V-392 erreichen kann, daher ist die synonyme Verwendung dieser Reaktorbezeichnungen in der IAS irreführend.

Die Entscheidung über das Design für die Fertigstellung von KNPP 3 & 4, welches auf der WWER-1000 Technologie basiert, ist zu einem gewissen Ausmaß nachvollziehbar, da nahezu alle in Betrieb befindlichen Reaktoren in der Ukraine WWER-1000 Reaktoren sind. Doch die Begründung, vor allem ökonomischer Natur (Verwendung der bestehenden Gebäude, Strukturen und Anlagen) anstatt von Sicherheitserwägungen (abgesehen von der Erfüllung der Anforderungen), ist für die getroffene Auswahl nicht nachvollziehbar. Geplant ist die Errichtung von zwei Blöcken, die dem Reaktortyp V-320 ähnlich sind und zur **Generation II** der WWER-1000 gehören, **obwohl fortgeschrittene WWER-1000** mit verbesserten Sicherheitsmerkmalen bereits **seit einigen Jahren verfügbar** sind bzw. bereits errichtet worden sind.

Unfallanalyse

Eine systematische Analyse der Auslegungsstörfälle (**Design Basis Accident –** DBA) und der Auslegungsstörfälle überschreitenden Störfälle (**Beyond Design Basis Accident** – BDBA) fehlt. Es werden nur die radiologischen Folgen eines DBA und eines BDBA diskutiert. Der betrachtete BDBA ist ein LBLOCA mit einem Versagen der aktiven Systeme für die Notkühlung des Kerns und das Sprinklersystem im Betrieb. Die berechnete Wahrscheinlichkeit des angenommenen BDBA liegt bei $4.29 \cdot 10^{-7}$ pro Reaktorjahr.

Eine Beschreibung der auslösenden Ereignisse und des Verlaufs der Katastrophensituation fehlt.

Darüber hinaus stellt der betrachtete BDBA kein „worst-case“ Szenario dar. Die Quellterme der für den Strahlenschutz relevanten Nuklide Cäsium-137 und Jod-131 dieses BDBA sind relativ gering (Jod-131: 88 TBq und Cäsium-137: 0,45 TBq).

Insgesamt betrachtet, ermöglichen die Informationen aus der IAS und dem UVP-Bericht keine zuverlässige Einschätzung der Auswirkungen der möglichen Unfälle der „neuen“ Blöcke des KNPP 3 & 4 auf österreichisches Staatsgebiet.

Zur Frage der Sicherheit stellen „Schwere Unfälle“ aus österreichischer Sicht die wichtigste Problematik dar, da diese Unfälle potentiell zu negativen Auswirkungen auf österreichisches Staatsgebiet führen können. Doch um die Konsequenzen von BDBAs bewerten zu können, ist es notwendig, eine Reihe von „Schweren Unfällen“ zu analysieren, so auch solcher mit frühem und mit spätem Containmentversagen in Bezug auf die Kernschmelze bzw. Schwerer Unfälle mit Containment-Bypass. Diese „Schweren Unfälle“ mit deutlich höheren Freisetzungen können bei dem in Erwägung gezogenen Reaktortyp nicht ausgeschlossen werden, obwohl die Wahrscheinlichkeit solcher Unfälle unter einem spezifischen Wert liegt. Diese Unfälle sind in die Bewertung einzubeziehen, da ihre Auswirkungen weitreichend und langfristig sein können und sogar Länder wie Österreich, die nicht direkt an die Ukraine angrenzen, betroffen sein können.

Das Einbeziehen eines Worst-case Szenarios ist von höchster Relevanz, insbesondere da die Resultate der EU Stresstests zeigten, dass das **Management Schwerer Unfälle** (Severe Accident Management – SAM), d. h. die Verhinderung Schwerer Unfälle bzw. die Einschränkung deren Folgen bei den ukrainischen KKW mit schweren Mängeln behaftet sind. Die SAM Vorkehrungen (SAMG, spezielle Hardware und Anlagenqualifizierung unter Bedingungen Schwerer Unfälle) wurden bisher in ukrainischen KKW nicht umgesetzt. Die ENSREG Peer Review unterstrich, dass die Umsetzung mit hoher Priorität zu erfolgen hat – denn hier kann es bei Schweren Unfällen zu „cliff-edge"- Effekten kommen.

Analysen zu Unfällen mit „station blackout" im Betrieb ohne passive Sicherheitssysteme zeigten, dass im „worst-case" nur **2–2,5 Stunden für Maßnahmen** zur Verfügung stehen, bis die Kernschmelze einsetzt. Für die Abklingbecken mit den abgebrannten Brennstäben beträgt bei den ukrainischen KKW die Dauer bis zur Erhitzung der Brennstäbe über die Designgrenzwerte hinaus unter den ungünstigsten Bedingungen – wenn der Reaktorkern in das Abklingbecken transferiert wurde – in etwa 6,5–7 Stunden.

Betreffend SAM wurden von der Aufsichtsbehörde umfassende Verbesserungen gefordert, einige der identifizierten Maßnahmen waren Teil des "Comprehensive (Integrated) Safety Improvement Program" (C(I)SIP)". Dennoch empfahl das ENSREG Peer Review Team die Umsetzung weiterer Verbesserungsmaßnahmen.

Unerwähnt bleibt in den Dokumenten, ob die Blöcke KNPP 3 & 4 in dem geplanten Sicherheitsprogramm enthalten sind. Informationen über die geplanten SAM für die "neuen" Blöcke KNPP 3 & 4 werden nicht zur Verfügung gestellt.

Radioaktives Abfallmanagement

Das Dokument IAS bietet in kurzer Beschreibung zur Frage der **Entsorgung von abgebrannten Brennstäben und radioaktiven Abfällen** nur sehr allgemein gehaltene Informationen. Außerdem wird nicht angeführt, auf welchen nationalen Anforderungen und internationalen Empfehlungen diese Entsorgung aufbaut. Informationen über die erwartete Menge an abgebrannten Brennstäben und hochaktivem Abfall der Blöcke KNPP 3 & 4 sind nicht angegeben. Über die Kapazitäten der Abklingbecken für abgebrannte Brennstäbe von KNPP 3 & 4 oder die geplante Dauer für die Lagerung in den Abklingbecken sind keine Informationen enthalten.

Laut IAS werden **Schema und Technologie der Lagerung** sowie des Transports der abgebrannten Brennstäbe der Blöcke KNPP 3 & 4 ähnlich wie bei den in Betrieb befindlichen Blöcken KNPP-1 & 2 ähnlich sein. In der IAS wird betont, dass die Möglichkeiten für die Implementierung von Schutzmaßnahmen bei Schweren Unfällen durch die aktuellen Unfallpläne beim KNPP untermauert sind. Im Gegensatz zu dieser Behauptung zeigten die Resultate der EU Stresstests, dass die Abklingbecken der in Betrieb befindlichen WWER-1000 Reaktoren (z. B. KNPP-1 & 2) Defizite betreffend Schwere Unfälle aufweisen. Darüber hinaus ist das Management Schwerer Unfälle (SAM) von sehr beschränktem Umfang.

Daher ist die Information über die Abklingbecken der abgebrannten Brennstäbe (insbesondere SAM, Kapazität und Lagerungsdauer) aus österreichischer Sicht von höchstem Interesse. Nachdem die abgebrannten Brennstäbe aus dem Abklingbecken beim Reaktor entnommen wurden, ist deren Lagerung in einem **eigenständigen zentralen Lagergebäude** außerhalb des KNPP-Areals vorgesehen. Eine Zwischenlagerung soll solange erfolgen bis eine Entscheidung über die letzte Phase der Entsorgung der abgebrannten Brennstäbe getroffen und umgesetzt worden ist (Wiederaufbereitung oder Entsorgung als radioaktiver Abfall). Es wurde keine Information dazu gegeben, in welches Zwischenlager die abgebrannten Brennstäbe transportiert werden. Der Standort für die Errichtung des Zentrallagers für abgebrannte Brennstäbe aus den ukrainischen WWER-Reaktoren liegt in der “exclusion zone” bei Tschernobyl.

Der aktuelle Stand der **„letzten Phase der Entsorgung“** der abgebrannten Brennstäbe ist im IAS nicht beschrieben. Es wird nicht erwähnt, ob Entscheidungen oder andere wichtige Meilensteine in diesem Projekt für die nächste Zeit erwartet werden. Auch wird nicht dargestellt, ob Wiederaufbereitung oder Endlagerung der abgebrannten Brennstäbe bevorzugt wird.

Grenzüberschreitende Auswirkungen

Betreffend grenzüberschreitender Auswirkungen kam man zum Schluss, dass bei keinem der untersuchten Unfälle das Niveau der Jahreseffektivdosis für Einzelpersonen einer kritischen Gruppe in den Nachbarländern überschritten wird. Es werden keine quantitativen Ergebnisse präsentiert. Da allerdings keine Analyse der „worst-case“ Unfallszenarien zur Verfügung gestellt wurde, ist diese Schlussfolgerung nicht glaubwürdig.

Wenn auch die Dokumente IAS und UVP-Bericht die möglichen Konsequenzen eines „worst-case“-Szenarios nicht darstellen, so zeigt allerdings eine Studie des Österreichischen Ökologieinstituts im Rahmen einer Überprüfung der UVP für die Fertigstellung von Khmelnitzky 2 & Rovno 4 (1998), dass ein schwerer Unfall (Worst-case Szenario) im KNPP einige Gebiete in Europa derart kontaminieren würde, wie es bereits im Mai 1986 in Folge des Unfalls in Tschernobyl der Fall war. Für den Osten Österreichs betrugen die errechneten Werte bis zu ca. 1000 kBq/m² für die Cäsium-137 Belastung (dabei handelt es sich um etwa das Fünffache der gemessenen Höchstwerte in Österreich 1986).

Die Ergebnisse des jüngst publizierten FlexRISK Projekts zeigen, dass nach einem schweren Unfall die durchschnittliche Cäsium-137 Bodenbelastung im Großteil des österreichischen Staatsgebiets über den Grenzwerten für die Interventionsschwelle für landwirtschaftliche Maßnahmen liegen würde (d.h. frühere Ernte, Verschluß der Gewächshäuser). Daher wäre Österreich von einem schweren Unfall in KNPP 3 & 4 mit hoher Wahrscheinlichkeit betroffen.

1 INTRODUCTION

The government of Ukraine is preparing the completion of units 3 and 4 of the Khmelnitsky nuclear power plant (KNPP-3,4). The construction of KNPP 3 & 4 started in 1985/1986, however, the 1990 moratorium on the construction of nuclear power units in Ukraine stopped the construction.

Completion of the units KNPP 3 & 4 with a capacity of 1000 MW each is one of the principal tasks of the Energy Strategy of Ukraine for the period up to 2030.

Commissioning of KNPP 3 & 4 (WWER-1000/V-392B) is scheduled for 2016 and 2017, respectively. At the KNPP site, the units KNPP-1,2 (WWER-1000/V-320) are already in operation.

With reference to the Espoo Convention, the Austrian Federal Ministry of Agriculture and Forestry, Environment and Water Management, has expressed its interest to take part in the transboundary Environmental Impact Assessment (EIA). The Environmental Agency Austria “Umweltbundesamt” was commissioned by the Austrian Federal Ministry of Agriculture and Forestry, Environment and Water Management to supervise the procedure with regards to content and organizational matters. The Austrian Institute of Ecology (Österreichisches Ökologie-Institut) in cooperation with Oda Becker, Helmut Hirsch, Andriy Andrusevych and Adhipati-Yudhistira Indradiningrat was assigned by the Umweltbundesamt to elaborate the expert statement on the document presented by Ukraine at hand.

In September 2012, the Parliament of Ukraine approved the construction of the two new 1000 MW nuclear units at the Khmelnitsky site without waiting for the results of the impact assessment required under the Espoo Convention. (EC 2013) The expert statement at hand does not aim to treat open procedural questions concerning this topic.

The Ukrainian side provided an English document which is **an Information and 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 KNPP-3,4.

The document (IAS 2011) was prepared by the SE “State Scientific and Technical Center for Emergency Response Control Systems” and was commissioned by the operator of KNPP Energoatom (100% public ownership). In the introduction of this IAS, the following is stated (IAS 2011, p. 6): “The IAS gives a short summary on the reference data and on the substantiations, describes basic technical decisions and results of the analysis, assessments and forecasts, presented in 23 volumes of the FS, including the Environmental Impact Assessment (OVOS).”

Chapter 14 of the OVOS was received 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"). The complete OVOS (EIA) itself was provided to the Austrian side in the original language. The Austrian side commissioned a German translation of relevant parts of the EIA section of the Feasibility Study (FS), especially the chapters of the EIA necessary to assess transboundary impacts.

The **principle topics of the FS** according to the IAS are as follows (IAS 2011, p. 9f):

- Necessity of the justification and the assessment of the economical expediency of KNPP extension;
- Confirmation of the compliance of the KNPP site with the requirements of the effective Normative Documents taking in account KNPP extension;
- Substantiation of the main technical decisions of the power units 3,4 and NPP in whole;
- Assessment of the impacts of KNPP on the environment during normal operations und during accidents, taking into account its extension;
- Assessment of basic technical and economical indicators of the power units 3 and 4 an of the NPP in whole;
- Preparation of the documentation for public consultations based on the elaborated FS.

The **goal of the expert statement** at hand is to assess if the IAS in combination with the relevant information in the EIA documentation allows making reliable conclusions about the potential impact of transboundary emissions. Therefore, particularly safety features, severe accident management and the accident analysis with a focus on airborne transboundary emissions and the potential impact to Austria are discussed.

2 THE NUCLEAR APPROVAL PROCEDURE IN UKRAINE

2.1 Nuclear approval procedures in Ukraine in general

Approval procedures for new nuclear installations in general have the following sequence in Ukraine:

5. approval decision to locate, design and construct a nuclear installation;
6. decision to commission (start operation of) a nuclear installation;
7. licensing the operation of a nuclear installation;
8. approval decision for the decommissioning of a nuclear installation.

The **decision to locate, design and construct a nuclear installation** is taken by the Parliament of Ukraine in the form of a Law of Ukraine. The proposal (draft law) is submitted by the Cabinet of Ministers of Ukraine. The required elements of such law are specified in detail by relevant legislation.

2.2 The nuclear approval procedure of KNPP-3,4

In Ukraine different approval procedures are applied to different nuclear activities, but they all follow the general sequence described above. Construction of KNPP 3 & 4 is an activity which falls under the category "nuclear installations and radioactive waste handling plants of national importance" (IAS 2011 uses the term "nuclear facilities and objects designed for radioactive waste management, which are of state importance").

Within the first stage of the process, the **preparation stage for the approval decision to locate, design and construct the nuclear installation**, as a minimum, the following documents/decisions have to be created:

a. Feasibility Study prepared by the licensee approved by Cabinet of Ministers;
b. conclusions of the state environmental review = expertiza (on the Feasibility Study);
c. conclusions of state nuclear safety review = expertiza (on the Feasibility Study)
d. outcomes of the consultative referendum
e. report on measures to inform neighboring states about possible impacts in a transboundary context.

In addition, the location of the nuclear installation must be approved (agreed upon) by the concerned local administrations and self-governing bodies (unless the location is within the Chernobyl zone).

As mentioned before, during the preparatory stage for the approval decision to locate, design and construct a nuclear installation the preparation of a **Feasibility Study** is obligatory. This Feasibility Study is a technical and economical justification of the project.

The Feasibility Study is the first of the **three stages of technical designing** required for such complex activities like a NPP (Feasibility Study > project > working documentation). Every next stage is more detailed and includes EIA documentation as well. During the development of a Feasibility Study (which is a set of technical documents) public consultations are required – the public has to be notified about the project, hearings have to be arranged.

2.3 Course of action

In 2008 – on the basis of tender results – the Government of Ukraine approved the use of the WWER-1000/V-392 reactor type as basis for developing the Feasibility Study and project for the construction of KNPP-3,4.

On July 4, 2012, the Cabinet of Ministers approved the Feasibility Study by its decision No.498-p[1].The reactor type approved is VVER-1000/392B.

On August 16, 2012, the draft Law of Ukraine on location, design and construction of Units 3 and 4 of Khmelnytska NPP was submitted to the Parliament of Ukraine by the Cabinet of Ministers. The Law was adopted on September 6, 2012 (Law No. 5217-VI).

By this, the decision of Ukraine to construct Khmelnytska NPP was made official, before transboundary EIA procedures were completed.

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1 http://zakon1.rada.gov.ua/laws/show/498-2012-%D1%80

3 DESCRIPTION OF THE PROJECT

3.1 Treatment in the IAS (and the FS EIA)

In chapter 1.2 of the IAS, some general information about the **previous activity** in constructing the KNPP is given: The choice of site and the name KNPP were defined by the act of the Government Commission of the Ukrainian Council of Ministers and approved by the Council of Ministers in 1975 (IAS 2011, p. 7). The technical design of the KNPP, which comprises four power units with a total capacity of 4,000 MW, was approved by the USSR Ministry of Energy in 1979 (IAS 2011, p. 68).

Construction of KNPP-1,2,3,4 was initiated in 1979, 1983, 1985 and 1986. While KNPP-1 was commissioned in 1987, construction of the units 2, 3 and 4 was terminated in 1990 due to the **moratorium** for construction of nuclear power units on the territory of Ukraine. At this time, construction readiness of the KNPP-2,3,4 was 80–85%, 35–40% and 5–10%, respectively. The moratorium was removed in 1993 and the construction of unit KNPP-2 was restarted. Commissioning of unit 2 was in 2005. **KNPP-1,2** are of the **reactor type** WWER-1000/V-320 (IAS 2011, p. 7). In 2008, the preparatory works were ongoing at the units 3 and 4 (IAS 2011, p. 7).

In chapter 6 of the IAS, the construction and **erection readiness** of the units 3 and 4 is specified with 28% and 10%, respectively. The definition of the duration of the preparation period (18 months) is taking into account the condition of the existing construction base. The initiation of the preparation period shall be defined by the moment of the law adoption on construction of KNPP-3,4. The duration of the main **construction period** of the units KNPP 3 & 4 is expected to be 54 months (4.5 years), including 42 months for unit 3. Estimated commissioning of the KNPP 3 & 4 will be in 2016 and 2017 (IAS 2011, p. 30f.)

The reactor type V-392B has been selected as reactor facility for the KNPP-3,4.

The planned **operating time** of the power units KNPP 3 & 4 according to IAS is 50 years. The units are aimed at the electric power generation in base load operation with the possibility of operation in power control mode. (IAS 2011, p. 18)

According to the EIA, the expected operation time is 45 years (FS EIA 2011, chapt. 3, para. 3.1.1) – the data provided of IAS and EIA on the topic of operation time therefore varies by five years. But the IAS also states that the specific life time and condition of implementation and specific characteristics of the operation mode will be defined at the stage “design” (IAS 2011, p. 18).

.It is foreseen to use the **existing structures** of the Reactor Compartment (RC), Reserve Diesel Power Plant (RDPP) and other objects of uncompleted construction for KNPP-3,4. The maintenance and renewal works are ongoing; its scope is defined according to the results of the inspection and assessment of the technical condition of these facilities (IAS 2011, p. 18).

Chapter 4 of the IAS provides a basic technical **description of the reactor project**. It is pointed out that for the Reactor compartment (RC) of the unit KNPP 3 & 4 technical decisions similar to the ones implemented at the operating power unit KNPP-2 are used, taking into account changes and improvements related to the new reactor facility (RF). A simplified principle scheme of the power units KNPP 3 & 4 is also presented[2] (IAS 2011, p. 19).

Chapter 4.2.6 of the IAS deals with **safety systems** of the units KNPP-3,4. Systems similar to the ones at the operating power units KNPP-1,2 (WWER-1000/V-320) are only listed; these are (IAS 2011, p. 21):

- Primary circuit protective systems from overpressure;
- Emergency gas removal system;
- Passive part of Emergency Core Cooling System (ECCS);
- High Pressure Emergency Core Cooling System (HPECCS);
- Low Pressure Emergency Core Cooling System (LPECCS);
- Secondary circuit protective systems from overpressure;
- Emergency water supply system into steam generator (SG).

The main difference between the reactor units V-320 (KNPP-1,2) and its improved variant V-392B (KNPP-3,4) consists in additional safety systems, which provides a significant increase of the safety level (FS EIA 2011, chapt. 3, para. 4).

The **additional safety systems** in comparison with systems in the reactor of the V-320 are shortly described; these are (IAS 2011, p. 22 and FS EIA 2011, chapt. 3, para. 2.2.2):

- Passive Core Reflooding Additional System (PCRAS);
- Passive Heat Removal System (PHRS) or SPOT;
- Emergency Core Cooling System (ECCS) Second Stage Accumulator System;
- Quick Boron Entry System (QBES).

PCRAS is designed for passive supply of boric acid solution into the core with the aim of long-term fuel cooling during accidents with the loss of the primary circuit coolant, which are accompanied by an ECCS active part failure. Pipelines of the PCRAS accumulators are connected to the main circulation circuit (MCC) through ECCS pipelines.

PHRS or SPOT is designed for long term residual heat removal from the core during Beyond Design Basis Accidents (BDBAs) with the loss of all sources of the alternating current power supply (station black out (SBO)). In case of leaks in the primary circuit, the systems operate together with the ECCS Second Stage Accumulators.

QBES is designed for functioning during emergency situations with the failure of the emergency protection (the need for the system is subject to clarification at the stage design).

[2] The legend is not translated.

Chapter 5 of the IAS provides a short overview about the "safety assurance". It is stated that **nuclear and radiation safety** is in line with the Ukrainian Requirement "*General provisions of nuclear power plants safety*", SNRIU 2008. Technological and organizational means to ensure nuclear safety regarding the fuel in the reactor core and in the spent fuel pool is described in general terms (IAS 2011, p. 25f). In chapter 5.3 of the IAS, it is stated that in addition to the means to ensure nuclear safety, radiation safety can be also ensured by (IAS 2011, p. 26ff):

- Use of the defence-in-depth concept;
- Low frequency of initiating events which violate normal operation;
- High reliability of the equipment, including the improved one, taking into account NPP operation experience;
- Decrease of probability of severe reactor core damage (core damage frequency – CDF) up to the level 5 x 10^{-6} per year (Ukraine Standard of 1997);
- Decrease of the probability of the acceptable accident release (large release frequency – LRF) (=discharges, by the excess whereof the measures for evacuation of the population outside the chosen area are to be taken into account) up to the level 10^{-7} per year (Ukraine Standard of 1997);
- Increase of the time reserve for the personnel in controlling the beyond design basis accidents (BDBAs);
- Protection from failures due to general cause and personnel´s error etc.

The **defence in depth concept** implemented in the design of the selected reactor facility (RF) is described very briefly and generally. Five levels are mentioned. It is stated that this defence in depth concept is based on the use of the system of sequential physical barriers between radioactive substances and ionizing radiation and the environment. The physical barriers are only listed (fuel matrix, fuel element cladding, coolant circuit bound, sealed enclosure of the reactor facility and biological protection).

In chapter 5.4 of the IAS (IAS 2011, p. 28f) it is stated that in line with the requirements of the Law of Ukraine "On Fire Safety" (No. 3745 of 17.12.1993) and other regulatory and legal acts, **fire safety** of power units KNPP 3,4 is ensured by the subsystems of the fire prevention and fire protection. It is emphasized that at the stage of the Feasibility Study only the principle solutions to ensure fire safety of the power units KNPP 3 & 4 are defined. These solutions are subject to clarification and detail at the next stages ("design", and "working documentation").

Chapter 5.6 of the IAS provides some basic information about the **physical protection** (IAS 2011, p. 30). It is pointed out that it is in line with the Ukraine law "o*n 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 KNPP-3,4, the current system of physical protection at KNPP will be extended territorially at preserving the concept of its structure and functioning.

In the reactor V-392B, in comparison to the reactor V-320, the number of regulating devices of the control and protection system increases from 61 to 121, thus the effectiveness of the system, significantly increases both in normal operation and in emergency situations (FS EIA 2011, chapt. 3, para. 2.2.4).

3.2 Discussion

It is not described which of the existing buildings or structures are intended to be used for completion of the units 3 and 4. Even the state of the existing buildings and structures is not specified accurately – the numbers are **contradictory**. In chapter 1 of the IAS, the mentioned **degree of completion** of the units 3 and 4 is 35–40% and 5–10% respectively, in chapter 6 it is 28% and 10%, respectively. The operator NNEGC "Energoatom" has stated completely different values, claiming that the construction of KNPP-3 is estimated to be 75% complete and that of KNPP-4 is 28% complete (ENERGOATOM 2012).

NNEGC Energoatom furthermore states that it "*has developed a detailed comprehensive program of preparatory activities related to the inspection of structures and renewal-corrosion prevention works. At present, based on findings of the inspection of structures, buildings and constructions, the repair-and-renewal works are underway*." (ENERGOATOM 2012) In Annex B of the IAS it is even mentioned that "a part of the equipment, delivered to the site, is in use". The meaning of this statement is not clarified. **Information about the conditions of the existing buildings, structures and equipment is missing** in the IAS. An aging monitoring and management program is also not mentioned in the IAS, despite the fact that aging of the about 25 years old structures is an issue. **Aging** is considered as a process which changes the physical characteristics attributes of a structure, system and component (SSC) in time or due to usage (WENRA 2006).

Although it is made clear in the EIA that the reactor type V-392B has been selected, the names of the reactor types V-392B and V-392 are used synonymously in the IAS – even though these are two different reactor types. The differences between reactor types V-392 and V-392B are not pointed out. Generally, it is not explained to which extent the planned units KNPP 3 & 4 will be identical with the design of type V-392. The reactor type V-392B unlikely reaches the same safety level as the type V-392 – the synonymous use of theses reactor type names in the IAS is therefore misleading.

Since it is planned to use the existing structures of the KNPP 3 & 4 already built in the 1980s, it can be expected that the units 3 and 4 will be **identical or similar to a relatively large extent to the design of the WWER-1000/V-320**.

Neither the wall thickness of the containment of the units KNPP 3 & 4 nor their **resistance against external impacts** (which depends to a considerable extent, but not exclusively, on the wall thickness of the containment building) are specified.

Both, the IAS and the FS EIA, do not provide a detailed **description of the safety relevant systems**, most of them are only listed, and information about the capacities, redundancies and spatial separation are not given. Of particular interest are the mentioned passive safety systems. However, it is not possible to gain a comprehensive picture of the functioning and reliability of those systems.

In a publication, the **passive systems for core flooding and heat removal** are explained in more detail (BUKIN 2006):

- SPOT – core decay heat removal system to prevent severe accidents resulting from station blackout (SBO),
- HA-2 – core flooding system to prevent severe accidents resulting from LOCA with active ECCS failed.

In BUKIN (2006), it is emphasized that these two BDBA sequences essentially contribute to the **core melt frequency** for existing WWER-1000/V-320. It is also pointed out that analysis of SBO and LBLOCA (Large Break Loss of Coolant Accident) sequences with and without operation of HA-2 and SPOT systems was performed. The analysis of SBO accidents without operation of the SPOT system has shown the exceeding of the maximum design limit of fuel rod damage already 2–2.5 hours after the initiating event. It is claimed, that operation of the SPOT system prevents any core damage during the BDBA under consideration.

The analysis of LBLOCA with active ECCS failed without operation of HA-2 system has shown the exceeding of the maximum design limit of fuel rod damage in a few minutes after initiation of the accident. It is claimed that operation of the HA-2 system prevents core damage above DBA acceptance criteria during this BDBA.

It is concluded: The analysis has demonstrated that the operation of the new passive safety systems (SPOT and HA-2) in the considered BDBAs ensures the effective core cooling within the required period of time.

However, in BUKIN (2006) the **constraints of the capacity** of these **safety systems** are also pointed out. It is emphasized that analysis was of realistic type, i.e.:

- Initial plant conditions correspond to normal operation at rated power without accounting for possible uncertainties in plant parameters;
- Core characteristics are assumed in accordance to design without accounting for the calculation of uncertainties and errors;
- Failures of equipment (other than assumed in scenarios) and operator errors are not taken into account.

The assumptions of the analysis show potential limitations of the passive safety systems because during an accident, additional equipment failures or operator errors cannot be excluded. Thus, the capability of these safety systems under real accident conditions could be limited.

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 KNPP-3,4. According to WENRA (2010), the units KNPP 3 & 4 are so-called deferred plants that are "*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 – formulated in a qualitative manner to drive design enhancements for new plants – should be also "*used as a reference for identifying reasonably practicable safety improvements for 'deferred plants' and existing plants in case of periodic safety reviews*" (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 (2009) 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. Safety objectives 5 to

7 deal with safety and security interfaces, radioactive waste management and safety management. In IAS (2011) and EIA, it is not mentioned that the WENRA safety objectives shall be applied for KNPP-3,4.

Regarding **physical protection** of the KNPP-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.

In the area of **fire safety**, the state of the art changed in the last decades, so it is also questionable whether the protection against fire hazards relies on requirements which are up to date.

A considerable number of **safety issues of the WWER-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 NPPs is significantly enhanced.

Nevertheless, according to recently performed safety assessments 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, covering the areas of design safety, operational safety, waste management and decommissioning, and regulatory issues. 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 programs (IAEA 2012). Under the framework of the 'design safety assessment', Ukrainian NPPs are found to be compliant with only 172 of 194 requirements of International Atomic Energy Agency (IAEA) NS-R-1 'Safety of Nuclear Power Plants: Design', published already in 2000. Issues that were found to be not fully compliant included: equipment qualification, consideration of severe accidents, NPP seismic resistance, completeness of probabilistic and deterministic safety analysis, and post-accident monitoring (USR 2012, p.4).

It would be of interest how the units KNPP 3 & 4 will overcome the various deficiencies; this is not dealt with in the IAS or the EIA.

A recently published article presented an original technical solution that could solve one of the safety problems: An analysis performed during a European Union pre-accession instrument (PHARE project) in Bulgaria at units 5&6 of the WWER-1000/V-320 Kozloduy NPP discovered a vulnerability of this design consisting in early (one-hour) containment melt-through via ionization chamber channels situated around the reactor pit. A technical solution (plugging the bottom of IC channels with high temperature-resistant materials) has been developed and examined with thermo-mechanical analyses and experiments (NEI 2012).

3.3 Conclusions

It is planned to use the existing structures of the KNPP-3,4, already built in the 1980s, thus, it can be expected that the "new" units 3 and 4 will be similar to the design of the WWER-1000/V-320. An ageing monitoring and management program is not mentioned, despite the fact that aging of the about 25 year old structures is an issue even without operational loads.

The highlights of the chosen reactor type for the completion of the KNPP 3 & 4 (WWER-1000/V-392B) compared with the operating WWER-1000/V-320 are passive safety systems. However, the functionality of the passive core flooding and heat removal system is not described in detail. According to a publication of the designer, the capability of the new passive safety systems under real accident conditions could be limited.

Project targets are only provided in a very general manner; WENRA safety objectives are not mentioned at all. Protection of fire hazards, for example, might be based on outdated requirements. Generally, it does not become evident, how the known safety issues of the WWER-1000/V-320 will be overcome. Thus, it has to be assumed that, on the basis of the available information, the safety level of the units 3 and 4 is only slightly better than the safety level of the old WWER-1000/V-320.

3.4 Questions

1. *Is it possible to provide detailed information about the project targets? Could more details be provided about means etc. to meet this project targets? What are the international requirements/recommendations these means are based on? Which initiating events (external and internal) are considered? How have the time reserves for the personnel in controlling the BDBAs been increased and what time reserves have been calculated?*
2. *Are the WENRA safety objectives considered in the selection procedure for the design of the units KNPP-3,4? Will these safety objectives be considered in the stage "design" of the KNPP-3,4? In particular, will the concept of defence-in-depth be implemented according to the WENRA safety objectives?*
3. *In which areas is the design of units KNPP 3 & 4 identical or similar to the design of units KNPP-1,2 (WWER-1000/V-320)? Does the design of units 3 and 4 differ from the design of the WWER-1000/V-392B? If so, in which areas?*
4. *Which are the improvements of the design, material etc. of the reactor pressure vessel (RPV) and steam generator (SG) of the reactor type V-392B compared with these components used at the reactor type V-320? How is an adequate physical separation of the feed water and steam lines ensured in the reactor type V-392B? 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 WWER-1000/V-392B?*
5. *Could information about the condition of the existing buildings, structures and equipment of the units 3 and 4 be provided? Which existing building, structures and equipment shall be used for the completion of KNPP-3,4?*

Does the usage of any existing buildings or structures impede the “normal” design of the reactor V-392B? (When) has an ageing management program been established?

6. *Could a description of the passive high-pressure boron injection system, the passive system for heat removal and of passive core flooding system (design, operating parameters, capabilities etc.) be provided? Are all of the passive systems designed to withstand the Maximum Design Earthquake (MDE), and are there any safety margins? How long is the required period of time of operation for these passive systems? Is their functionality ensured under severe accident conditions and adverse weather conditions?*
7. *What are the wall thicknesses (cylinder and dome) of the containment building of units KNPP-3,4? What are the parameters of the maximum aircraft crash (plane mass and speed) the containment building can withstand? Regarding external explosions, what are the maximum shockwave overpressures the containment building can withstand?*
8. *To which degree are the fire prevention and fire protections systems resistant against earthquake? Are there any improvements regarding fire protection compared to KNPP-1,2? Which international recommendations will be used for design etc. of the fire protection systems?*
9. *Which are the international requirements the physical protection is based on?*

4 SITE EVALUATION

4.1 Treatment in the IAS (and FS EIA)

The KNPP site is located on the territory of "Slavuta rayon, Khmelnytska oblast, 100 km to the north from Khmelnystky and 45 km to the south-east from Rivne" (IAS 2011, p. 43)

The site was selected and approved for a NPP with a capacity of 4,000 MW in line with the legal requirements in 1975 (IAS 2011, p. 7). It is emphasized that the construction of KNPP 3 & 4 at the existing KNPP site is based on a governmental decision[3] and therefore alternative variants of generation or locations are not subject to the study in the Feasibility Study (FS) (IAS 2011, p. 13).

In Chapter 3.2 of the IAS it is stated , that in line with standard documents and international recommendations[4] the site is considered suitable for NPP location if the possibility to ensure its safe operation in all modes is proven, taking into account factors characteristic for the site, including:

- Soils and underground water conditions;
- Natural phenomena and events;
- External events, related to human activity;
- Existing and perspective environmental and demographical characteristics of the NPP location area;
- Conditional storage and transport of fresh and Spent Nuclear Fuel (SF) as well as Radioactive Waste (RW);
- Possibility to implement protective activities in case of severe accidents (IAS 2011, p. 15).

The IAS (2011) points out, that the above mentioned factors have been studied in the FS. As a result of this analysis, in particular regarding natural hazards, the KNPP site is in **compliance with the requirements of the standard documents and international recommendation**[5]. The seismic characteristic is specified as follows: intensity 5 for the Design Basis Earthquake (DBE); intensity 6 for the Maximum Design Earthquake (MDE). (IAS 2011, p. 16)

Furthermore, it is pointed out that as site elevation is 206 m, **floods** of melt waters and rain waters on the river Horyn are of no danger (IAS 2011, p. 16).

Natural conditions limiting the NPP location include the location of the site in the **tornado** hazardous area. The factor (Kr=2.75) is unfavorable, but the location is "allowed under the implementation of engineering activities" according to IAS (2011) which means it can be used as a site for new reactors if appropriate

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[3] CoM Order "On approval of the Energy Strategy of Ukraine for the period up to 2030" N 145-p of 15.03.2006 and
CoM Order "On the primary measures in construction of KNPP-3,4" N 118 of 18.02.2009

[4] The quoted international recommendation is the IAEA document: "*Safety Guides Nuclear Power Plant Safety - Selection of sites for NPP*, No. 50-C-S; (1988).

[5] The quoted international recommendation is the IAEA document: "*Consideration of earthquakes and related phenomena when selecting the sites for nuclear power plants*", Safety Guide, No 50-SG-S1; 1994.

technical provisions are taken. In particular, during construction of KNPP-3,4, it is specified to equip the spray pond of the cooling system of the reactor buildings with protection against tornados (IAS 2011, p. 16).

According to the impacts of external factors of anthropogenic nature, including **external fire and external explosion**, the site is in compliance with the requirements and recommendations. It is claimed that fires and explosions will have no impact on the facilities significant for safety. It is also stated that shock waves caused by explosion are significantly lower than the rated values accepted in the design for the reactor building and the back-up diesel engine power plant (IAS 2011, p. 16).

According to the environmental conditions, the site is in compliance with the requirements specified in the standard documents. Based on the results of the inspection of the Reservoir-Cooler (RC), recommendations are prepared on the **improvement of the cooling capacity** of the RC in order to ensure stable operation of NPP at nominal capacity of four WWER-1000 power units, including operation under unfavorable (hot) hydro-meteorological conditions in summer time (IAS 2011, p. 16).

Regarding this topic, there is no further relevant information in the translated parts of the FS EIA (2011).

4.2 Discussion

The information provided in the IAS shows that the site evaluation is not in compliance with current international requirements because the quoted international recommendations are outdated. In the introduction of an IAEA document published in 2003, it is emphasized: "*This Safety Requirements publication supersedes the Code on the Safety of Nuclear Power Plants: Siting, which was issued in 1988 as Safety Series No. 50-C-S. It takes account of developments relating to site evaluations for nuclear installations since the Code on Siting was last revised*." (IAEA 2003)

Regarding **earthquakes**, the quoted international recommendation is also outdated as it was published nearly 20 years ago. For the evaluation of seismic hazards, for example, a new IAEA Safety Guide has been published recently (IAEA 2010).

However, according to the Peer Review Country Report of the EU stress tests (UCR 2012), a re-assessment of the seismic hazard was carried out at Ukrainian NPPs from 1999 until 2010, taking IAEA recommendations into account (UCR 2012, p. 7f). According to this report, the actual value of MCE[6] applied to KNPP is PGA=0.1g.[7]

[6] MCE (=Maximum Calculated Earthquake) corresponds to Seismic Level 2 (SL-2) in IAEA practice and Safe Shutdown Earthquake (SSE) in USA practice

[7] The Peer Review Country Report also stated that this information is not explicitly mentioned in the National Report, and it has only been confirmed during the country visit (UCR 2012, p. 8).

In the National Report of the EU stress tests it was stated that a seismic PSA for all Ukrainian NPPs still has to be developed, as a part of the "Comprehensive (Integrated) Safety Improvement Program for Ukrainian NPPs" (C(I)SIP) (UNR 2011, p. 47). Furthermore, it was mentioned that "*based on assumptions made in the stress tests, quite a large amount of WWER-1000 safety related equipment is resistant to seismic impacts of 0.1–0.2g*" (UNR 2011, p. 43). According to the National Report, calculations have been performed to assess the seismic impact to the containment integrity of V-320 in the framework of the EU stress tests (UNR 2011, p. 44).

While the IAS only mentioned possible **floods** of melt water or rain water at the site, the Country Report of the EU stress tests also mentioned a dam failure. It is stated that for the Khmelnitsky site, "*the leveling elevation of the plant site and the cooling water reservoir dam top constitute 206 m, while the maximum level of a flooding wave in case of dam failure is 203 m*" (USR 2012, p. 11). In the National Report it is concluded that "*there is no need for developing and implementing additional actions to increase the robustness of the Khmelnitsky NPP against potential external floods.*" (UNR 2011, p. 54)

The National Report provides some more information about the **tornado** hazard at the KNPP site. It is stated that "*tornado strike on the ... Khmelnitsky … NPP sites can potentially result in a failure of spray ponds of the essential service water systems (ESWS) due to its impact on the open water surface (water ejection; water funnels resulting in air plugs inside suction lines; drift of trash resulting in clogging of suction line baskets). Loss of ESWS can cause failure of emergency power supply from emergency diesel generators (EDG).*" And therefore, "*measures on tornado resistance enhancement for the Khmelnitsky … shall be developed and implemented*." (UNR 2011, p. 64f)

4.3 Conclusion

IAS/EIA do not demonstrate that the KNPP site evaluation is in compliance with current international recommendations. Regarding seismic resistance of the containment and of the equipment some questions have been raised. Improvement of the cooling capacity of Reservoir-Cooler (RC) in hot summer times is necessary. The KNPP site is located in the tornado hazardous area. Protection measures against tornadoes are required; especially the essential service water system (ESWS) is vulnerable to the impact of tornadoes.

4.4 Questions

1. *Is the site in compliance with current IAEA recommendations?*
2. *Could some more details regarding the calculation of the DBE and MCE be provided (year of calculation, exceedance probability)? Is it planned to apply a PGA value of 0.1 g for the MCE at KNPP-3,4? Can be more accurately specified which safety related equipment of WWER-1000 is qualified for seismic impacts of 0.1–0.2 g; and which equipment is not qualified for such*

seismic impacts? Have calculations of the containment integrity of the units KNPP 3 & 4 against seismic impact already been performed? If so, could the results be provided? Are the units KNPP 3 & 4 also going to be included in the seismic PSA mentioned in the National Report? If not, when will a seismic PSA be developed?

3. *Is it possible to get more information regarding the recommended improvement of the cooling capacity of the Reservoir-Cooler?*
4. *How will it be assured that the maximum water level in case of dam failure at Khmelnitsky site will not exceed 203 m? Does the KNPP 3 & 4 have the same level of robustness against potential external floods as the KNPP-1,2?*
5. *Could more information about the protection measures against tornadoes and time schedule for implementation be provided?*

5 SELECTION OF THE NPP TYPE

5.1 Treatment in the IAS (and the FS EIA)

In Annex B of the IAS ("Description of alternative types of a reactor facility for construction of KNPP 3 & 4 and substantiation of the benefits of the chosen type"), the **procedure to select the reactor facility** (RF) for the construction of KNPP 3 & 4 is described. Before the elaboration of the Feasibility Study, the reactor facility was chosen. The choice of the RF comprised two stages (IAS 2011, p. 93):

- Tentative analysis of possible alternatives;
- Selection of the RF suppliers through international tenders.

Five **potential suppliers** of reactor facilities were invited to participate in the tender (OKB "Gidropress" (Russia), SKODA JS (Czech Republic), AREVA (France/Germany), Westinghouse (USA), KEPCO (Republic of Korea)). Finally, only two companies participated in the tender OKB "Gidropress" with the design of the WWER-1000/V-392B; KEPCO with the design of the APR-1400.

It is stated that in line with the conclusion of the tender committee and of the recommendation of the Scientific and Technical Council of the Ministry of Fuel and Energy Industry Board (13.10.2008), "***the reactor facility V-392 was chosen as the RF for new power units.***" (IAS 2011, p. 93)

The results of the tentative analysis are shortly described. The analysis algorithm during the selection of the optimal power unit is presented: There are two pre-selection criteria (technology applied (K1) and unit capacity (K2)). In the next step, the compliance with safety and technical indicators was reviewed. As the result, variants for detailed analysis were chosen. The criteria for the final selection were especially focused on economic aspects.

Basic safety criteria of the power unit selection, among others, were

- Availability of the systems to prevent development of DBA into the BDBA and mitigation of the BDBA consequences/control in the power unit design (K3.3);
- Probabilities of the severe core damage and maximum permissible accident discharge, which for the newly designed power unit in the Ukraine make up 10^{-5} and 10^{-6} per reactor/year respectively (K3.4);
- The criteria of the choice of the new type of power unit lie in the fact how much its safety level is higher than the safety indicators of the operating power units (K3.5).

Experience of the international nuclear energy sector as well as experience in construction and operation of nuclear power plants in Ukraine has lead to the preference of PWR/WWER. According to the degree of compliance with the established selection criteria, the evolutionary power unit designs WWER-1000, AP-1000, APR-1400 and the EPR-1600 were determined as the alternative variants.

A summary of the selected designs including their advantages and disadvantages is presented (The description of the APR-1400 design is missing.) It is highlighted that the **EPR** has a significantly improved level of safety, especially in the mitigation of severe accidents through double containment, which is resistant to outside impacts, including a crash of a big airliner. However, general disadvantages of EPR-1600 and AP-1000 regarding the completion of KNPP 3 & 4 are listed as follows:

- Impossibility to use and the necessity to dismantle part of the existing construction of the units 3 and 4 (infrastructure and equipment);
- No experience in operation, repair and maintenance, thus commissioning before 2016 is questionable;
- Involvement of Ukrainian enterprises in construction, repair etc. will be restricted;
- Difficulties in preparation of the operational and maintenance personnel;
- Necessity of servicing of a new fuel cycle;
- Impossibility of the railway transportation of the most equipment.

Regarding the **WWER-1000**, the operation experience (more than 300 reactor years) in Ukraine is highlighted. It is stated that the analysis did not show significant discrepancies of the WWER-1000 usage at the KNPP site in line with the criteria of the pre-selection. However, the advantages of using the WWER 1000 for completion of KNPP 3 & 4 are listed as follows:

- Compliance with the requirements of the effective regulatory documents in Ukraine;
- Possibility to use the completed construction part of the power units 3 and 4 and of existing infrastructure, usage of the supplied equipment;
- Supply of the biggest part of the equipment can be ensured by Ukrainian suppliers;
- Advantages of the uniformity of power units at the KNPP site:
- Usage of the standard WWER fuel; tested procedure of fresh and spent nuclear fuel management;
- Usage of the experience in operation;
- Usage of standard repair and maintenance technologies with the involvement of Ukrainian enterprises;
- A lot of experience in construction of power units with WWER-1000;
- Availability of the system to train the operational and maintenance staff.

The main **variants** based on **WWER-1000 technology** are as follows:

- Modernized WWER-1000, analog of the NPP Temelin;
- Design V-392B (Balakovskaya NPP);
- Design Belene 87/92 (V-466).

Design V-392B is the adaption of the conceptual design AES-92 to the power unit 5 of the Balakovskaya NPP (integration into a new construction part of the V-320) with double containment. The design offers a number of improvements based on the analysis of the operating experience and IAEA recommendations for operating NPPs with VVER-1000. "*Equipment layout does not require serious changes of the buildings, infrastructure, update of the systems and equipment; a part of the equipment, delivered to the site, is in use.*" (IAS 2011, Annex B). Regarding the **design V-466,** it is pointed out that the technical peculiarities are on the one hand, that the improved and additional safety systems in comparison with the serial WWER-1000 are applied. On the other hand, the reconstruction of the reactor compartment and the manufacturing of the new equipment shall result in a significant rise in cost of the design.

According to a table (IAS 2011, Annex B, table 7) providing design characteristics of the reviewed reactor models, **V-392B belongs to Generation II of WWER-1000** reactors.

In the summary chart comparing the conformity of the power unit type with the selecting criteria, the above mentioned safety criterion K3.5 is missing. Furthermore, the RF V-392M is added in this chart which is not discussed at any other paragraph of the IAS.

It is claimed that the criteria were not ranged according to their influence on the results of the analysis.

In the **general conclusion of the tentative analysis** it is stated that according to the conformity of the aggregate of technical, economical and safety criteria, the most efficient variant for KNPP 3 & 4 conditions is to construct the power units with the RF based on the evolutionary design WWER-1000. Furthermore, it is emphasized that it is necessary **to take into account social and economical facts** of the implementation of the high-tech design by the national industry. Economical efficiency is realized

- through the possibility to use the ready-made construction part of the power units and the existing infrastructure;
- through the maximum participation of the Ukrainian side and, in this connection, development of industrial and energy complex and economy of the Ukraine.

5.2 Discussion

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. Especially the differences between these reactor types are not explained in the IAS. On the website of the designer Gidropress, the reactor type V-392B is not mentioned. The **main features of the reactor type V-392** are shortly listed (GIDROPRESS 2012):

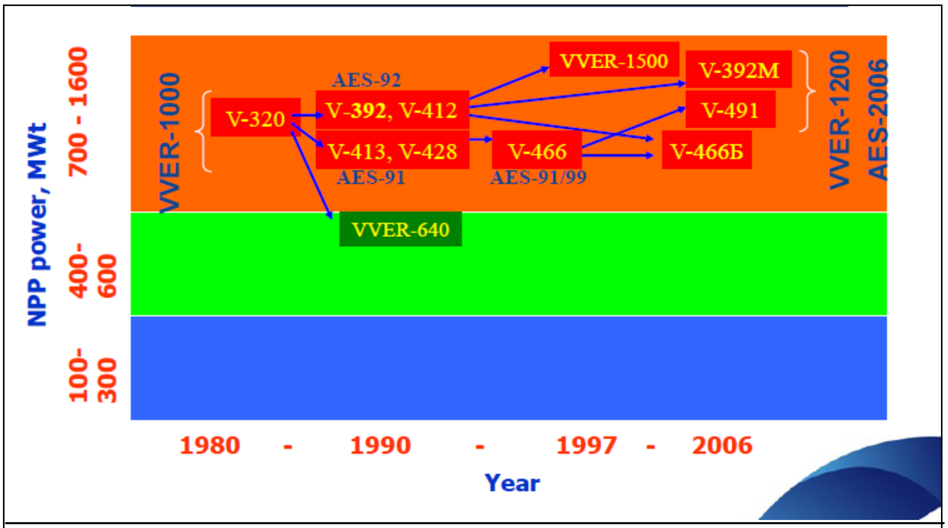
- advanced WWER-1000 reactor, including application of the advanced, more efficient and reliable core (excluding positive reactivity effects due to parameter feedbacks);
- passive heat removal system;
- additional system of core flooding;
- passive quick boron injection system modernized steam generator;
- reactor coolant pump (RCP) with advanced seals;
- I&C including a complex of diagnostic system;
- “leak before break” concept.

It is also claimed that the reactor type V-392 is designed for seismic impact under operating basis earthquake of magnitude 7 according to MSK 64 scale and under safe shutdown earthquake of magnitude 8 according to MSK 64 scale.

The choice of a design of the WWER-1000 reactor family for the completion of KNPP 3 & 4 is comprehensible to some extent, given the fact that nearly all of the operating reactors in Ukraine are WWER-1000. But the fact that **mainly**

economic aspects (using the existing buildings, structures and equipment) **instead of safety aspects** (apart from compliance with the requirements) **account for the choice of the specific reactor type** is not comprehensible. It is planned to build two units which are similar to the reactor type V-320 and belong to Generation II of the WWER-1000, although advanced WWER-1000 with different reactor types and enhanced safety features have been available for several years; and have been already built.

The following chart (figure 1) shows the **evolution of the WWER-1000** with different reactors types:



Source: GIDROPRESS (2010)

Figure 1: VVER Technology Evolution:

The main reactor design being deployed until now has been the reactor type V-320 version of the WWER-1000 pressurized water reactor. It´s basic design life time is 30-years – the design dates from the 1980s. A later version of the V-320 aimed for export is the reactor type V-392, with enhanced safety and seismic features. Advanced versions of this WWER-1000 with western instrument and control systems have been built at Tianwan (AES-91) in China and are being built at Kudankulam in India (AES-92). The AES-91 was bid for Finland in 2002. The AES-92 was bid for Sanmen and Yangjiang in China in 2005 and was accepted for Belene in Bulgaria in 2006. AES-91 and AES-92 have a 40-year design life, major components of the two designs are the same except for a slightly taller pressure vessel in AES-91, but cooling and safety systems differ. The AES-92 has greater passive safety features (WNA 2012).

The important difference between the chosen reactor type V-392B and the also considered reactor type V-466 for completion of the KNPP 3 & 4 is the so-called **core catcher**[8] **– V-392B does not have a core catcher**. If this corium localization device is functioning as planned, it would have the potential to reduce the probability of large releases in case of a severe accident. However, there is no

[8] The V-428 in the AES-91 is the first Russian reactor to have a core-catcher, V-412 in AES-92 also has core catcher (WNA 2012)

guarantee, to date, that it will indeed fulfil its purpose because a number of problems have not been sufficiently clarified so far (for example the hazard of steam explosions) (UMWELTBUNDESAMT 2009).

While the values of the core damage frequencies (CDF) of the reactor type V-392B and possible alternatives for the completion of KNPP 3 & 4 are listed, the values of the **large release frequencies (LRF) are missing**. However, LRFs are quite interesting regarding possible transboundary impacts of a severe accident.

5.3 Conclusions

The information provided by the IAS clearly indicates that the selection of the reactor type was mainly based on economic aspects instead of safety aspects. The main reason for the choice of the reactor type V-392B for the completion of KNPP 3 & 4 is the possibility to use the existing buildings, structures and equipment.

Given the fact that nearly all of the operating reactors in Ukraine are WWER-1000, the choice of a of WWER-1000 design as RF is comprehensible. It is planned to build two reactor facilities which are similar to the reactor type V-320 and belong to Generation II of the WWER-1000, although advanced WWER-1000 with different reactor types and enhanced safety features have been available for several years; and have been already built.

5.4 Questions

1. *Which of the above mentioned features of the reactor type V-392 are also implemented at the reactor type V-392B?*
2. *What are the differences between the reactor types V-392 and V-392B (particularly regarding safety systems, protection against external events as PSA results (CDF and LRF))?*
3. *Could the reasons for the choice of the reactor type (V-392B) be explained in more detail? In particular: Why was a type without "core catcher" selected?*
4. *Could more information regarding the statement be provided, which declares that the analysis did not show significant discrepancies of the WWER-1000 usage at the KNPP site in line with the criteria of the pre-selection?*
5. *Were the large release frequencies (LRF) of the different alternatives taken into account in the selection procedure? Which values were assumed for the different reactor types?*

6 ACCIDENT ANALYSIS

6.1 Treatment in the IAS (and the FS EIA)

In chapter 10 (EIA part of the IAS (IAS 2011, p. 43)) it is stated that for the **analysis of accidents** the **following accidents** were chosen:

- Maximum Design Basis Accident (MDBA) conditioned by the guillotine rupture of the main circulation pipeline with two-sided leak;
- Beyond Design Basis Accident (BDBA) conditioned by the guillotine rupture of the main circulation pipeline with the failure of the active systems of the emergency cooling of the core and operating sprinkler system.

In Annex F of the IAS, it is pointed out that in reviewing the **MDBA**, the following **conservative assumptions** are adopted:

- Instantaneous bilateral rupture of the main circulate pipelines, which leads to a leak equivalent diameter of 2x850mm (this accident is postulated as the DBA in the regulations);
- Damage of all fuel rod claddings;
- Functioning of only one (of three) line/s of the sprinkler systems.

In reviewing the **BDBA**, it is assumed additionally:

- All fuel elements of the core are melting;
- Malfunction of the active emergency core cooling systems (ECCS).

In chapter 10.4 of the IAS, it is pointed out 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 (IAS 2011, p. 53).

The **activity of release** of all nuclides and the activity of the release of all iodine isotopes into the air are given:

Release	MDBA	BDBA
Total (all nuclides)	$3*10^{13}$ Bq (30 TBq)	$3*10^{15}$ Bq (3000 TBq)
Iodine Isotopes	$3*10^{12}$ Bq (3 TBq)	$5*10^{14}$ Bq (500 TBq)

In the FS EIA (2011), the activities of about 50 radionuclides (inventory, release of MDBA and release of BDBA) are listed (FS EIA 2011, chapter 3, para. 4.6.1). The releases of the radiological relevant radionuclides iodine (I-131) and cesium-137 (Cs-137) are as follows[9]:

	MDBA [Bq]	BDBA [Bq]
I-131	$1.1*10^{12}$	$8.8*10^{13}$
Cs-137	$2.3*10^{10}$	$4.5*10^{11}$

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

The calculated probability of the reviewed BDBA is $4.29*10^{-7}$ per reactor year (IAS 2011, Annex E). According to the FS EIA (2011), the probability of this BDBA for the operating reactor KNPP-2 is considerable lower: $5.4*10^{-9}$ per reactor year (FS EIA 2011, chapt.3, para. 4.6.1)[10],

In Annex G of the IAS it is stated that during design of KNPP-3,4, a tentative Safety Analysis Report (SAR) will be elaborated which is necessary to obtain the license for construction of the nuclear facility. According to the result of the construction and erection, installation and start-up work as well as pilot production, the final SAR will be elaborated. The SAR is necessary to obtain the license for a power unit operation.

The permissible radiation doses for the population, and the emission 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) (FS EIA 2011, chapt. 3, para. 5).

As acceptance criteria of the project KNPP 3 & 4 the following values have been defined, in accordance with NRBU-97 (FS EIA 2011, chapt. 3, para. 4.6.1):

- For DBA, sheltering of children (limit value of the effective dose is 10 mSv)
- For BDBA, evacuation of population (limit value for the effective dose is 500 mSv).

6.2 Discussion

A systematic analysis of design basis accidents (DBA) and beyond design basis accidents (BDBA) is not presented. Both, the IAS and the EIA, only discuss the radiological impact of one DBA and one BDBA. It is not explained whether more accidents have been analyzed so far. To assess the consequences outside the plant it is necessary to analyze 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.

The description of the initiating events and of the progress of the emergency situation is also missing.

Furthermore, the described **BDBA** does **not constitute a worst-case scenario**. In the context of safety, severe accidents are the issue of foremost interest from the Austrian point of view since such accidents can potentially lead to adverse effects on Austrian territory.

Severe accidents with releases of a considerably higher activity than 500 TBq caused by the release of all iodine isotopes cannot be excluded for the considered reactor type; although their probability might be below a specific value. There is no convincing reason why such accidents should not be addressed in the IAS; quite to the contrary, it would appear rather evident that they should be included in the assessment since their effects can be widespread and long-

[10] The reason why the calculated probability of the reviewed BDBA is by a factor of about 100 higher for KNPP-3,4 in comparison to KNPP-2 is not explained.

lasting and even countries not directly bordering Ukraine, like Austria, can be affected (UMWELTBUNDESAMT 2008). The information contained in the IAS and the FS EIA does not permit a meaningful assessment of the effects of conceivable accidents at the "new" KNPP 3 & 4 on Austrian territory.

For all existing reactors and also for the new Generation III reactors now under construction, severe accidents with a release in the range of some percent of the radioactive cesium inventory (2–20%) cannot be excluded. Even if the frequency of occurrence of accidents with a large release appears very small according to PSA[11], such severe accident source terms should be considered in a transboundary EIA (UMWELTBUNDESAMT 2009).

According to the operator of **the KNPP, the Feasibility Study is being finalized along with the** preliminary safety analysis and environmental impact assessment (ENERGOATOM 2012), however, the preliminary safety analysis is not presented in the IAS.

In the Ukrainian National Report of the EU stress tests, the results of analyses to identify cliff edge effects of WWER-1000/V-320 reactors as well as spent fuel pools (SFP) were presented. For SFP of Ukrainian NPPs it was stated that "*the time margin to fuel heat-up above the design limits established for the most unfavorable conditions, with the reactor core unloaded to SFP, constitutes about 6.5–7 hours*." (UNR 2011, p. 74)

The analysis of station blackout (SBO) accidents without operation of the passive safety systems has shown, as mentioned above, that the **time margin before fuel damage in the worst-case is only 2–2.5 hours**.

There are several measures listed in the Country Report to increase the robustness of currently operating reactors against loss of power scenarios to prevent cliff edge effects (USR 2012, p. 21).

The National Report concludes on the need to reinforce the spent fuel pool (SFP) water makeup and cool-down through (UNR 2011, p. 76):

- Restoration of power supply to normal SPF makeup and cooling pumps;
- Water injection into the SFP from independent Mobile Diesel Generator and Pumping Unit (MDGPU) or from the fire extinguishing system;
- Possibility of SFP passive heat removal.

Severe Accident Management (SAM)

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 Ukrainian NPPs shows **a lot of shortcomings**. According to the Peer Review Country Report "*SAM provisions (SAMG, dedicated hardware means and equipment qualification in severe accident conditions) have not yet been implemented for the Ukrainian NPPs and it is an area for improvement*." (UCR 2011, p. 27) The peer review team highlighted that this im-

[11] PSA results in any case should only be taken as very rough indicators of risk. It is problematic to compare results of different studies where different methodologies might have been applied. Furthermore, all PSA results are beset with considerable uncertainties; and there are factors contributing to NPP hazards which cannot be included in PSAs (UBA 2009).

plementation must have a high level of priority due to the possibility of cliff-edge effects in the case of a severe accident.

According to the Country Report, the measures identified from the lessons of the Fukushima accident and the ENSREG stress tests review have been incorporated into the "**Comprehensive (Integrated) Safety Improvement Program" (C(I)SIP).**[12] It is intended to accelerate the following measures (UCR 2012, p. 27f):

- SAMG 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 (active core melt) 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.

Additionally, the following measures were addressed:

- Qualification of I&C and communication lines for severe accident conditions;
- Power supply to the system in full discharge batteries (to 8 hours) and subsequent connection to Mobile Diesel Generators.

It is pointed out in the Country Report that the Ukrainian regulator requested implementation of the **filtered containment venting system** for all WWER-1000 shortly after the Fukushima accident (UCR 2012, p. 28).

In the Ukraine National Report it was stated that in the framework of "C(I)SIP", Severe Accident Management Guidelines (SAMGs) are currently being developed. (UNR 2012, p. 81)

According to the Country Report there are currently on-going analyses on the vulnerability of Ukrainian NPPs in case of severe accidents, incl. analysis of the applicability of strategies for rated power and shutdown states (UCR 2012, p. 26).

In addition to the envisaged improvements**, the peer review team** submitted the following topics as recommendations for consideration by the Ukrainian regulator (UCR 2012, p. 28):

- 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 in priority (hydrogen management, control, reliability of reactor coolant system (RCS) depressurization function in severe accident condition);

[12] Implementation of necessary improvements is on-going under the recently adopted Upgrade Package (e.g. Comprehensive (Integrated) Safety Improvement Program for Ukrainian NPPs (C(I)SIP). Scheduled completion of the main improvements is 2012-2017. It is recommended by the ENSREG peer review team "*that the national regulator considers giving priority to achieving or enhancing this schedule"* (UCR 2012, p. 4).

- A strategy and program 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 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 an 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 center should be assessed.

The schedule for hardware and procedures implementations should stay under strict control of the regulator.

6.3 Conclusion

There is no systematic analysis of design basis accidents (DBA) and beyond design basis accidents (BDBA) presented. Only the radiological impact of one DBA and one BDBA is discussed. Furthermore, this BDBA does not constitute a worst-case scenario. Severe accidents with considerably higher releases (500 TBq of all iodine isotopes) cannot be excluded for the considered reactor type – although their probability is below a specific value. All in all, the information does not permit a meaningful assessment of the effects of conceivable accidents at the “new” KNPP 3 & 4 on Austrian territory. This is of utmost importance because 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 Ukrainian NPPs shows a lot of shortcomings. SAM provisions (SAMG, dedicated hardware means and equipment qualification in severe accident conditions) have not yet been implemented for the Ukrainian NPPs. Comprehensive improvements are required by the regulator, further improvements are recommended by the ENSREG peer review team.

6.4 Questions

1. *Which is the reference for the release in case of the DBA and the BDBA presented in the IAS? Have BDBAs beyond that are presented in the IAS been considered? If not, are such considerations planned for a later stage?*
2. *Which DBA and BDBA scenarios have been analyzed by the designers of the WWER-1000/V-320B?*
3. *Is it possible to present the results of the preliminary safety analysis of the KNPP-3,4?*
4. *Have analysis to identify cliff edge effects of the WWER-1000/V-392B been performed?*
5. *Have the results of the EU stress tests implications on the project KNPP 3 & 4 (e.g. regarding time schedule, scope of the safety analysis, strengthening or addition of safety features)?*
6. *Are the measures listed in the County Report of the EU stress tests to increase the robustness of operating reactors against loss of power scenarios to prevent cliff edge effects also to be considered at KNPP-3,4?*
7. *Is it expected that the spent fuel pool (SFP) of WWER-1000/V-392B will have the same cliff edge effects (time margin) as the SFPs of operating Ukrainian reactors WWER-1000/V-320? Are the reinforcements planned for the operating Ukrainian reactors also needed/planned for the SFP of WWER-1000/V-392B?*
8. *Are the units KNPP 3 & 4 generally included in the "Comprehensive (Integrated) Safety Improvement Program for Ukrainian NPPs (C(I)SIP)"? Which measures of the "C(I)SIP" regarding severe accident management have to be carried out for WWER-1000/V-392B?*
9. *When are SAMGs for the units KNPP 3 & 4 expected to be developed? Is their development integrated in "C(I)SIP" for Ukrainian NPPs? Which significance does the currently on-going development and implementation of SAMGs have for the licensing process of the units KNPP-3,4?*
10. *Are the units KNPP 3 & 4 also taken into account in the analyses mentioned in the Country Report on the vulnerability of Ukrainian NPPs in case of severe accidents?*
11. *Is it planned to install a filtered containment venting system at the units KNPP-3,4? (Which requirements do the filtered venting systems have to fulfill, particularly regarding earthquake resistance?)*
12. *Are all of the recommendations of the ENSREG peer review team regarding SAM considered for the units KNPP-3,4?*
13. *What is the time schedule for implementation of all required SAM by the Ukrainian regulator and by the peer review team? In particular, will the implementation be finished before commissioning of the units KNPP-3,4?*
14. *What is the reason the calculated probability of the reviewed BDBA is by a factor of about 100 higher for KNPP 3 & 4 in comparison to KNPP-2?*

7 TRANSBOUNDARY IMPACTS

7.1 Treatment in the IAS (and the FS EIA)

Chapter 10.11 of the IAS provides results of an "impact assessment on the environment in the transboundary context". It is emphasized that the general risk of occurrence of stochastic effects during MDBA and BDBA, even without countermeasures, is already significantly lower on the border of the KNPP site is than the established limit of the individual risk of 5 x 10^{-5} per year. Thus, for the population of the neighboring countries, the risk of occurrence of stochastic effects is significantly lower than the acceptable limit of the individual risk (IAS 2011, p. 67).

Annex C of the IAS provides some information about the used methods, assumptions etc. used to calculate the transboundary impact. Taking into account that KNPP is located at a distance of 160 km from the border with Belorussia and of 190 km from the border with Poland, a mesogrid model is used to simulate the **transboundary transfer**. 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 reconstruction of the radioactive contamination with radionuclides cesium-137 and iodine-131 of the territory of Ukraine in the initial period after the Chernobyl accident (IAS 2011, Annex C).

Three typical **meteorological situations** were chosen for the simulation "*where there may be an intensive transboundary carry-over of the activity in the direction of Poland and Belorussia*." For that purpose real atmospheric data of three different time periods[13] were used. These data were 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 Belorussia (IAS 2011, Annex C).

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). As reference group for the population, rural residents which consume mainly food of their own production were chosen. 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 program 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 (IAS 2011, Annex C).

In Annex E of the IAS "Description of the potential impact", the quantitative results of the calculations, described in Annex C, are not provided. However, it is highlighted that findings of the assessment of the **transboundary impact** indicate that during none of the studied accidents the level of the individual annual effective dose for the individuals of the critical group in the neighboring countries will be exceeded (see also FS EIA 2011, chapt. 17, para. 2.10.3). Furthermore, some general qualitative results are presented (children are the critical group, main contribution to the radiation dose comes from ingestion, and main dose-forming radionuclide is iodine-131) (IAS 2011, Annex E, see also (FS EIA 2011, chapt. 17, para. 2.10.3).

[13] 10-12 February, 1984; 26-27 November, 1982 and 6–9 May, 1986

In Annex F of the IAS, it is pointed out, that in reviewing the BDBA the following conservative assumption is adopted: Since the height of the emission at a given accident is not uniquely defined, the emission occurs with zero height and shielding at the nearby buildings are not taken in account (IAS 2011, Annex F).

7.2 Discussion

Only qualitative results of the transboundary impact assessment are presented, **quantitative results are completely missing**.

The described **approach** to calculate the transboundary impacts is partly comprehensible**.** The reasons of the used meteorological situations are not explained in detail, thus it is not possible to assess whether worst-case meteorological conditions were applied. The general assumptions regarding the perceptions are conservative, but the used perception intensity is very low (i.e. it is not conservative, because higher perception 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 so in higher ground contamination in larger distances.

However, in particular the conclusion regarding possible transboundary impacts is not comprehensible because of the considered BDBA which does not constitute a worst-case accident scenario at the units KNPP 3 & 4 (see chapter “accident analysis”).

Because of the lack of such analysis, the conclusion that findings of the assessment of the transboundary impact indicate that during none of the studied accidents the level of the individual annual effective dose for the individuals of the critical group in the neighboring countries will be exceeded is not credible.

As both, the IAS and the FS EIA, do **not provide possible consequences of a “worst-case” scenario**, 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 (ÖÖI 1998). In order to assess the consequences of a severe accident at Khmelnitsky 2 (KNPP-2), results of source term calculations from Kozloduy NPP in Bulgaria (both WWER-1000/V-320) were used.

It was not intended to predict the exposition for the population in the affected areas; therefore only **cesium-137** was considered. The releases for cesium-137 that are related to severe accidents are estimated between 4% and 50% of the total inventory (core melt down 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%).

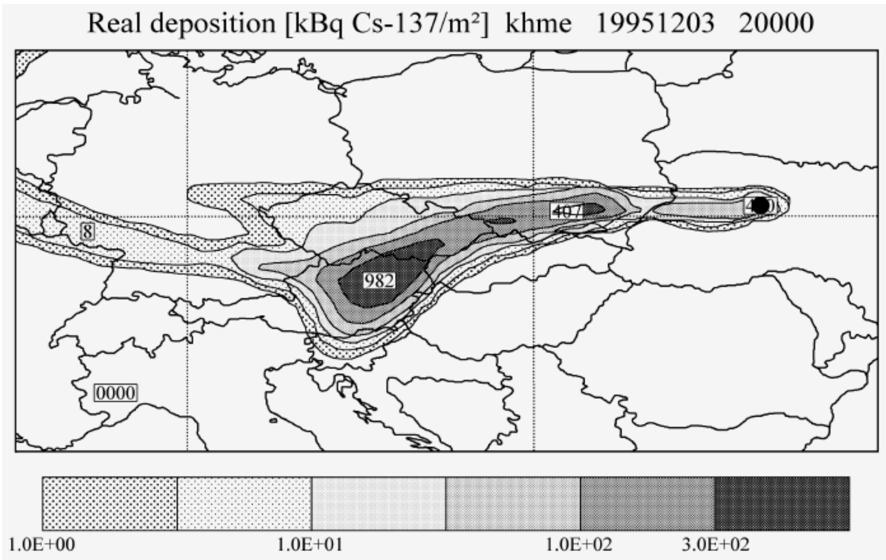
To investigate the possible impact following a severe accident at Khmelnitsky-2 (KNPP-2), a release of 20% of the total core inventory of cesium-137 was assumed (5.5×10^{16} Bq). To account for plume rise due to associated release of energy (heat), the source was assumed to be equally distributed between 76 m (roof height) and 200 m. Furthermore, a release of the 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 the doses in Austria comes from the deposition (groundshine and ingestion), only deposition was evaluated.

The **meteorological input** to the model was taken from model output of the European Center for Medium Range Weather Forecasting (ECMWF). A meteorological situation was selected that did occur in reality. Releases were simulated twice a day for the whole year 1995. It turned out that an accident on December 3 would have 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 of time (3 and 4 December 1995) was characterized by a strong and stable high pressure system over Scandinavia and a low pressure system over the Mediterranean. Figure 2 shows the resulting deposition pattern. The track of the contaminated air is clearly visible. In addition to the main maximum in Austria, there are secondary maxima in southern Poland and close to the NPP[14].



Source: Ööı (1998) umweltbundesamt

Figure 2: Deposition of cesium-137 from a hypothetical BDBA in KNPP-2.

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

[14] 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 **probability of a severe accident** with a large release (core damage frequency (CDF) and large release frequency (LRF)) is probably lower at KNPP 3 & 4 compared to KNPP-2, however such severe accidents could occur. Reactor core inventory and other reactor characteristics of the reactor types of KNPP-2 and KNPP 3 & 4 that determinate the emissions of such an accident are comparable. Thus, the presented results of an accident at KNPP-2 illustrate the consequences of a potential severe accident at KNPP-3 or KNPP-4.

Additionally, calculations of the recently published **flexRISK project** can be used for the estimation of possible impacts of transboundary emission of KNPP 3 & 4 (FLEXRISK 2013). The flexRISK project modeled 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.[15]

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 cesium-137 deposition per square-meter (Cs-137 Bq/m²) is used as the contamination indicator.

Figure 3 (page 50) illustrates the average deposition of cesium-137 after a severe accident at KNPP-3.

An accident could result in a considerable contamination of the Austrian territory; the average deposition of Cs-137 in the simulation being between 500–5000 Bq/m². Most parts of Austria show depositions of 800 Bq/m² or more.

If the contamination of ground beyond a certain threshold can be expected, a set of agricultural intervention measures is triggered (FLEXRISK 2013). The measures include earlier harvesting, closing of greenhouses and covering of plants, putting livestock in stables etc. Austrian and German authorities defined a threshold for cesium-137 ground deposition of 650 Bq/m² (SKKM 2010; SSK 2008). As within the simulation the average ground depositions of most areas are higher than this threshold, Austria would be most likely affected from a severe accident at KNPP-3,4.

[15] For each reactor, an accident scenario with a large release of nuclear material was selected. To determine the possible radioactive release for the chosen accident scenarios, the specific known characteristics of each NPP were taken into consideration. The accident scenarios for the dispersion calculation are core melt accidents and containment bypass or containment failure; the release rates are in the range of 20% to 65% of the core inventory of cesium.

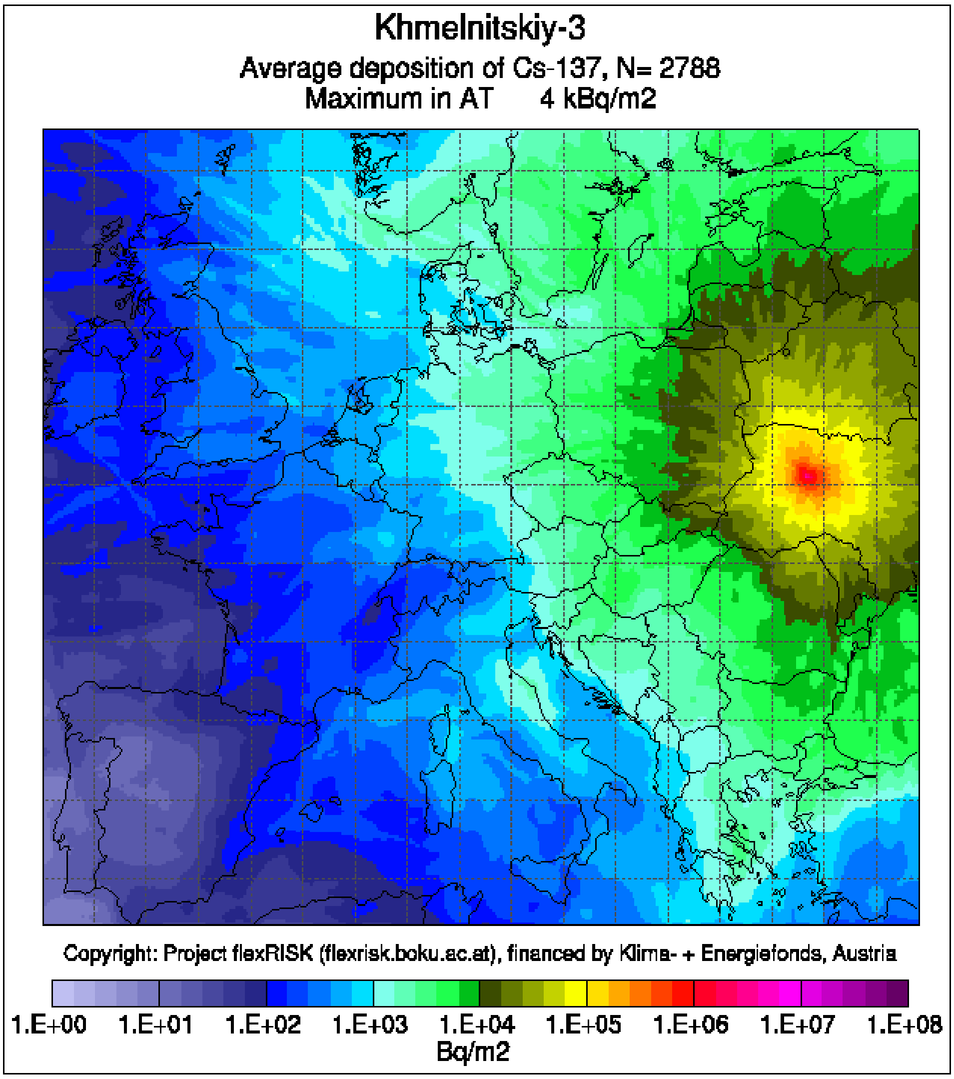


Figure 3 Average deposition of Cs-137 after a hypothetical BDBA in KNPP-3

7.3 Conclusions

Because of the lack of analysis of the worst-case scenarios, the conclusion of the IAS and FS EIA that during none of the studied accidents the level of the individual annual effective dose for the individuals of the critical group in the neighboring countries will be exceeded, is not credible.

The results of the calculations of the Austrian Institute of Ecology (1998) indicate that a severe accident (worst-case scenario) at KNPP would contaminate several regions in Europe, as it happened in May 1986 after the Chernobyl accident. The contamination maxima could be even higher as in 1986. For the Eastern part of Austria, the calculation resulted in values up to approx. 1,000 kBq/m² of cesium-137 contamination (which is about 5 times the highest values measured in Austria in 1986).

The results of the recently published FlexRISK project indicate that after a severe accident, the average cesium-137 ground depositions of most areas of the Austria territory would higher than the threshold for agricultural intervention measures (e.g. earlier harvesting, closing of greenhouses). Therefore, Austria would be most likely affected from a severe accident at KNPP-3,4.

7.4 Questions

1. *Could the quantitative results of the calculated transboundary impacts be provided?*
2. *Could the reasons for the choice of the meteorological situations be explained? Have analysis been performed with different meteorological assumptions? Could the choice of the emission height be explained? Have simulations with other emissions heights been performed?*

8 RADIOACTIVE WASTE MANAGEMENT

8.1 Treatment in the IAS (and the FS EIA)

Chapter 8 of the IAS deals with the **radioactive waste management** (RWM) of the units KNPP-3,4. Amounts of the spent fuel formation of KNPP 3 & 4 will be determined by the type of the used fuel and by the schedule of the core unloading (IAS 2011, p. 39). The fuel type will be specified at the stage “design” (IAS 2011, p. 36).

It was stated in the IAS that **spent fuel** (SF), after unloading of the reactor core, will be placed in a cooling pool in order to decrease its activity and heat release up to a level acceptable for transportation and technological storage of the SF outside the power units. It is emphasized that such storage is foreseen in a separate centralized WWER spent fuel storage (outside the KNPP site) until the decision on the final stage of the SF management (reprocessing or disposal as radioactive waste) has been taken and implemented (IAS 2011, p. 39).

The spent fuel is stored for at least three years in the cooling pools of KNPP 3 & 4 (FS EIA 2011, chapt. 3, para. 2.2.11).

In chapter 3 of the IAS, the compliance with the requirements of the legislation and international **requirements** is discussed. It is stated that scheme and technologies of storage and transportation of fresh and spent fuel of units KNPP-3, 4 will be similar to the ones used at the operating units KNPP-1,2. It is emphasized that the possibility of the implementation and the sufficiency of protective measures in case of severe accidents are confirmed by the substantiation of the current accidents plans at KNPP (IAS 2011, p. 17).

In chapter 5 of the IAS, technological and organizational means in order to ensure the nuclear safety of the SF during storage in the cooling pools are described in general terms (IAS 2011, p. 25f).

The liquid and solid radioactive waste management systems are located in the existing special building common for KNPP-1,2,3,4 (IAS 2011, p. 39). The subsystems of the liquid waste system as well as their capacity are listed. It is stated that a reconstruction and modernization of the liquid radioactive waste (LRW) collection and storage system is not foreseen (IAS 2011, p. 39). The existing solid radioactive waste management system (including buildings, used container and procedures) is described (IAS 2011, p. 40).

8.2 Discussion

In general, the description of the spent fuel management (SFM) and radioactive waste management (RWM) is very short. The condition of the existing special building is not explained. It is stated, without giving a reason, that reconstruction and modernization of the LRW system is not foreseen. Radioactivity levels for the classification of liquid and solid radioactive wastes (high, medium, low level waste) are not given. The radioactive waste handling system is described without details. Information on the estimated **amount of spent fuel and high radi-**

oactive waste of the units KNPP 3 & 4 is not provided. Furthermore, it is not said which national requirements and **international recommendations** the SFM and RWM are based on.

It is not specified to which **interim storage facility** the spent fuel will be transported. Currently, a centralized interim storage facility is planned. On February 9th, 2012 the Law "*On Spent Nuclear Fuel Management with regard to siting, designing and construction of the centralized Storage Facility for Spent Nuclear Fuel from WWR type reactors of Ukrainian Nuclear Power Plants*" was approved. The Centralized Storage Facility will be constructed in the "Exclusion zone" (Chernobyl) and will be designed for the storage of 16,529 spent fuel assemblies. The dry surface storage technology will be used (CHNPP 2012).

Contrary to the statement of the IAS, that the possibility of the implementation and the sufficiency of protective measures in case of severe accidents are confirmed by the substantiation of the current accidents plans at KNPP (paragraph 3.2.6), the EU stress tests revealed, as mentioned above, that the spent fuel pools of the operating WWER-1000 reactors show deficiencies regarding severe accidents, moreover that the severe accident management to cope with these accidents is very limited (see chapter "Accident analysis"). Thus, information about the spent fuel pool is of utmost interest from the Austrian point of view. The IAS does not provide any information about the duration of storage in the spent fuel pools of KNPP 3 & 4 or their capacities.

The current state of the **final stage of SF management** is not mentioned in the IAS. It is not specified when the decision of this project or other important deadlines of the project are expected to take place. It is also not clarified whether processing or final disposal of the spent fuel will be preferred. Geological final disposal is considered to be the safest long-term method of storing high level radioactive waste and spent fuel at present, however, no country worldwide is operating such a geological repository yet.

8.3 Conclusions

The EU stress tests revealed that the spent fuel pools of the operating WWER-1000 reactors show deficiencies regarding severe accidents. Moreover, the severe accident management to cope with these potential accidents is very limited. Thus, information (particular regarding capacities) of the spent fuel pool is of utmost interest from the Austrian point of view. But both, the IAS and the FS EIA, do not provide any information about the capacities of the spent fuel pools of KNPP-3,4.

8.4 Questions

1. *Could information about the expected amount of spent fuel in the spent fuel pools of the reactors be provided? Does the statement in paragraph 3.2.6 of the IAS have to be changed because of the stress tests results? Which improvements of spent fuel pools are to be performed?*
2. *Is it intended to store the spent fuel of KNPP 3 & 4 in the Centralized Storage Facility constructed in the "Exclusion zone" (Chernobyl)?*
3. *Is there a time schedule for the decision of the final stage of spent fuel management? Is there any preference yet? Is there a procedure for the discussion and approval of a strategy for the final stage of spent fuel management?*
4. *What radioactivity levels are used for the classification of radioactive wastes (high level, medium level, low level waste)? Which amount of high level radioactive waste is expected to be produced at KNPP 3 & 4 after commissioning?*

9 QUESTIONS

9.1 Description of the Project

1. *Is it possible to provide detailed information about the project targets? Could more details be provided about means etc. to meet this project targets? What are the international requirements/recommendations these means are based on? Which initiating events (external and internal) are considered? How have the time reserves for the personnel in controlling the BDBAs been increased and what time reserves have been calculated?*
2. *Are the WENRA safety objectives considered in the selection procedure for the design of the units KNPP-3,4? Will these safety objectives be considered in the stage “design” of the KNPP-3,4? In particular, will the concept of defence-in-depth be implemented according to the WENRA safety objectives?*
3. *In which areas is the design of units KNPP 3 & 4 identical or similar to the design of units KNPP-1,2 (WWER-1000/V-320)? Does the design of units 3 and 4 differ from the design of the WWER-1000/V-392B? If so, in which areas?*
4. *Which are the improvements of the design, material etc. of the reactor pressure vessel (RPV) and steam generator (SG) of the reactor type V-392B compared with these components used at the reactor type V-320? How is an adequate physical separation of the feed water and steam lines ensured in the reactor type V-392B? 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 WWER-1000/V-392B?*
5. *Could information about the condition of the existing buildings, structures and equipment of the units 3 and 4 be provided? Which existing building, structures and equipment shall be used for the completion of KNPP-3,4? Does the usage of any existing buildings or structures impede the “normal” design of the reactor V-392B? (When) has an ageing management program been established?*
6. *Could a description of the passive high-pressure boron injection system, the passive system for heat removal and of passive core flooding system (design, operating parameters, capabilities etc.) be provided? Are all of the passive systems designed to withstand the Maximum Design Earthquake (MDE), and are there any safety margins? How long is the required period of time of operation for these passive systems? Is their functionality ensured under severe accident conditions and adverse weather conditions?*
7. *What are the wall thicknesses (cylinder and dome) of the containment building of units KNPP-3,4? What are the parameters of the maximum aircraft crash (plane mass and speed) the containment building can withstand? Regarding external explosions, what are the maximum shockwave overpressures the containment building can withstand?*
8. *To which degree are the fire prevention and fire protections systems resistant against earthquake? Are there any improvements regarding fire protection compared to KNPP-1,2? Which international recommendations will be used for design etc. of the fire protection systems?*
9. *Which are the international requirements the physical protection is based on?*

9.2 Site Evaluation

1. *Is the site in compliance with current IAEA recommendations?*
2. *Could some more details regarding the calculation of the DBE and MCE be provided (year of calculation, exceedance probability)? Is it planned to apply a PGA value of 0.1 g for the MCE at KNPP-3,4? Can be more accurately specified which safety related equipment of WWER-1000 is qualified for seismic impacts of 0.1–0.2 g; and which equipment is not qualified for such seismic impacts? Have calculations of the containment integrity of the units KNPP 3 & 4 against seismic impact already been performed? If so, could the results be provided? Are the units KNPP 3 & 4 also going to be included in the seismic PSA mentioned in the National Report? If not, when will a seismic PSA be developed?*
3. *Is it possible to get more information regarding the recommended improvement of the cooling capacity of the Reservoir-Cooler?*
4. *How will it be assured that the maximum water level in case of dam failure at Khmelnitsky site will not exceed 203 m? Does the KNPP 3 & 4 have the same level of robustness against potential external floods as the KNPP-1,2?*
5. *Could more information about the protection measures against tornadoes and time schedule for implementation be provided?*

9.3 Selection of the NPP Type

1 *Which of the above mentioned features of the reactor type V-392 are also implemented at the reactor type V-392B?*

2 *What are the differences between the reactor types V-392 and V-392B (particularly regarding safety systems, protection against external events as PSA results (CDF and LRF))?*

3 *Could the reasons for the choice of the reactor type (V-392B) be explained in more detail? In particular: Why was a type without “core catcher” selected?*

4 *Could more information regarding the statement be provided, which declares that the analysis did not show significant discrepancies of the WWER-1000 usage at the KNPP site in line with the criteria of the pre-selection?*

5 *Were the large release frequencies (LRF) of the different alternatives taken into account in the selection procedure? Which values were assumed for the different reactor types?*

9.4 Accident Analysis

1 *Which is the reference for the release in case of the DBA and the BDBA presented in the IAS? Have BDBAs beyond that are presented in the IAS been considered? If not, are such considerations planned for a later stage?*

2 *Which DBA and BDBA scenarios have been analyzed by the designers of the WWER-1000/V-320B?*

3 *Is it possible to present the results of the preliminary safety analysis of the KNPP-3,4?*

4 *Have analysis to identify cliff edge effects of the WWER-1000/V-392B been performed?*

5 *Have the results of the EU stress tests implications on the project KNPP 3 & 4 (e.g. regarding time schedule, scope of the safety analysis, strengthening or addition of safety features)?*

6 *Are the measures listed in the County Report of the EU stress tests to increase the robustness of operating reactors against loss of power scenarios to prevent cliff edge effects also to be considered at KNPP-3,4?*

7 *Is it expected that the spent fuel pool (SFP) of WWER-1000/V-392B will have the same cliff edge effects (time margin) as the SFPs of operating Ukrainian reactors WWER-1000/V-320? Are the reinforcements planned for the operating Ukrainian reactors also needed/planned for the SFP of WWER-1000/V-392B?*

8 *Are the units KNPP 3 & 4 generally included in the "Comprehensive (Integrated) Safety Improvement Program for Ukrainian NPPs (C(I)SIP)"? Which measures of the "C(I)SIP" regarding severe accident management have to be carried out for WWER-1000/V-392B?*

9 *When are SAMGs for the units KNPP 3 & 4 expected to be developed? Is their development integrated in "C(I)SIP" for Ukrainian NPPs? Which significance does the currently on-going development and implementation of SAMGs have for the licensing process of the units KNPP-3,4?*

10 *Are the units KNPP 3 & 4 also taken into account in the analyses mentioned in the Country Report on the vulnerability of Ukrainian NPPs in case of severe accidents?*

11 *Is it planned to install a filtered containment venting system at the units KNPP-3,4? (Which requirements do the filtered venting systems have to fulfill, particularly regarding earthquake resistance?)*

12 *Are all of the recommendations of the ENSREG peer review team regarding SAM considered for the units KNPP-3,4?*

13 *What is the time schedule for implementation of all required SAM by the Ukrainian regulator and by the peer review team? In particular, will the implementation be finished before commissioning of the units KNPP-3,4?*

14 *What is the reason the calculated probability of the reviewed BDBA is by a factor of about 100 higher for KNPP 3 & 4 in comparison to KNPP-2?*

9.5 Transboundary Impacts

1 *Could the quantitative results of the calculated transboundary impacts be provided?*

2 *Could the reasons for the choice of the meteorological situations be explained? Have analysis been performed with different meteorological assumptions? Could the choice of the emission height be explained? Have simulations with other emissions heights been performed?*

9.6 Radioactive Waste Management

1 *Could information about the expected amount of spent fuel in the spent fuel pools of the reactors be provided? Does the statement in paragraph 3.2.6 of the IAS have to be changed because of the stress tests results? Which improvements of spent fuel pools are to be performed?*

2 *Is it intended to store the spent fuel of KNPP 3 & 4 in the Centralized Storage Facility constructed in the "Exclusion zone" (Chernobyl)?*

3 *Is there a time schedule for the decision of the final stage of spent fuel management? Is there any preference yet? Is there a procedure for the discussion and approval of a strategy for the final stage of spent fuel management?*

4 *What radioactivity levels are used for the classification of radioactive wastes (high level, medium level, low level waste)? Which amount of high level radioactive waste is expected to be produced at KNPP 3 & 4 after commissioning?*

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11 GLOSSARY

AES ....English: NPP (nuclear power plant)

APR ....Advanced Pressurized Reactor

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

CDF ....Core Damage Frequency

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

DBA ....Design Basic Accident

DBE ....Design Base Earthquake

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

ECCS ....Emergency Core Cooling System

EDG....................Emergency Diesel Generator

EIA......................Environmental Impact Assessment

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

EPR ....European Pressurized Reactor

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

EU ....European Union

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

g ....Acceleration of free fall

HPECCS ....High Pressure Emergency Core Cooling System

IAEA ....International Atomic Energy Agency

IAS......................Information and Analytical Survey

I&C ....Instrumentation and Control

KNPP..................Khmelnitsky nuclear power plant

LBLOCA ....Large Break Loss of Coolant Accident

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

LOCA..................Loss of Coolant Accident

LPECCS ....Low Pressure Emergency Core Cooling System

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

LRW ....Liquid Radioactive Waste

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

MCC ....Main Circulation Circuit

MCE ....Maximum Calculated Earthquake

MCR ....Main Control Room

MDE ....Maximum Design Earthquake

MDBA.................Maximum Design Basis Accident

MDGPU.............. Mobile Diesel Generator and Pumping Unit

PCRAS............... Passive Core Reflooding Additional System

PGA .... Peak Ground Acceleration

PHRS .... Passive Heat Removal System

PSA.................... Probabilistic Safety Assessment

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

QBES .... Quick Boron Entry System

RC...................... Reactor Compartment

RC...................... Reservoir Cooler

RCP .... Reactor Coolant Pump

RSC .... Reactor Coolant System

RDPP .... Reserve Diesel Power Plant

RF .... Reactor Facility

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

RPV.................... Reactor Pressure Vessel

RW .... Radioactive Waste

RWM.................. Radioactive Waste Management

SAM .... Severe Accident Management

SAMG .... Severe Accident Management Guideline

SAR.................... Safety Analysis Report

SBO .... Station Black Out

SF .... Spent Fuel

SFP .... Spent Fuel Pool

SFM .... Spent Fuel Management

SG...................... Steam Generator

SSC.................... Systems and Components

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

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

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