Critical Review of the "Ukraine NPP Safety Upgrade Program"

Why the European Bank for Reconstruction and Development and EURATOM should not finance the lifetime extension program of Ukrainian nuclear power plants

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1. EXECUTIVE SUMMARY

Our report examines the "Ukraine NPP Safety Upgrade Program" (SUP) and the 2011 ecological assessment (EA) of Energoatom, within the framework of the loan applications to the EBRD and EURATOM. The EBRD is currently preparing a EUR 300 million loan with the final decision to be made in September 2012, and EURATOM prepares granting its EUR 500 million loan in May 2012.

Proponent of the SUP, the Ukrainian state nuclear operator NEC Energoatom claims that SUP measures will address only safety measures and are not a precondition for the lifetime extension of reactors. However our report shows this claim is misleading: SUP measures will be used to provide a sufficient safety level to extend operations and are not necessary for safely shutting down the reactors.

While the EA for the SUP claims that the planned safety upgrade measures are not part of extending reactor lifetime beyond their designed 30-year lifetime, this study shows that the safety measures for 15 reactors are in fact connected to the lifetime extension program. SUP measures like those related to component integrity are conditions for extending the lifetime of reactors. The reasons for this are as follows:

- Measures to address only safety issues and not lifetime extension simply do not exist. The EA SUP explains that "security systems and other essential safety equipment are kept operating until the final stop and first phase of the decommissioning, i.e. until the unloading of the spent nuclear fuel." The dates on which Ukraine's reactors reach the end of their design lifetime are indicative of the need of reactor's life-time extension *one unit in 2012, two in 2014, two in 2015, two in 2016, two in 2017 and two in 2019 (See Table 1).*
- Economic viability - both loans need to be repaid, and EURATOM cannot grant loans without a statement from the European Investment Bank (EIB) showing that the loans can be repaid, likely to be based on the future operation of those NPPs.

Officially these European institutions have been asked to finance the programs labeled as safety upgrades, though it is impossible to argue this technically or economically. This claim seems to have been chosen because:

1. EBRD and EURATOM financing conditions allow only for safety upgrade financing so the lifetime extension needs to be concealed;

2. this avoid a discussion about ageing problems of Soviet-era NPPs once the lifetime extension plans for all 15 reactors by 15 years would become known
3. this avoids conducting an SEA; the SUP is not only called a safety upgrade program but also substitute sectoral policy by intending to modernise and prolong a whole nuclear power-producing sector; even pilot projects were run. A full SEA would require assessment of alternatives to reactors life-extension and transboundary involvement.

This report finds that no information about the SUP was provided outside of Ukraine, and it is probable that neighbouring states would demand full transboundary SEA and EIA for such a sensitive topic.

Instead only the EA designed solely for the SUP was conducted in Ukraine without any transboundary assessment. Our report shows that this approach is far from best practice in the nuclear field and does not comply with international conventions like the ESPOO convention on transboundary impact assessments or the Aarhus Convention on access to environmental information, nor does it even come close to fulfilling EU legislation. The EU's SEA directive would have to be applied to assess alternatives to safety upgrades and lifetime extension; instead the EA concludes that there are no alternatives to safety upgrades and claims those measures are needed even for safe closure.

We expect EURATOM, the European Commission and EBRD to follow their guidelines and to enforce good governance, public participation and information disclosure and good practice with respect to international conventions like the SEA protocol, Espoo and Aarhus.

More broadly nuclear energy today is causing even more concern than before the nuclear accident at Fukushima. European institutions should encourage project applicants to inform the public about their projects in line with all available tools like Espoo contact points. It is unacceptable that a major, high-risk project is being considered for financing from European institutions without the public in EU member states being informed.

One year after the Fukushima accident, the European public would welcome information about the lifetime extension of NPPs that are already three decades old.

The SUP was prepared prior to the nuclear disaster at Fukushima, and it is not acceptable that decisions on the program are taken before the stress tests are completed and the EU draws its first conclusions about reactor safety. We believe that these institutions will not finance Ukrainian reactor safety measures before the peer review of Ukraine's stress test report has been prepared.

The EBRD and Euratom want to hide the fact that they are contributing both financially and politically to at least another 15 years of nuclear risk. The argument that Ukraine would go ahead and operate the reactors even without EBRD and Euroatom funding is troubling and implicitly alleges that the Ukrainian operator and regulator would act irresponsibly.

The Ukrainian authorities already licensed lifetime extensions at Rivne reactors 1 and 2 without first applying the Espoo Convention. The Espoo implementation committee is now inquiring about violations in this case. **We expect both Euratom and the EBRD to withhold a decision about SUP pending a resolution to the Rivne 1 and 2 lifetime extension decision.**

Some modernisation measures are “significant changes” e.g. the planned nuclear fuel exchange and call for EIA implementation. One of the first SUP objectives is the introduction of second generation fuel with improved cycles in order to reduce neutron fluence on the reactor vessel to mitigate embrittlement effects. The switch to longer fuel cycles is not mentioned in the SUP but is an objective of the energy strategy. High fuel burn-up increases the risk of accidents, because it accelerates the accident progression.

The reliability of the Ukrainian nuclear safety programs are cause for concern. A 2006 EBRD press statement says “…a modernisation programme for all nuclear power plants in Ukraine currently being implemented will upgrade all 13 nuclear reactors to internationally recognised nuclear safety level by 2010.“ (EBRD 2006). Thus the question of why are new programmes, including the SUP within the „Comprehensive Safety Upgrade Program,” necessary? Our study provides an overview of the very non-transparent management of safety improvement programmes in Ukraine. It seems that all safety measures not implemented by 2010 were merely incorporated into the SUP for the period 2010 to 2017.

2. INTRODUCTION

In November 2010 the EBRD and the EU's Euroatom announced plans to finance the nuclear power plant (NPP) safety upgrade project (SUP) for Ukraine.

According to the ecological assessment (EA) report released in October 2012, the SUP program costs around **EUR 1.34 billion**, though EBRD estimates are upwards of 1.45 billion. The EA report estimates 12 billion UAH for the complete modernisation of all Ukrainian reactors (ENERGOATOM 2011). The EBRD intends to grant up to **EUR 300 million** for the project, and **EUR 500 million** is to be provided by the EURATOM loan facility. Currently both institutions are preparing loans and the EBRD's Board of Directors is scheduled to decide on this loan on 18 September, 2012 and EURATOM in May 2012.

The EBRD and EC have requested a strategic environmental assessment (SEA) for the SUP[1]. However as early as the project's scoping stage, the public was informed that **EBRD staff and Energoatom agreed only to an ecological assessment (EA)** for the project in line with procedures outlined in European SEA Directive 2001/42/EC regarding public participation.

SUP includes measures for the safe modernisation of all of Ukraine's 15 operating nuclear reactors and should be implemented by 2017. Twelve of these reactors were designed to finish operations before 2020, and two units were supposed to be taken off the grid in 2010 and 2011 but received licenses to operate for additional 20 years. The SUP is therefore designed for nuclear reactors that face the end of their designed lifetime.

In 2005 Ukrainian NPPs provided about 50 percent of the electricity produced in the country. According to Ukrainian energy strategy till 2030, this proportion of nuclear power should remain until 2030 (UKRAINE 2006). This decision is justified by the presence of domestic uranium deposits, the stable operation of existing NPPs and the high costs of constructing new NPPs.

According to the Energy Strategy, by 2030 seven units will have received a license for a lifetime extension of 15 years, including Zaporizhia NPP 3-6, Rivne NPP 3, Khmelnitsky NPP 1, South Ukrainian NPP 3 and two units that started operation in 2004: the Khmelnitsky NPP 2 and Rivne NPP 4. In 2004 the Ukrainian Cabinet of Ministers approved the "nuclear reactors lifetime extension plan", which foresees extending the lifetime of all operating nuclear reactors by an additional 15 years.

Prolonging the operation of the NPPs from 30 to 45 years requires a huge effort in terms of modernisation and safety improvements in order to

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[1] See the procurement notice at http://www.devex.com/en/projects/235147/print.

reach internationally-acceptable status. The EA SUP however (ENERGOATOM 2011) concerns only the safety improvements, and this is only one side of the development. The other side is the material degradation of reactor components of which the most important is the reactor pressure vessel (RPV). The RPV is the only component which cannot be replaced. Due to harsh conditions in the primary system (high temperature and pressure and high neutron flux),embrittlement, corrosion, cracks and abrasion weaken the primary cooling system material. A failure of primary system components could lead to a loss of coolant accident.

To prevent the development of a severe NPP accident, so-called accident management measures are implemented. The SUP mentions such measures as guidelines for organisational activities and emergency measures.

Another important influence isfrom the EU NPP "stress test" that Ukraine has agreed to participate. In its report the Ukrainian nuclear authority has already defined some measures that are to be **completely** implemented at the NPPs, if the operators wish to apply for lifetime extension. The peer-reviewed results will not be known until May 2012 and may offer new insights and subsequently new safety measures to be required at the Ukrainian NPPs.

In fact, EURATOM and the EBRD have been asked to finance a program labeled only as 'safety upgrades', though it is impossible to argue this both technically and economically. This inaccurate claim seems to have been chosen deliberately because both the EBRD and EURATOM are allowed only to finance safety upgrades.

EURATOM loan facility

EURATOM loans for projects in third countries are subject to the following conditions:

- Financing is only available for projects relating to nuclear power stations or installations in the nuclear fuel cycle which are in service, or under construction, or for the dismantling of installations where modification cannot be justified in technical and economic terms;
- The project should have received all the necessary authorisation at the national level and in particular the approval of the safety authorities; and,
- The project should have received a favorable opinion from the European Commission in technical and economic terms.

Financial support from the Euratom loan facility is limited to 20 percent of the total project cost for Member States and 50 percent of the cost of the 'safety and efficiency' measures for third countries like Ukraine.

European Bank for Reconstruction and Development (EBRD) financing conditions

The EBRD environmental and social policy begins *"The EBRD is committed to promoting "environmentally sound and sustainable development…"* Nuclear energy is a very controversial energy form and one of the reasons that the EBRD energy policy prohibits bank investments in new NPPs. But the EBRD does support safety upgrades. For projects like the SUP in Ukraine, the EBRD is unlikely to finance safety upgrades without Euratom involvement, so both institutions' conditions must be fulfilled.

The following two conditions of the EBRD environmental and social policy (2008) are of relevance for the SUP:

"3. *The EBRD will seek to ensure through its environmental and social appraisal and monitoring processes that the projects it finances:*

- *are socially and environmentally sustainable*
- *respect the rights of affected workers and communities*
- *and are designed and operated in compliance with applicable regulatory requirements and good international practice.*

…. The Bank is committed to promoting European Union (EU) environmental standards as well as the European Principles for the Environment, to which it is a signatory…"

"7. … Such stakeholder interaction should be consistent with the spirit, purpose and ultimate goals of the United Nations Economic Commission for Europe (UNECE) Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters, the EU Environmental Impact Assessment Directive and, for projects with the potential to have significant environmental impact across international boundaries, the UNECE Convention on Environmental Impact Assessment in a Transboundary Context, regardless of the status of ratification."

3. EXAMPLES OF EIA AND SEA IN THE NUCLEAR ENERGY SECTOR

3.1 Examples of EIA and SEA in the field of nuclear energy projects in Europe

„The ecological assessment (EA) is to be carried out in compliance with the national legislation and international conventions signed by Ukraine as well as „best international, environmental and social guidelines." The terms of reference for the EA aimed to follow „international best practice in EIA and public information and consultation." (ENERGOATOM 2011, page 330)

The EBRD does not seem eager to promote this project. While the EBRD homepage is regularly updated with the newest renewable energy projects, the Ukrainian nuclear project is not widely emphasised. However the EBRD already has a history of nuclear projects with great public interest like the Mochovce NPP 1 and 2 projects in the early nineties and K2/R4 NPP project in Ukraine.

At this point we want to recall the basic ideas of the Espoo Convention:

“The Espoo Convention sets out the obligations of Parties to assess the environmental impact of certain activities at an early stage of planning. It also lays down the general obligation of States to notify and consult each other on all major projects under consideration that are likely to have a significant adverse environmental impact across boundaries.”

Ukraine’s approach and the EBRD’s acceptance is very much out of line with the transboundary SEA widely applied in Europe. Below are a few examples of recent transboundary SEA and EIA for energy strategies and programs as well as nuclear reactor modification programs:

<u>Paks LTE 2006</u>

In 2005 Hungary notified its neighbors about its intentions to extend the lifetime of four VVER 440 reactors from the original 30 year lifetime by an additional 20. The first phase consisted of scoping not only in Hungary but also neighbouring states and their public. An Environmental Impact Statement (EIS) was prepared with inputs collected during this process. For example the EIS was available in Austria online, hard copies were available at national and regional authorities in local language, and the EIA process and public hearings were announced in print media. Hungary also organised hearings on the project outside the country. Experts were invited to examine initiating events and accidents and consult with Hungarian counterparts.

<u>Mochovce units 3/4</u>

This NPP project is a very controversial case where the project applicant and the state of origin, Slovakia, insisted that an EIA and Espoo procedure would not be needed because national legislation did not require it. In the end a compromise was agreed that included a „voluntary EIA“ not only in Slovakia but also for states who were interested in taking part. While this approach is still not best practice, at least the public in Slovakia and abroad were informed about the existence of the project and the basic information about it. Hearings were held in neighbouring countries, with bilateral governmental consultations organised on initiating events and accidents.

Polish Nuclear Energy Program

In 2011 Poland provided extensive information about its nuclear energy program and Sweden, Finland, Denmark, Germany, Austria, Czech Republic, Slovakia and Luxembourg took part in the scoping processes.

Additionally the following programs and strategies were notified under the Espoo Convention in the past years: the energy strategy of Slovenia 2010-2030, Slovak energy strategy 2008, Slovak nuclear back-end strategy 2008, in 2010 the United Kingdom notified Espoo countries about several energy policy strategies related to energy infrastructure, nuclear policy and so forth.

Swedish non-Espoo nuclear plans

The Swedish cases are of particular interest. Though Sweden concluded that upgrading its Oskarshamn and Forsmark NPPs in 2004 and 2005 respectively were not cases to be notified under Espoo, information was provided to neighbouring countries.

3.2 Ukraine and Espoo

A quick survey shows that Espoo Convention countries, including Ukraine´s neighbours Poland and Slovakia, were not informed about the Ukrainian government's plan for NPP lifetime extension, no about the preparation of SUP.

In general Ukraine tends to provide only minimal information - only neighboring countries were notified about the ongoing EIA procedure for the new reactors 3 and 4 at Khmelnitzky NPP in 2010 and 2011. Current practices like those in Finland and Poland are good examples of wide information dissemination, and all European countries usually are notified according to the Espoo Convention.

The following list prepared by the Espoo Convention secretariat offers a good overview:

> *Many examples of the application of the Espoo Convention to more recent nuclear energy-related activities were reported in completed questionnaires on the implementation of the Convention in recent years, including:*
>
> *(a) Bulgaria (Belene NPP);*
>
> *(b) Czech Republic (Temelin interim storage facility for spent nuclear fuel);*
>
> *(c) Finland (Olkiluoto-4, Loviisa-3 and Fennovoima NPPs, and a final repository for spent nuclear fuel);*

(d) Germany (interim storage facilities for spent nuclear fuel);

(e) Hungary (Paks NPP lifetime extension);

(f) Lithuania (Ignalina NPP decommissioning projects (near-surface repository for low- and intermediate-level short-lived radioactive waste; land-fill facility for short-lived very-low-level waste; new solid radioactive waste management and storage facilities) and Visaginas NPP);

(g) Romania (Chernavoda NPP, units 3 and 4);

(h) Slovakia (Jaslovske Bohunice NPP V-1 decommissioning);

(i) Sweden (Barseback, Forsmark and Ringhals NPPs, and encapsulation plant and the final repository for spent nuclear fuel).

Current examples include plans for activities in: Belarus (Astravets NPP); France (decommissioning of Chooz A NPP); the Netherlands (Borssele NPP); and Slovakia (Mochovce NPP, units 3 and 4). A list of operating nuclear plants and plants under construction in the UNECE member States was presented to the Working Group on EIA at its thirteenth meeting in May 2010 and subsequently revised by Parties. (UNECE 2011)

The program on which SUP is based – the Long-term strategy safety upgrade of power units of Ukrainian NPPs and the energy strategy for Ukraine until 2030– were not notified under Espoo. A SEA was not conducted, because this concept is not part of Ukrainian legislation and the SEA protocol is still not ratified by Ukraine.

In general the Ukrainian side seems rather reluctant to inform about its nuclear programs. The letter sent by the Espoo Implementation Committee[1] inquiring about NGO complaints concerning the Rivne NPP lifetime extension without an EIA, dated 23 June 2011, did not receive a reply from the Ukrainian side until February 2012.

The approach of Ukraine and the EBRD with respect to SUP is certainly not best practice for the application of international conventions on SEA and EIA. In recent years more information dissemination and public involvement is becoming the trend, and this is gaining momentum after the Fukushima accident. The 2011 Meeting of the Parties of the Espoo Convention gave special attention to the issue of lifetime prolongation of NPPs. For this meeting, the "Background note on the application of the Convention to nuclear energy-related activities" was prepared, commented and discussed. While nuclear power plants clearly fall under the Convention, lifetime extensions are somewhat unclear. The Background note sums this up:

"The renewal of an NPP license is generally subject to EIA, though the location, technology and operating procedures may remain unchanged (see appendix III to the Convention). However, in many UNECE countries, NPPs are licensed without any lifetime limitation. Questions remain as to whether an extension of the designed operation period of an NPP is subject to the Convention if no license renewal process is needed. The unlimited license is normally coupled with the obligation to perform periodic safety reviews, usually every 10 years. Such a review could lead to a modification of the NPP and its operating license; national legislation does not always require EIA in such cases." (UNECE 2011)

Rivne NPP 1 and 2 lifetime extensions: in breach of Espoo?

The Espoo Implementation Committee is currently investigating whether Ukraine violated the Espoo Convention by failing to implement Convention requirements regarding the lifetime extension of Rivne NPP-1,2. We quote from the forthcoming report of the Espoo Implementation Committee from its December 2011 session. The Committee will return to this question and may refer it to the Espoo members. The Committee concluded:

42. Based on the information provided, the Committee concluded that Ukraine had not applied the Convention in relation to the planned extension of the nuclear power plant. However, it noted that the main issue was to establish whether the activity in question was a proposed activity subject to the Convention.

43. In that regard, the Committee concluded that lifetime extension of nuclear power plants could be considered as a major change to an activity in appendix I, and thus fell under the scope of the Convention. The Committee also referred to the background paper for the nuclear panel discussion held during the Meeting of the Parties in June 2011 (ECE/MP.EIA/2011/5). However, before reaching its final conclusion on the issue, each Committee member was invited to consider the matter further and to present their views for discussion and conclusions at the next session of the Committee. (ECE 2011)

4. ANALYSIS OF THE ECOLOGICAL ASSESSMENT OF THE NPP SUP

4.1. The hidden scope of SUP: reactor lifetime extension

The introduction to the EA says "*The SUP involves safety improvements at existing NPPs, with no new construction, no capacity increase and no life extension".*

However, section 1.5.3 'Purpose of the Upgrade Program' says "*The purpose of SUP is further implementation of safety upgrade works in terms of long-term state safety upgrade strategy of power units of Ukrainian NPP."*

In spite of Energoatom's claims, the loan Energoatom seeks is needed for a long-standing program to operate nuclear power plants beyond their designed lifetime. The strategy was published in the International Atomic Energy Agency (IAEA) country profile on the Ukraine: *„Rovno NPP-1,2 and South Ukraine NPP-1 were identified as pilot power units for lifetime extension beyond the designed period. Their designed lifetime expires in 2010, 2011 and 2012, respectively. Activities on extension the NPP units operation beyond the design lifetime are carried out in compliance with the "Comprehensive Program for Lifetime Extension of Operating Nuclear Power Units" … At the end of 2008, Rovno NPP-1, 2 were taken out of operation for long outage to implement the activities envisaged by the schedules. Activities on extension of South Ukraine NPP-1 operation beyond the design lifetime are being developed and programs and guidelines are being agreed upon now. Extension of Zaporozhe NPP-1 (pilot unit in viewpoint of lifetime extension of power units with standard WWER-1000) operation beyond the design lifetime is at the initial stage.*" *(IAEA: UKRAINE 2011)*

According to the "Energy strategy of Ukraine until 2030," lifetime extensions of at least 15 years states, "Volumes of electric power generated by nuclear power plants will increase due both to commissioning new and rehabilitating existing NPP power units, extending their service life at by least 15 years."

The claim of the EA for the SUP – that the measures would serve only safety and not lifetime extension – is incorrect. The EA explains "*security systems and other essential safety equipment are kept operating until the final stop and first phase of the decommissioning, i.e. until the unloading of spent nuclear fuel. Most of these systems and equipment are also required at the following stages of decommissioning – to complete removal of all wastes from the unit."* When a nuclear plant is shut down, only cooling, water and ventilation is needed, depending on power supply, until the plant arrives at a safe status; **none of the planned safety measures within the SUP requires this.**

Power uprates in the future

While power uprates are not discussed for Ukrainian NPPs, safety modernisation measures at old NPPs were usually followed by power uprates to increase installed capacity and the power produced.

Safety and lifetime extension

Today lifetime extension is a goal that seems relatively easy to implement in Ukraine. The proposal to build 20 GW of new nuclear plants seems utopian, particularly after the Fukushima disaster and skepticism towards nuclear power.

Prolonging the operation of the NPPs from 30 to 45 years requires significant effort to modernise and safely improve these plants to reach an internationally-acceptable status. The EA of the SUP concerns only safety improvements, but this is only one side of the development. Part of these safety improvements need to be implemented to achieve current EU safety standards. On the other hand, a power plant that has operated for 30 years is not the same as it was originally. 30 years of operation leave marks on an NPP, the most important being the aging phenomena. The hazards resulting from aging components and systems set in approximately 20 years after plant operation and further increased by lifetime extension. Aging renders NPPs more incident-prone.

Aging can occur in many different forms in different components. The most significant aging phenomena in WWERs (as in all PWRs) concerns the reactor pressure vessel – **RPV**[2] (HIRSCH et al 2005):

Materials close to the core:

Embrittlement (reduced toughness, shift from the ductile to the brittle-transition temperature) results from neutron irradiation. This effect is particularly relevant if impurities are present. Copper and phosphorus favor embrittlement, as well as nickel at very high neutron fluences as encountered at VVER reactor vessels. Neutron embrittlement is mostly relevant for PWRs.

Welds: Crack growth occurs because of changing thermal and mechanical loads. For PWRs, this occurs mostly in embrittled welds close to the core;

Vessel head penetrations: Crack formation and growth due to corrosion mechanisms;

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[2] Reactor pressure vessel

Inner edge of nozzles: Strong concentration of stresses because of varying wall thickness, with changing thermal and mechanical loads as well as corrosion and erosion effects. This leads to the hazard of crack formation or growth of cracks. Inspection is complicated because of geometric lay-out and high-wall thickness.

Pipelines: cracks in pipelines develop due to mechanical and thermal loads, erosion and corrosion. Thinning and material fatigue due to resonance vibrations, water hammer and so on are very difficult to keep under surveillance. For these reasons, damages become more likely with aging materials.

Main Coolant Pumps: Crack formation and crack growth can occur due to thermal- and high-frequency fatigue processes, supported by corrosive influences. Inspections are difficult.

The planned 15 years lifetime extension for all operating NPPs in Ukraine needs significant effort to monitor and guarantee safety in light of aging reactor components. If the aging process of the primary circuit system's components (in particular, the RPV) does not allow the operation over the next 15 years, the reactor would have to be shut down. Besides the SUP measures it is not clear whether the lifetime extension can be achieved without violating the continuous developing safety requirements of WENRA[3] and IAEA. It also cannot be excluded that during these 15 years some units will have to be shut down because of unresolved safety problems.

4.2. Compliance with the Espoo convention and SEA protocol

To even remotely fulfill the international obligations of SEA and EIA and/or EU environmental legislation, the **SUP program also lacks**:

Transboundary EIA and SEA

Analysis of alternatives

The SEA protocol augments the Espoo Convention by ensuring that individual parties integrate environmental assessment into their plans and programs at the earliest stages.

Article 4.2.of the SEA protocol states:

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3 *WENRA* - **Western European Nuclear Regulators' Association**

A strategic environmental assessment shall be carried out for plans and programs which are prepared for agriculture, forestry, fisheries, ***energy****, industry including mining, transport, regional development, waste management, water management, telecommunications, tourism, town and country planning or land use, and which set the framework for future development consent for projects listed in annex I and any other project listed in annex II that requires an environmental impact assessment under national legislation.*

"The participation of the public in strategic decision-making builds on the Convention on Environmental Impact Assessment in a Transboundary Context (the Espoo Convention) and the Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters (the Aarhus Convention)." (SEA Protocol 2007)

Information about how and in what form an SEA was conducted for the SUP is unclear. It seems that the current EA report was commissioned in such a way as to include some elements of SEA. This is probably the result of a compromise with the Ukrainian government[4].

The December 2011 EA report for the SUP seems to have been prepared as an EIA report; at the same time the "Ukraine NPP Safety Upgrade Program" is a program and an SEA would be required. The correct approach would have been to conduct a full SEA process examining whether the program of upgrading and extending the operation of 15 reactors beyond their original lifetimes is the best method to supply electricity demand. The SUP itself also shows features of a program, because the upgrading measures of two pilot plants are to be implemented at all other plants.

No SEA was conducted prior to the EIA in Ukraine. Additionly neighboring countries possibly affected by the SUP were not offered the possibility to comment on the strategy, and they were not even informed about the SUP program. Because the Aarhus Convention was not applied, the public outside the Ukraine was not informed and could not get involved.

The EBRD project description of December 2011 has a different view:

„Implementing best practice in terms of corporate governance and stakeholder engagement with a Strategic Ecological Assessment (SEA). The Assessment will supplement the environmental study undertaken by Energoatom of the specific upgrade projects and allow for an overall Ecological Assessment of the upgrade program in Ukraine. This will be among the first SEAs of its type in Ukraine, and the first for the Nuclear sector." (EBRD)

- No international NGOs like Friends of the Earth or Greenpeace were informed.

[4] if footnote No. 2 on page 329 of the EA is interpreted correctly.

- States including Austria, Czech Republic,Slovakia or Sweden were neither notified nor informed.

EBRD is obliged to demand from their clients:

"Such stakeholder interaction should be consistent with the spirit, purpose and ultimate goals of the United Nations Economic Commission for Europe (UNECE) Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters, the EU Environmental Impact Assessment Directive and, for projects with the potential to have significant environmental impact across international boundaries, the UNECE Convention on Environmental Impact Assessment in a Transboundary Context, regardless of the status of ratification."

This EA report describes the planned safety measures and examines the expected environmental impacts. Nuclear power plants of course have transboundary impacts with which the report deals, but no potentially affected country was notified according to Espoo. The argument that Espoo does not clearly demand notification in the case of lifetime extension plans cannot be used as a legal argument for failing to inform neighboring and other potentially-affected countries. The fact that an EIA was conducted makes the Aarhus Convention applicable, because this is part of communicating to the concerned public. The public concerned however is not limited to Ukraine but all public concerned beyond its borders. The standard approach in this case could be to inform neighboring states via Espoo contact points or on an individual basis. The difference between Espoo and Aarhus is also that the Espoo convention focuses on communication and information between states, whereas the Aarhus convention also includes informing the public.

4.3. Alternatives to SUP and Lifetime extension

The Ukrainian state-owned energy utility Energoatom released the EA report for SUP 30 September 2011. As outlined above, only this EA reporr served as an SEA at the same time.

A full SEA would deliver in this case requires (at this point we do not differentiate between SEA protocol under the Espoo convention and EU SEA directive):

1. Screening - to assess whether an SEA is required
2. Scoping – to determine the scale of the assessment
3. Environmental report – to assess the impacts of the plan on the environment and assess reasonable **alternatives**
4. Public participation

5. Decision making
6. Publishing and explaining the decision; and
7. Monitoring the impacts

The SUP does not present any alternatives simply because its objective is upgrading. This is the wrong approach. A full SEA would have to formulate the objective first, in this case electricity supply, and then assess different approaches, one of which is the lifetime extension of existing reactors with the necessary safety upgrades. Usually two to three alternatives should be elaborated.

4.4. Assessment of accidents: transboundary impacts

The EA report assesses that normal operation and design-based accidents will not result in significant impacts at further distances from the plant. The maximum DBA emissions are limited by radiation protection individual dose limits. (In the EU the limit is set at 1 mSv/yr).

"In case of an accident of level 5 or more on the INES scale, the pollution of the environment by radioactive substances would result in ecological impacts directly related to the quantity, type and distribution of emitted radionuclides. Depending on the meteorological conditions radioactive substances transported through the atmosphere would also have an impact outside the Ukrainian territory." (ENERGOATOM 2011)

"With this, e.g. the investigations done on RNPP had demonstrated that the probability of the negative impact on the population health of the neighbouring countries (average scholastic[5] fatal risk) resulting from non-designed accident is for Belarus – approx.1,4E-5[5] /yr, for Poland – 9,3E-7/yr, for Moldova and Romania – 6,1E-7/yr....., which is by orders less than the level of acceptance set for the population by the national norms and international recommendations (5xE-5/yr.)" (ENERGOATOM 2011)

The EIA must do more than present results - it is explicitly required by the Espoo convention to describe the methods and parameters for the assessment. Without this information it is not possible to prove the presented results. Because of the steady decrease of risk with distance, we assume that a simple dispersion model is used.

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5 Probably - "stochastic"

The severe accident source term assumed in the calculation should be given as well as the meteorological data used for the assessment. In order to calculate the stochastic individual fatal risk the individual dose received from radiation exposure has to be calculated as well.

In the EU dose limits are used in order to determine protection measures for the population in case of a radiological emergency due to a nuclear accident. Individual risk limits can be derived from the dose limits. Risk governance may be used in the Ukraine; it is also used in the Netherlands. However there is a dose limit, but no risk limit, for the exposure of the EU's population limit. Moreover the allowable individual fatal risk in the Netherlands is a bit lower than in the Ukraine.

According to the Dutch risk policy two criteria must be met:

1. The maximum allowable individual risk to die as a consequence of operation of a certain installation is 1E-6 per year. According to the Dutch risk approach, the individual risk shall be calculated for one year- old children, since this is generally the most vulnerable section of the population.

12. The societal risk is defined as the risk of 10 or more casualties, which are directly attributable to the accident, and this risk shall be lower than 1E-5 per year for 10 deaths, 1E-7 per year for 100 deaths, 1E-9 per year for 1000 deaths, etc.

As long as it is not possible to exclude entirely accidents at NPPs, a serious examination of the potential impacts has to be provided.

Even if the SUP concerns only safety improvements, these improvements are for the long term operation of the Ukrainian NPPs. Lifetime extensions are envisioned for at least 15 years at all the old reactors (beginning with Rivne 1/2) the SUP program could probably be a compensation of safety deficits and aging phenomena. But Energoatom still has to proof that severe accidents can be excluded.

CONCLUSION

European institutions like the EBRD and Euratom claim to ensure that the projects they finance comply with international conventions and best practices.

No country was informed about this very controversial project, and all nuclear projects are controversial. This controversy is

reflected already by the fact that the EBRD is not allowed to finance new nuclear power plants.

We do not accept this attempt to hide a lifetime extension of reactors older than 30 years behind the so-called necessary safety upgrades, and we demand implementation of best international practices, environmental and social guidelines, and full transboundary SEA and EIA that include alternatives to the lifetime extension program and an assessment of severe accidents.

4.5. Safety objectives and improvements

4.5.1. History of safety modernisations

In 2002 the first safety upgrade program started in Ukraine with the endorsement of the Cabinet of Ministers. This program is based on the IAEA Issues Books IAEA-EBP-WWER_03, IAEA-EBP-WWER_05 and IAEA-EBP-WWER_14. [6] While implementation was planned between 2002 and 2005, during this period 65 percent of the program was not implemented and therefore was carried out later in the next safety upgrade program between 2006 and 2010.

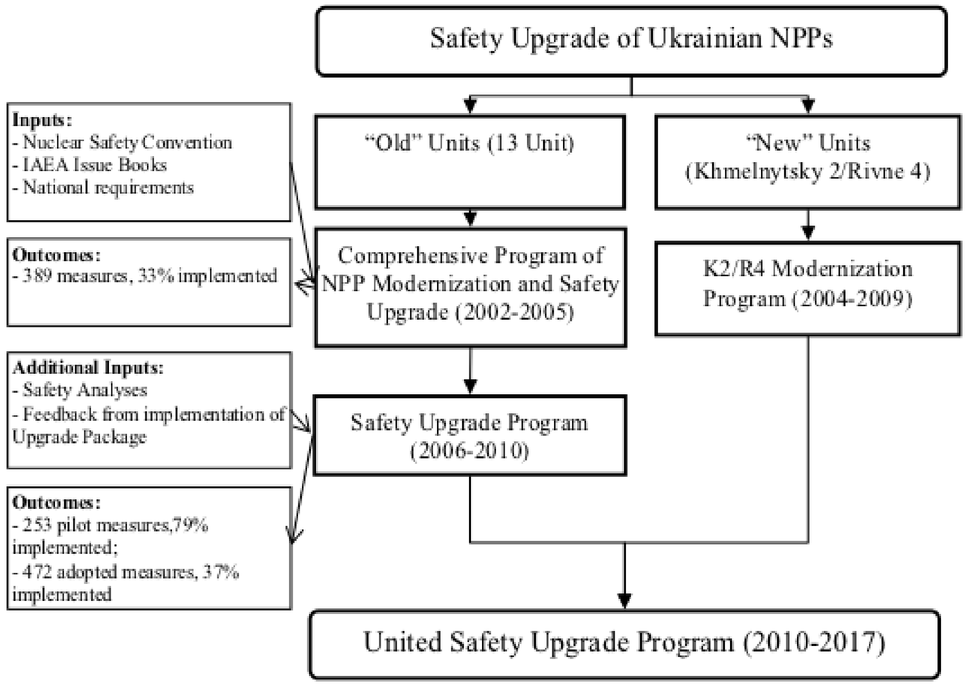

Fig. 1. Safety upgrade programs for Ukrainian NPPs

(Figure: IAEA 2009)

The unimplemented measures from the first program (2002-2005) were adopted during the second program (2006-2010), and additional measures to address safety issues were introduced, including safety analysis and feedback from the first implementation period.

Of the pilot measures in the second safety upgrade program, 20 percent have not been implemented, and 63 percent of the adopted measures are not complete.

A comparison of the programs' outcomes described in the Convention on Nuclear Safety (CNS) Reports of Ukraine from 2003 and 2007 show that

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[6] The results of the WWER issues books are collected in IAEA-EBP-WWER-15

only a small number of measures were completed and only a minority of these were of a high priority.

In parallel to the first two safety upgrade programs, the modernisation program for two new WWER 1000/V320 units at Khmelnitsky 2/Rivne 4 began.

It seems that all safety measures that were not implemented by 2010 are now being incorporated into the SUP for 2010 to 2017.

The modernisation programs were first supported by the IAEA, TACIS, EBRD and Euratom. The TACIS program between 1991 and 2006 provided Ukraine with over EUR 500 million, part of which was used for the Chernobyl shelter.

To finance the current "Consolidated NPP Safety Upgrade Program" Ukraine has applied for a loan from the EBRD and Euratom, and the EBRD requires an environmental assessment for this project.

The European Commission, the EBRD, Euratom and the IAEA supported the safety analysis of WWER and RBMK reactors and provided significant funds to enhance the safety of these plants. As outlined above, the implementation required a lot of time and money. Modernisation efforts were not completed when the second project finished in 2010. The "TACIS" program (nuclear safety activities) was converted into the "Instrument for nuclear safety cooperation" (INSC) and launched a new program for 2007 until 2013.

Since 1986 many safety improvements were completed in the Ukraine, but modernisation is a continuous development and does not end until the NPP is safely closed. Safety standards (WENRA) for operating NPPs are to be fulfilled also at Ukrainian plants. The WENRA safety objectives for new NPPs "should be used as a reference for identifying reasonably practicable safety improvements for "deferred plants" and existing plants during periodic safety reviews" (WENRA 2010).

Thus it must be clear that safety standards in the nuclear field are constantly evolving and the requirements keep increasing. While an old NPP can use modern systems, the material of large components has an expiration date.

Excerpt of the WENRA safety objectives for new NPPs
Objective 1: Normal operation
Enhance plant capability to stay within normal operation. Reducing the potential for escalation to accident – enhance the capability to control abnormal events.
Objective 2: Accidents without core melt
Ensure minor radiological impact (in particular, no necessity of iodine prophylaxis, sheltering nor evacuation)

<u>Reducing</u>
⅄ **the core damage frequency, accounting for all types of credible hazards and failures and credible combinations of events;**
⅄ **the releases of radioactive material from all sources.**
Objective 3: Accidents with core melt
⅄ **Reducing radioactive releases to the environment – also in the long term, accidents with core melt that would lead to early or large releases have to be "practically eliminated"** [1]
⅄ **for accidents with core melt that have not been practically eliminated, design provisions have to be taken so that only limited protective measures in area and time are needed for the public (no evacuation, limited sheltering ..).**
Objective 4: Independence of all levels of defense-in-depth
Strict independence of all levels of defense-in-depth, diversity and separation

4.5.2. Content of the safety upgrade program

The IAEA document (IAEA 1999) presents a ranking of all safety issues for the three WWER types. For WWER 440/213 and WWER 1000 units no Category IV safety problems are described. Thus the highest hazards in Ukrainian NPPs are of Category III.

In the following we present a comparison of the solutions for important safety issues fo Category II and III at the Ukrainian NPPs as of 2011 and the safety issues described in the new safety upgrade program (ENERGOATOM 2011**)** (Priority I and II, where I is of high and II is of medium priority). The ranking of safety measures in SNRIU 2011 is related to their contribution to the mitigation of hazards according to probabilistic safety assessment (PSA). Therefore a precondition for the SUP program is to carry out PSAs in all NPPs.

PSAs are used to calculate the probability of damage to the core as a result of accident sequences identified in the study. PSAs can now also be used to assess the size of radioactive releases from the reactor building in the event of an accident, as well as the impact of such releases on the public and the environment. These studies are referred to as level 2 and level 3 PSAs respectively (level 1 corresponding to the assessment of the risk of core damage). Level 3 analyses are used for emergency planning.

The results of these analyses can therefore identify not only the weaknesses but also the strengths with regard to the plant's safety and thus assist in setting priorities.

A PSA is an analysis that is used during both the design and the operating stages of a nuclear plant to identify and analyze every possible situation and sequence of events that might result in severe core damage.

Re

NPP, Unit No.	Electric power, MW	Reactor type	Connection to the grid	Design lifetime expiry date
ZNPP				
1	1000	V-320	10.12.1984	10.12.2014
2	1000	V-320	22.07.1985	22.07.2015
3	1000	V-320	10.12.1986	10.12.2016
4	1000	V-320	18.12.1987	18.12.2017
5	1000	V-320	14.08.1989	14.08.2019
6	1000	V-320	19.10.1995	19.10.2025
SUNPP				
1	1000	V-302	31.12.1982	31.12.2012
2	1000	V-338	09.01.1985	09.01.2015
3	1000	V-320	20.09.1989	20.09.2019
RNPP				
1	420	V-213	22.12.1980	22.12.2010*
2	415	V-213	22.12.1981	22.12.2011*
3	1000	V-320	21.12.1986	21.12.2016
4	1000	V-320	10.10.2004	10.10.2034
KhNPP				
1	1000	V-320	22.12.1987	22.12.2017
2	1000	V-320	08.08.2004	08.08.2034

The SUP EA Report (ENERGOATOM 2011) uses PSA results for external events to assess the probability of impacts that could damage the plant. In particular the likelihood of an aircraft crash on the NPPs resulting in core melt accident is given in the report. Because the probability for an occurrence of such a severe accident is below

1E-7 is not further analysed in the report. The EA documents exclude unlikely events from the analysis by stating that such events cannot happen. From our point of view this is not acceptable, because severe accidents in nuclear facilities are rare events, but their impact can be significant, as Chernobyl and Fukushima prove.

TABLE 1: Information on operating units

*) The operational lifetime was extended 10 December 2010 based on the results of periodic safety review for power units (SNRIU 2011)

The content of the new program is to complete the safety measures from the former programs plus the adoption of new requirements from international organizations (IAEA and WENRA) and the Ukrainian nuclear authority SNRIU.

4.5.3. Technical safety upgrade measures: summary and conclusions

More detailed lists of safety issues and improvements in the documents from 1999 and 2011 are presented in Annexes 2 through 4. A summary and our conclusions of the comparison of these documents can be found below in two parts with respect to the two different WWER types (WWER 440, WWER 1000).

WWER 440/V 213 - RNPP 1/2

These are the first NPPs in Ukraine that have reached their original 30 year lifetime of operation. Relevant safety relevant issues from 1999 are not completely solved for RNPP 1/2. In spite of this, the operational lifetime of both WWER 440/V213 units was extended in December 2010.

General

Summary: The qualification and documentation of structures, systems and components (SSC) is not finished.

Conclusion: The lack of qualification and documentation of properties and status of buildings and equipment is deficient because the documentation of the original properties and changes due to the aging is of high relevance for assessment of the aging process of SSCs.

Reactor core

Summary: A change to second generation fuel is planned, and this fuel allows improved cycles and will reduce the neutron fluence on the RPV[7]. In addition rebuilding the SNF cooling pool into a compact storage is planned.

Conclusion: Usually the change to more efficient fuel leads to longer durations between fuel change and higher fuel burn-up. This concerns cask and storage of the spent nuclear fuel as well as the opportunity of inspections in-situ.

Components Integrity

Summary: Monitoring in order to implement the "leak before break" concept for the core cooling system to prevent the plant from LOCAs[8]. For the RPV a performance monitoring is to be implemented (vessel material specimens will be inserted in the mid of the core where the neutron fluence is higher than on the vessel's wall).

Conclusion: This is usually done to forecast vessel material fatigue and weakening. The monitoring measures are mentioned in the new SUP EA report (SNRIU 2011 in Table 67) as "to extend power units operation lifetime". This confirms that some of the SUP measures are conditions for the plant's lifetime extension. It is not mentioned whether the properties and status of the reactor pressure vessel before start of the reactor is documented and whether there have been changes of the material properties (this concerns also the weldings).

Systems

Summary: Accident management measures are to be implemented to prevent LOCAs due to a leak of the SG9 collector cover (diameter 100). (PRISE10). Modernisation of the SG pipe monitoring equipment is to be implemented. Hydrogen monitoring in hermetic compartments for SG, MCP[11] and the pressuriser is to be implemented.

Conclusion: These measures are also relevant for the lifetime extension, because aging of the very small SG pipes can cause cracks and breaks. This

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7 Reactor pressure vessel
8 Loss of coolant accident
9 Steam generator
10 Primary to secondary coolant leak
11 Main cooling pump

results in leakages from reactor cooling water into the secondary cooling system. Moreover, clogging of SG pipes due to abrasion diminishes the efficiency of heat transport of the SG.

Hydrogen monitoring is a first step for the prevention of hydrogen explosions. Moreover an in-depth analysis of hydrogen ignition in the turbine hall is foreseen to develop appropriate fire prevention measures.

Electrical power supply

Summary: Several improvements to the electrical power supply are still planned, such as modernisation of accumulators, UPS[12], switches, relays and so on. Modernisation of the auxiliary power supply is also required, including the installation of a redundant auxiliary transformer.

Conclusion: In this respect not all measures from 1999 are fully completed, and implementation of the planned improvements is urgent.

Internal hazard

Summary: In the new program the modernisation of the fire alarm system and the improvement of the fire extinguishing system is ongoing.

Conclusion: Fire was the most important hazard for RNPP 1/2 in 1999. However not all deficits in this field were eliminated by 2011. Improvement of fire prevention and modernising the fire extinguishing system is urgent.

External hazard

Installation of equipment for seismic monitoring is planned.

WWER 1000 – SuNPP 1-3, RNPP 3/4, KhNPP 1/2, ZNPP 1-6

South Ukrainian NPP 1 is probably the next candidate for lifetime extension. The original operational lifetime of Unit 1 ends 31 December 2012. V302 and V 338 are earlier models of the VVER 1000/320. In the 1999 IAEA ranking, the relevance of physical separation of safety systems (ECCS, I&C) is emphasised for the V302 and V338 models (SUNPP 1/2).

With the exception of RNPP 1/2 and SUNPP 1/2 all other operating reactor units in the Ukraine are WWER 1000/V320 models.

The listing of improvement measures in the SUP EA document are grouped for the "small series" (V 302 & V338) and for the V320 models that constitute a majority; therefore we will summarize the improvement measures and our conclusions for all WWER 1000 reactors together.

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[12] Uninterruptible power supply

The 13 WWER 1000 units operating in Ukraine were connected to the grid over a period between 1982 and 2004. Therefore it has to be assumed that the units show several differences. A detailed discussion of all the safety improvement measures is far beyond the scope of this study.

General

Summary: Qualification, classification and reliability analysis of structures, systems and components (SSC) is not finished for all Ukrainian WWER 1000 plants.

Conclusion: The lack of qualification, classification and reliability analysis of SSC and documentation of the original properties of buildings and equipment is a significant oversight. The documentation of original properties and monitoring material fatigue is highly relevant. Monitoring ageing and management is a standard for all NPPs in Europe, and in particular if lifetime extensions are planned, as is the case for all units in Ukraine.

Reactor core

Summary: Prevention of deformation of the fuel assemblies to ensure the reliability of control rod insertion. Improvement of in-core monitoring system;

Conclusion: Fuel development is not mentioned in the SUP for WWER 1000 reactors. The change to longer fuel cycles is one objective of the energy strategy of Ukraine till 2030. This development is a major change – new fuel assemblies with burnable absorbers and higher enrichment of the uranium fuel results in higher spent fuel burn-up and the negative impacts described above.

Component integrity

Summary: For WWER 1000 reactors, measures to prevent cold overpressure in primary circuit and the "leak before break" concept are currently being implemented. Also ongoing is the assessment of state and lifetime of the RPV as well as the improvement of RPV joints and connections.Measures to manage PRISE13 accidents - primarily secondary leaks due to SG collectors breaking and mitigation of accidents related to secondary piping breaks outside the containment - are under implementation.

Conclusion: At least some of the SUP measures obviously are preconditions for the plant's lifetime extension. It is not mentioned whether the properties and status of the reactor pressure vessel before start of the reactor is documented and whether there have been changes of the material properties (this concerns also the weldings).

Even if the "leak before break" concept is implemented, complete "guillotine" breaks have already occurred at NPPs, for example, in Surry in 1987 and Loviisa in 1990, where there was a break in the secondary circuit without leakage beforehand. (HIRSCH et al 2005)

Besides the RPV, the SG is the second big component of the reactor system. Both are exposed to heavy loads (tension, neutron flux, temperature, pressure); in particular changes of these loads contribute to material fatigue. After 30 years these effects could be substantial. Several NPPs SG had to be repaired or were exchanged. The measures foreseen for the WWER 1000 reactors are preconditions for exceeding the designed life of the plants.

Systems

Strengthening the reactivity control system to prevent repeated criticality and find more options for boron concentration monitoring.

Increase the reliability of heat removal from the primary circuit, including the "blow-down-makeup". Assurance of the working capacity of the fast acting release station and the reliable performance of the emergency pressure release.

Implementation of the upgraded ECCS heat exchanger density diagnostic system is planned. Modernisation of the LP and HP ECCS serves to control discharge pressure under primary system pump operation.

Replacing the SG safety valves (upgrade with valves that can cope with steam, water and a mix of both) assures cooling the reactor core via SG by steam discharge into the atmosphere by the fast acting reducing station.

Conclusion: Upgrading the deficiencies in safety systems are planned and partly implemented. These upgrades are to achieve a safety standard acceptable in the EU.

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[13] Primary to secondary coolant leak

Instrumentation & Control

Several new monitoring systems are to be implemented for movements of primary circuit piping, hydrogen control in the containment for severe accident conditions; installation of an information system for DBA and BDBA.

The modernisation of generator hydrogen cooling system is planned.

To prevent common cause failures control and emergency systems pulse lines must be physically separated.

Moreover modernising several monitoring systems is ongoing: neutron flux, emergency protection, core control and protection system including control rod drives and position indicators.

Conclusion: The modernisation of the instrumentation and control system of the NPP is required to achieve a safety standard acceptable in the EU. Reactor control and emergency systems have to be strengthened to keep the nuclear fuel under control in all design basis accidents and to guarantee information for the reactor crew also under severe accident conditions.

Electrical power supply

Summary: Strengthening the electrical power supply is an important issue for all WWER 1000 reactors. Replacing and modernising DC panels, accumulators, UPS[14], switches, relays and so forth and the modernisation of the auxiliary power supply is required. (A list of the detailed measures is presented in the SUP table 65).

Conclusion: In this field a lot of work is still to be done to achieve the acceptable standard concerning redundancy, separation and diversity.

Containment

Summary: Installing a remote control for tension of the reinforcing cable system of the containment is planned. Also planned is the prevention of early containment bypass resulting from ingress of melting core masses into the channels of the ionizing chambers of the neutron flux monitoring system and the implementation of hydrogen concentration monitoring and mitigation measures in the containment for BDBA conditions.

Conclusion: The containment has two functions: to protect the environment from radioactive contamination e.g. keep the nuclear material inside the building, even in case of a severe accident, and to protect the reactor vessel and the spent fuel pool from external impacts like earthquakes, airplane crashes and the like.

Hydrogen explosions must be prevented to mitigate the risk of containment failure in case of an accident. However protection against external impacts has a low priority in the SUP.

[14] Uninterruptible power supply

Internal hazard

Summary: Strengthening the fire prevention and extinguishing system is more or less completed. Some specific issues have still to be solved.

Conclusion: Regarding fire prevention not all shortcomings were eliminated by 2011. Deterministic and probabilistic safety assessments will give more insight into internal initiating events and will support the development of a higher safety level.

External hazard

Summary: An assurance of seismic resistance of safety relevant equipment is planned.

Conclusion: In the SUP only seismic design is mentioned as a relevant issue to external hazards. In this document the potential impacts were presented site specifically.

6. THE UKRAINIAN STRESS TEST

Earthquake and flood hazard

Ukraine's 'Stress test report' (SNRIU 2011) describes the seismicity of all sites with operating NPPs as follows:

SL 1 (design earthquake= operating basis earthquake): intensity of 5° on MSK 64; probability of exceeding of 1 in 100 years. PGA[15]= 0.05

SL2 (maximum calculated earthquake = safe shutdown earthquake): intensity of 6° on MSK 64; probability of exceeding of 1 in 10 000 years. SL2 is the safety relevant indicator to prevent disaster by earthquake.

In the report (SNRIU 2011) it is stated that seismic investigations were conducted "in accordance with IAEA recommendations and state-of-the art international practice, to specify the seismic hazards of Ukrainian NPPs sites, additional instrumental seismic investigations were conducted:

- 1999-2001 - Khmelnitsky NPP and Rivne NPP sites
- 2009-2010 - South Ukraine NPP site
- starting from 2011 – seismic investigations at the Zaporizhzhya NPP are ongoing".

The results of the additional instrumental investigations confirm the design basis. Only for SUNPP site the PGA was found to be higher than the original design basis: 0.093g instead of 0.06g. The SNRIU board decided to establish an engineering margin of 30 percent of PGA=0.093g for seismic assessments of SSCs i.e. PGA= 0.12g is accepted.

[15] Peak ground acceleration

The method to derive the maximum PGA for the site from the monitoring data is not clear. If a safety margin of 30 percent is decided for SUNPP, why is it not also required for the other sites?

In highly active areas, where both earthquake and geological data consistently reveal short earthquake recurrence intervals, periods on the order of tens of thousands of years may be appropriate for the assessment. In less active areas, it is likely that much longer periods are appropriate (IAEA 2010). The German authorities use the SL2 recurrence period of 100.000 years instead of 10.000 years in Ukraine.

The general approach to seismic hazard evaluation should be directed towards reducing the uncertainties at various stages of the process. Experience shows that the most effective way of achieving this is to collect a sufficient amount of reliable and relevant data. (IAEA 2002).

<u>Loss of containment integrity has been modeled with the following result</u>:

WWER 1000/V320 threshold value is PGA = 0.17g

WWER 1000/V302 & V338 threshold value is PGA = 0.15g

WWER 440/V213 threshold value is PGA = 0.185g.

Seismic qualification of equipment is still ongoing in the NPPs.

<u>A dam break resulting from an earthquake is a hazard for a NPP site :</u>

<u>Zaporizhia NPP:</u> Break of a Dnieper dam upstream from the plant. The elevation of the ZNPP site is 22 metres, while the maximum possible flood level is 19.36 metres. Flood is about 2.6 metres below the site level, however the equipment of the pump stations and spray ponds could fail.

<u>Khmelnitsky NPP:</u> Elevations of the Khmelnitsky NPP site and top of the dam are the same at 206 metres, while the maximum initial level of the flooding wave will be 203 metres. Thus Khmelnitsky NPP structures are located higher than the maximum level of the flooding wave.

<u>Rivne NPP:</u> A break of the water reservoir dam located upstream from the river Styr may be a potential cause of an earthquake-driven flooding of the Rivne NPP. The water level near the Rivne NPP water intake area will hardly increase (no more than one-tenth of a metre) in the event of break of the water reservoir dams, given that water flow spreads along the riverbed. The analyses and assessments demonstrate that the Rivne NPP site is resistant to external flooding.

<u>South Ukraine NPP.</u> The rise of water levels at the Yuzhny Bug river does not pose a hazard for buildings and structures located on the South Ukraine NPP site since its level at 104 metres is more than 70 metres higher than the water level in the river.

Indirect consequences of earthquakes and floods could be fire and flooding by failure of pipes or tanks. Runoff water from flood waves or heavy rain could flood basement floors, and electrical equipment of safety relevant systems including switches and pumps could fail.

A conclusion of the stress test is that the Ukrainian nuclear authority requires the complete implementation of the following measures as a mandatory condition for the lifetime extension beyond 30 year for Ukrainian NPPs (SNRIU 2011):

1. Ensure robustness of equipment, piping, buildings and structures required for the main safety functions to seismic impacts not less than 0.1 g (0.12g for South Ukraine NPP)
2. Ensure performance of equipment for the main NPP safety functions in "harsh" environments
3. Implement containment venting systems at WWER-1000 plants
4. Implement measures to ensure SG and spent fuel pool cool down under long-term station blackout and/or loss of ultimate heat sink.
5. Introduce at NPP units:

Severe accident management guides relating to core and spent fuel pools and

symptom-based emergency operating procedures for shutdown states.

For the EU NPP stress test, the Ukrainian nuclear authority has already defined some measures that are to be **completely** implemented at the NPPs if the operator wants to apply for lifetime extension. The ENSREG stress test peer review is still ongoing and while the outcomes will be published in April 2012, official EU results are not expected before June 2012. The report could demand further analysis and measures and might bring new insights and subsequent safety measures. To fulfill WENRA and IAEA safety reference levels, more improvements might be required for the Ukrainian NPP fleet e.g. containments are not designed to resist crashes of commercial airlines.

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ANNEX 1

Possible argumentation for the Espoo Convention covering severe accidents beyond the design base

Article 1, item (vii), defines impact as "any effect caused by a proposed activity on the environment", and article 1, item (viii), defines transboundary impact as "any impact not exclusively of global nature".

The UNECE publication *Current Policies, Strategies and Aspects of Environmental Impact Assessment in a Transboundary Context* (ECE/CEP/9) provides an important resource for determining the significance of a transboundary impact. Part three, chapter II, on "Significance" of adverse transboundary impact, states: "Many risks related to transboundary impacts are characterised by low probability. Thus, there would be no or very weak empirical justification for analysis based on frequencies. For example, estimates of risks of nuclear accidents ... could only to a limited extent be based on empirical data for frequency of occurrence. A systematic evaluation of potential impacts of low probability and of factors influencing the probability is likely to be important" (pp. 49–50).

Furthermore, annex II of the report by the secretariat, "Specific Methodologies and Criteria to Determine the Significance of Adverse Transboundary Impact" (CEP/WG.3/R.6), which provides a tool for determining the significance of impacts, recommends in supra note that "if significant impacts are expected only in the event of an accident, the full table can be filled in to illustrate the worst case scenario."

In addition, the EIA checklist regarding NPPs, presented on the UNECE website, suggests that radioactive emissions and their impact on human health and safety should be assessed on the basis of listed factors like risk of nuclear accident, risk of explosion, and so on.

The inclusion of severe accidents is of importance since it has effects on the scope of the EIA, but more importantly, it directly relates to the scope of the application of the Convention. Not covering severe accidents means weakening the Convention and its goals, especially in the context of NPPs.

…

From: Background note on the application of the Espoo Convention to nuclear energy- related activities (UNECE 2011)

ANNEX 2

Nuclear energy: controversial energy and its environmental record

1. Nuclear is not necessarily low-carbon energy

Like many others, the EBRD in the past year regards nuclear power as a low-carbon energy source. While this is debatable, decreasing ore grade might prove this wrong, and uranium in Ukraine is certainly not of highest grade. The LCA study on the life cycle of nuclear power concluded: "The contribution of nuclear power to climate protection is relativised when taking into account the declining ore grades: Nuclear power can be referred to as "low-carbon" when the ore grade are high (0,1 bis 2 %). However, ore grades around 0.01 percent increase CO2 emissions up to 210 g CO2/kWhel. While those emission values are still lower than those of coal or oil (600–1200 g/kWhel), they are significantly higher than for wind (2,8–7,4 g/kWhel), hydropower (17–22 g/kWhel) and photovoltaics (19–59 g/kWhel)." (WALLNER et.al. 2011)

2. Other unresolved, major problems of nuclear energy production:

- No **final repository** is available to store the already 245.000 tons of spent fuel elements worldwide.
- **Accident liability** is unresolved. NPPs are legally exempt worldwide from the liability for catastrophic accidents. In the end the state pays i.e. the taxpayer, as was again the case of the Fukushima disaster.

Japan might stop using nuclear power by April 2012

Even in Japan, nuclear power proponents are becoming rare. After the Fukushima nuclear disaster public opinion turned critical toward nuclear power companies, and local residents near NPPs began demanding the expansion of safety agreements between their municipalities and power companies. As a result, it has become increasingly difficult for an electric power company to meet the requirements for restarting a nuclear reactor, with a local municipality's consent.

In response to this situation, Yukio Edano, Minister of Economy, Trade and Industry, announced that the government is planning to meet electricity demand during the summer of 2012 without operating a nuclear reactor or imposing an order to restrict electricity consumption. This announcement came after a government think tank, the Japan Institute of Energy Economics, estimated that electricity supply would be only 7 percent short of peak demand even in case of an unusually hot summer.

ANNEX 3

Structures, Systems and Components (SSC)

1.1.1 Systems performing safety functions:

- reactor scram system
- high-pressure injection system
- low-pressure injection system
- ECCS hydroaccumulators
- primary makeup and letdown system
- primary overpressure protection system
- primary steam-gas mixture removal system
- SG emergency feedwater system
- auxiliary feedwater system
- secondary overpressure protection system
- containment spray system
- isolation valve system
- essential service water supply system
- auxiliary power supply system
- common-unit reliable power supply system
- air-conditioning and ventilation systems

1.1.2 Buildings and Structures

- Reactor building
- Auxiliary building
- Turbine hall
- Emergency diesel generator building
- Auxiliary building ventilation stack
- Auxiliary building, fresh fuel storage
- Boron solution storage building
- Spray ponds, cooling towers (essential service water system)

ANNEX 4

Safety Issues for WWER 440/213 Nuclear Power Plants

CATEGORY III & II (IAEA 1999)

1.1.3 General

III Qualification of equipment

II: Classification of components,

Reliability analysis of class 1 and 2 systems

1.1.4 Reactor core

II: Prevention of uncontrolled boron dilution

1.1.5 Components Integrity

III: Non-destructive testing

II: Reactor pressure vessel integrity,

Primary pipe whip restraints,

Steam generator collector integrity

Steam generator tube integrity

1.1.6 Systems

III: ECCS sump screen blocking,

Feedwater supply vulnerability

II: Primary circuit cold overpressure protect ion

Mitigation of a steam generator primary collector break

Reactor coolant pump seal cooling system

Pressuriser safety and relief valves qualification for water flow

ECCS suction line integrity

ECCS heat exchanger integrity

Steam generator safety and relief valves qualification for water flow

Steam generator safety and relief valves performance at low pressure

Main control room ventilation system

Hydrogen removal system

Primary circuit venting under accident conditions

Essential service water system

1.1.7 Instrumentation and Control

II: I&C reliability

Review of reactor scram initiating signals

Human engineering of control rooms

Physical and functional separation between the main and emergency control

Primary circuit diagnostic system

Reactor vessel head leak monitoring system

Accident monitoring instrumentation

Technical support center

1.1.8 Electrical power supply

II: On-site power supply for incident and accident management

Emergency batteries discharge time

1.1.9 Containment

III: Bubbler condenser behavior at maximum pressure difference under LOCA2

II: Bubbler condenser thermodynamic behavior

Containment leak rates

Maximum pressure differences on walls between compartments of hermetic boxes

1.1.10 Internal hazards

III: Fire prevention

hazard due to high energy pipe breaks

II: Systematic fire hazards analysis

Fire detection and extinguishing

Mitigation of fire effects

1.1.11 External hazards

III: Seismic design

II: Man induced external events

SUP measures for WWER 440/213 - RNPP1/2 (Energoatom 2011)(Priority I & II)

1.1.12 General

I Qualification and documentation of components and equipment - still ongoing

1.1.13 Reactor core (new measures)

II Use second generation fuel to reduce neutron fluence on RPV walls

Modernisation of SNF cooling pool re-racking for compact storage

1.1.14 Components integrity (new measures)

I Implementation of "leak before break concept" for primary core cooling circuit Accident management for PRISE[16] with diameter 100 (completed)

II Monitoring program for the RPV performance to exposure of metal specimens in the core **"to extend power units operation lifetime" (**table 67**)**

1.1.15 Systems

I Modernisation of the SG pipes monitoring equipment (ongoing)

Improvement of emergency power supply (at reactor low power and shutdown state) (completed)

Implementation of a redundant possibility to remove decay heat with LP ECCS[17] (completed)

1.1.16 Instrumentation and Control

I Hydrogen monitoring system in SG, MCP and pressurizer compartments (ongoing)

1.1.17 Electrical power supply

I Modernisation of the accumulators for the safety systems (planned)

Modernisation of switches, relays, DC panels (ongoing)

Modernisation of UPS[18] units (ongoing)

Modernisation of auxiliary power supply system (planned)

Installation of the secondary standby auxiliary transformer (ongoing)

1.1.18 Internal hazards

II Modernisation of automatic fire alarm system (ongoing)

installation of a fire line system with steel pipes and steel valves (ongoing)

1.1.19 External hazards

II seismic monitoring equipment (ongoing)

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[16] Primary to secondary coolant leak

[17] Low pressure emergency core cooling system

[18] Uninterruptible power supply

ANNEX 5

The Energy Strategy of Ukraine until 2030: nuclear energy sector

Chapter IV of the Ukrainian energy strategy till 2030 (UKRAINE 2006) addresses the development of the nuclear power industry.

In 2005 the installed Ukrainian NPPs provided about 50 % of the electricity produced in Ukraine. This share of the nuclear power is to be kept up for the period of 2006-2030. This decision is justified by the presence of domestic uranium deposits, the stable operation of the NPPs and the option to construct new NPPs.

In 2030 according to the Energy Strategy 7 units will have received a license for life time extension by 15 years: ZNPP 3-6, RNPP 3, KhNPP 1, SuNPP 3 and 2 units, which started operation in 2004 KhNPP 2 and RNPP 4. This is not enough, additional 20 GW of new nuclear capacity would need to be installed.

The findings of the ENSREG stress test results might also require the implementation of new safety measures in the Ukrainian NPPs.

The Ukrainian nuclear development strategy has the following objectives:

1. Commissioning two new reactor units at KhNPP 3 and 4 is planned for 2016.
2. Decreasing the timeframe from 12 to three years for siting, licensing, constructing and commissioning new plants scheduled for operation in 2021.
3. Enhancing fuel efficiency by prolongation of the fuel load cycle from three to five years.
4. Finding new nuclear fuel suppliers. Besides the Russian facilities that have until now supplied Ukraine, Westinghouse manufactured test assemblies for SuNPP3.
5. Increasing its domestic uranium production, with the goal of producing enough uranium to supply all its NPPs.
6. Concerning radwaste and spent fuel, Ukraine has not yet developed a management strategy. Currently all radioactive waste is stored in the interim storages at the individual plants. This so-called "deferred" solution is applied for SNF management i.e. long-term, (50 years and more) dry storage – to retain the final decision of recycling or direct final disposal.
7. The strategy lacks concrete plans for future decommissioning of plants which are shut-down at the end of their (extended) lifetime. The strategy states "It is necessary to ensure the efficient decommissioning of NPP units after completion of their operational life and timely construction of new facilities to complement

and replace those that are decommissioned." There is no plan to accumulate funds for the decommissioning and the radioactive waste storages that will be needed.

Are lessons of Chernobyl learnt?

The Ukrainian government obviously did not learn lessons from the Chernobyl accident. In spite of having lost four large reactor units, the idea that the other NPPs would continue to operate safely persisted. The accident at Chernobyl in 1986 not only destroyed unit four by the power excursion but also three more units had to be shut down because of high radiation levels at the site. In addition, the 30 kilometre zone had to be evacuated and 600.000 people – the so-called liquidators – had to be transported tothe site to bring the destroyed reactor to a more or less safe state. Moreover, contaminated land made agriculture and living impossible, and most equipment used for decontamination had to be disposed of as radioactive waste. Many people suffer from radiation-related illnesses, including thyroid issues like cancer; leukemia and other diseases). Radioactive particles could be found in most of Europe, and in some regions, substantial contamination occurred as in Sweden, Bavaria and in the alpine area of Austria.

The Chernobyl accident necessitated that the nuclear community prove that NPPs in all European countries are safe, focusing in particular on NPPs designed in the Soviet Union. The result of the safety assessments under IAEA's leadership was a series of "Green Books" for safety improvements of all types of WWER and RBMK reactors. These constitute the basis of improvements also for the Ukrainian WWERs.

Fuel development

One of the main SUP objectives is the introduction of second-generation fuel with improved cycles in order to reduce the risk of fluence on the reactor vessel. The change to longer fuel cycles is not mentioned in the SUP, but is an objective of the energy strategy.

The economics of a nuclear power plant can be improved by leaving the fuel elements longer in the core. Part of the economic optimisation strategy for NPPs is to raise the enrichment of the fuel elements and reach higher burn-ups. High burn-up over 50 MWd/kg causes higher fuel tube cladding corrosion and high release of fission gas from the fuel pellets. The changes induced by the high burn-up can negatively influence the core cooling during accidents.

Longer fuel load cycles are economically efficient, but the time between inspections in situ is also prolonged. This can have a negative impact on safety because cracks and faults in places that cannot be inspected during operation could be detected too late.

The international trend is towards a combined lifetime extension and power uprate. This makes the NPP operation more profitable, however, also increases the operational risk in most cases. The originally-designed lifetime for VVER reactors was 30 years. If the intention is to keep NPPs in service for 45 (or even 60 years), it would have been necessary to impose different requirements concerning the material as well as the documentation. Power uprate causes accelerated aging of the plant, and this will cause problems in NPPs where the power uprate was performed after decades of operation.

Fuel supply

Ukraine now seeks new nuclear fuel suppliers. Besides the Russian facilities that have supplied Ukraine until the present, Westinghouse manufactured test assemblies for SuNPP 3. Since the first load at the Temelin NPP reactors 1 and 2 in 2002 -2003, both units used fuel assemblies made by Westinghouse. Several problems occurred at both units, including corrosion (grid to rod fretting), fuel assembly bow, and twist and growth. The result of this deformation was that control rod insertion was incomplete. This phenomenon was studied by Westinghouse, changes were made and the problem with control rod insertion was solved. But the grid to rod fretting problems continued. Since 2010, a new type of fuel - TVSA-T from Russian company TVEL - has been used at unit 1. A program for post-irradiation inspection was used at Temelin. The research center REZ, Temelin and Westinghouse have cooperated on fuel inspection and repair (MALA et.al). After ten years of operation with fuel from Westinghouse, the Czech utility CEZ reported in July 2011 that the NPP has completed its changeover to TVEL fuel from Russia. In 2006 the TVEL company won the tender for the fuel supply at Temelin until 2020(CEZ 2011). The experiences with Westinghouse fuel for VVER 1000 reactors was not encouraging, and Ukraine has the possibility to draw lessons from the experiences at Temelin NPP.

Fuel production

Ukraine is looking to increase uranium production to supply its reactors with its own uranium. The plan is to increase uranium production beyond 1000 tonnes in 2011. The increase is to be supplied by "industrial scale" mines in the Kirovograd and Dnipropetrovsk regions. Together the three operating mines in Ukraine hold deposits of about 150.000t uranium ore with an ore grade of 0.1 - 0.2 percent. The third mine deposit originally held a maximum of 25.000 t with an ore grade of 0.05 – 0.1 percent. Two deposits are now under development: - one with a maximum of 100 000 t and an ore grade between 0.1-0.2 percent and another one with a maximum 25.000 t and an ore grade between 0.5-1 percent. (UDPO.UA REPORT)

From 100 000 tonnes of uranium ore with an ore grade of 0.1 percent uranium, about 100t uranium can be extracted. A lot of radioactive waste rock amasses at the mine that is hazardous to the environment. The lower the ore grade the more energy is needed for extraction. Uranium extraction of ore grades less than 0.01 percent needs more than 50 percent of the energy that could be generated with this amount of uranium. Probably no energy can be gained from the fuel cycle once the ore grade is as low as 0.008 percent. (WALLNER et.al. 2011)

While there are also plans for a fuel fabrication plant, Ukraine will abstain from uranium enrichment.

Management of spent nuclear fuel and radioactive waste

Ukraine has not yet developed a management strategy for radioactive waste and spent nuclear fuel. Currently all radioactive waste is stored in interim storages at individual plants. The so called "deferred" solution is applied for SNF management, i.e. long term (50 years and more) dry storage – to keep open the final decision of recycling or direct final disposal. The construction of new NPP units in the Ukraine without a specified program for the siting and construction of safe repositories for radioactive waste and spent nuclear fuel is irresponsible.

New NPPs for Ukraine

Shortening the building period for new NPPs in Ukraine down to only three years for siting, construction and all necessary licensing procedures is unrealistic. Even the Russian reactor construction companies need six years to build and commission a new reactor.

ANNEX 6

Safety issues for small series WWER 1000/ 308, 338 - SUNPP 1/2 CATEGORY III & II (IAEA 1999)

1.1.20 General

III Qualification of equipment

II: Classification of components,

Reliability analysis of class 1 and 2 systems

1.1.21 Reactor core

II: Prevention of inadvertent boron dilution

Control rod insertion reliability/Fuel assembly deformation

1.1.22 Component integrity

III: RPV embrittlement and its monitoring

Non-destructive testing

Steam generator collector integrity

Steam and feedwater piping integrity

II: Primary pipe whip restraints

Steam generator tube integrity

Structural integrity related monitoring

1.1.23 Systems

III: ECCS sump screen blocking

Feedwater supply vulnerability

Physical separation and functional isolation of the ECCS

II: Primary circuit cold overpressure protection

Mitigation of a steam generator primary collector break

Pressurizer safety and relief valves qualification for water flow

ECCS heat exchanger integrity

Steam generator safety and relief valves qualification for water flow

Ventilation system of control rooms

Hydrogen removal system

Limited boron acid storage for HP injection

1.1.24 Instrumentation & Control

III: Reactor protection system redundancy

II: I&C Reliability

Human engineering of control rooms

Primary circuit diagnostic systems

Accident monitoring instrumentation

Technical support center

Separation of the primary circuit instrumentation taps to I&C detectors

1.1.25 Electrical power supply

III: Emergency batteries discharge time

II: On-site power supply for incident and accident management

Ground faults in DC circuits

1.1.26 Internal hazards

III: Fire prevention

II: Systematic fire hazards analysis

Fire detection and extinguishing

Mitigation of fire effects

Protection against flood for emergency electric power distribution boards

Protection against the dynamic effects of main steam and feedwater line breaks

Polar crane interlocking

1.1.27 External hazards

II: Seismic design

Man induced external events

ANNEX 7

SUP measures for WWER1000 /302, 338 - SUNPP 1/2

(Priority I & II (ENERGOATOM 2011)

1.1.28 General

I Elaboration of the materials and certification of the power unit elements

(ongoing)

1.1.29 Components integrity

I Prevention of consequences related to the secondary piping break outside the containment (ongoing)

Elaboration of the organiaational and technical measures to manage accidents the primary to secondary

II Protection reliability enhancement of the primary circuit from high pressure in cold state (ongoing)

Implementation of the “leak before break” concept for the primary RCP

(planned)

Implementation of the upgraded ECCS heat exchanger density diagnostic system (planned)

Assessment of the technical state and the lifetime of the reactor pressure vessels during operation (ongoing)

Implementation of equipment to upgrade main reactor flange pressurisation

(planned)

1.1.30 Systems

I Implementation of an automatic system of the vortex-current control of the heat-exchange pipes and steam generator SG-collectors bridges (planned)

Replacement of the SG safety valve with certification on steam, water & mixture for emergency pressure release from SG (planned)

Increase of the reliability of heat removal from the primary circuit (including the “blowdown-makeup”) (ongoing)

Modernisation of the LP and HP ECCS to control discharge pressure under primary system pump operation (ongoing)

Assurance of the working capacity of the fast acting release station and assurance of reliable performance of the emergency pressure release (ongoing)

II Introduction of the complex diagnostic system of the RF (ongoing)

1.1.31 Instrumentation & Control

II Instrumentation for BDBA conditions (ongoing) monitoring of primary circuit pipes movement (planned)

Monitoring of primary circuit pipes leaks (ongoing)

in-core monitoring of fuel (ongoing)

Modernisation of the emergency diesel generator control system (planned)

1.1.32 Electrical power supply

II Modernisation of power supply and accumulator systematic (planned)

Modernisation, replacement & complementation of cables, switches, relays and other equipment for normal operation and accident conditions (planned)

1.1.33 Containment

II Implement hydrogen monitoring system for BDBA conditions & measures to decrease hydrogen concentration (ongoing)

supply remote control of the tension of the reinforcing cable system of the containment (ongoing)

Internal hazards

I Measures related to leak detection and prevention inside the NPP in case of pipe break (ongoing)

Physical separation by a access and protection from fire (ongoing)

II Modernisation of the fire alarm system in the rooms with safety systems (planned)

automatic monitoring system of the oil filled equipment in the power distribution system (planned)

External hazards

II assurance of the seismic resistance of SSCs relevant for safety (ongoing)

ANNEX 8

Safety issues for WWER 1000/320 ZNPP1-6 K 1/2, RNPP 3/4, SUNPP 3 CATEGORY III & II (IAEA 1999)

General

III Qualification of equipment

II: Classification of components,

Reliability analysis of class 1 & 2 systems

Reactor core

III: Control rod insertion reliability/Fuel assembly deformation

II: Prevention of inadvertent boron dilution

Subcriticality monitoring during reactor shutdown conditions

Component integrity

III: RPV embrittlement and its monitoring

Non-destructive testing

Steam generator collector integrity

Steam and feedwater piping integrity

II: Primary pipe whip restraints

Steam generator tube integrity

Systems

III: Steam generator safety and relief valves qualification for water flow

II: Primary circuit cold overpressure protection

Mitigation of a steam generator primary collector break

Reactor coolant pump seal cooling system

Pressurizer safety and relief valves qualification for water flow

ECCS sump screen blocking

ECCS water storage tank and suction line integrity

ECCS heat exchanger integrity

Steam generator safety valves performance at low pressure

Ventilation system of control rooms

Hydrogen removal system

Instrumentation & control

III: Reactor vessel head leak monitoring system

II: I&C reliability

Human engineering of control rooms

Control and monitoring of power distributions in load follow mode

Primary circuit diagnostic systems

Accident monitoring instrumentation

Technical support center

Electrical power supply

III: Emergency battery discharge time

II: On-site power supply for incident and accident management

Containment

II: Containment bypass

Internal hazards

III: Fire prevention

II: Systematic fire hazards analysis

Fire detection and extinguishing

Mitigation of fire effects

Flood protection for emergency electric power distribution boards

Dynamic effects of main steam and feedwater line breaks

Polar crane interlocking

External hazards

II: Seismic design

Man induced external events

SUP measures for WWER1000 /320 - ZNPP 1 KNPP 1/2, RNPP 3/4, SUNPP3; Priority I & II (Energoatom 2011)

General

I Elaboration of the materials and certification of the power unit elements (planned & ongoing)

Reactor core and fuel

II mitigation of core damage risk during refueling (planned)

replacement of shelves in the SNF in cooling ponds (completed in 7 units)

Components integrity

I Elaboration of the organisational and technical measures to manage accidents; the primary to secondary coolant leak with equivalent cross-section diameter 100 mm (planned & ongoing)

II Increase of the primary circuit overpressure protection reliability in cold state

(completed in 8 units)

Implementation of the “leak-before-break” concept for primary circuit

(completed in 2 units)

Prevention of the consequences related to secondary piping break outside containment (completed in 9 units)

Implementation of improved diagnostic system of the ECCS active core tightness (completed in 4 units)

Assessment of state and lifetime of RPV (completed in 3 units)

Improvement of the reactor joints and connections (completed in 4 units)

Systems

I Modernisation of safety channels actuation to control negative reactivity and prevent repeated criticality. (completed in 6 units)

Replacement of the SG safety valve with certification on steam, water & mixture for emergency pressure release from SG (completed in 9 units)

Duplication of the residual heat removal system (completed in 8 units)

Modernisation of the LP and HP ECCS to control discharge pressure under primary system pump operation (planned and ongoing)

II Emergency procedure: substantiate the mode of HP and LP ECCS operation from the adjacent sump through the schedule cool down line without emergency cool down heat exchanger. (completed in 6 units)

Prevention of simultaneous introduction of positive reactivity from two or more ways (completed in 8 units)

Assurance of the possibility to actuate the blow-down-makeup system in case of the containment localisation and assurance of the automatic actuation of the boric concentrate in case of the primary circuit leakage (completed in 2 units)

Automatic bypassing of the blocking for MSIV shutting upon the transfer of the fast acting reducing station with steam discharge into the atmosphere into the cooling mode (planned)

Enhancement of the reliability of the heat sink from primary system (completed in 8 units)

Introduction of a complex diagnostic system for reactor control (completed in 2 units)

New places to monitor boron concentration in primary circuit (completed in 4 units)

Implementation of an "in-process" cleaning system for service water spraying pools of vital parts (completed in 2 units)

Modernisation of the "periodic" and "permanent" steam generator blow down system to prevent defects in joints of SG headers (completed in 8 units)

1.1.34 Instrumentation & Control

II Instrumentation for accident conditions (planned & onoging)

Monitoring of the movement of primary circuit pipe lines (completed in 2 units)

Modernisation of the generator hydrogen cooling system control (planned)

Prevention of a common-cause failure of control and emergency protection systems resulting from absence of physical separation of pulse lines (completed in 5 units)

Modernisation of the neutron flux monitoring system (completed in 5 units)

Modernisation of the emergency protection system (completed in 7 units)

Modernisation of the control and protection system (CPS) control rod (CR) drives, including electromagnet units and position indicators (completed in 7 units)

Information system for DBA and BDBA (completed in 8 units)

Electrical power supply

I Replacement of 6kV switches for safety systems (completed in 2 units)

Modernisation of the emergency power supply system, including DC panels and batteries (planned and ongoing)

Modernisation of in-house 6 kV system (completed in 1 unit)

Modernisation of 0,4 kV distribution devices (planned and ongoing)

Modernisation of relay protection and automation circuits (planned)

II Replacement of 0,4 and 6 kV motors in safety systems (completed in 1 unit)

Modernisation of containment penetrations for power and control cables (ongoing)

Containment

I Prevention of the early containment bypass resulting from ingress of melt core masses into channels of NFMS ionizing chambers. Modernise reactor cavity doors (planned)

Monitoring of hydrogen concentration and mitigation measures in the containment under BDBA conditions (planned)

II Supply remote control of tension of the reinforcing cable system of the containment (planned)

Internal hazard

II automatic monitoring system of the oil-filled equipment in the power distribution system (planned)

Improvement of MSIV1 to ensure resistance to internal and external impacts (planned)

External hazard

II assurance of seismic resistance of safety relevant equipment (planned)