Answers to the questions in the report number REP-0947 - *ENVIRONMENT IMPACT ASSESSMENT NPP CERNAVODĂ 1 AND INTERIM WASTE STORAGE (ROMANIA) - EVALUATION OF ANSWERS*, attached to the letter with the subject *Espoo Convention, Cernavodă NPP (refurbishment of unit 1 and extension of intermediate dry spent fuel storage), Expert evaluation* and the reference number: 2024-0.908.731, received by the Ministry of Environment, Waters and Forests of Romania, on the 12.12.2024, from the BMK - Department V/11 (Plant-related Environmental Protection, Environmental Assessment & Air Pollution Control) of the Federal Ministry of the Republic of Austria

1) Q1-1) Based on your answer, we would like to know what will happen if the dedicated RW storage (DIDR-U5) is not be ready on time?

Answer: The new RW storage facility (DIDR-U5) will be available in due time to receive materials resulted from the U1 refurbishment activities.

The EIA has been conducted integrating all Unit 1 refurbishment activities, both those that will be executed prior the refurbishment outage (which include DIDR-U5 sub-project, other civil office buildings and warehouses, site infrastructure (site-internal roads, access points, and so on), as well as those that will be executed during the refurbishment outage. Taking this into account, all the refurbishment activities of Unit 1 will be carried out through a single EPC (Engineering, Procurement, Construction) contract. Through the EPC contract, the planning of the refurbishment activities execution will be integrated, based on the technological and regulatory sequentially, and the start of each activity will be conditioned by the completion of the previous activity (for example: no activity will be started that requires the storage of radioactive waste if there is no available approved location for their storage).

2) Q4-1) Our question was related to the external consultation process (not with the national public). Could you therefore answer the question what would happen if, during the Espoo consultations, a negative opinion from the public of the countries potentially affected is received?

Answer:

Regarding the environmental licensing procedure, as both the internal and the external consultation process are managed by the Ministry of Environment, Waters and Forests and the external consultation is an integral part of the EIA procedure, the review of the results of the internal and external consultation process is submitted to the Technical Advisory Committee, comprising of the most senior management representatives of all the national authorities and Ministries with responsibilities on environmental matters, which is summoned by the Ministry of Environment, Waters and Forests, for debate and decision. Comments received during the consultation process, internal or external, have equal status in this debate.

Supposing that a negative opinion would be received from the public in the consultation process, the basis for this opinion has to be analysed: if the negative opinion is justified based on valid technical considerations, then the issues are investigated and evaluated by experts in the Committee together with the nuclear regulator in order to determine their significance in relation to the national legislation and international standards and the best actions are decided, giving nuclear safety and radiological protection the first priority; if the negative opinion has no technical grounds, an explanation of the technical criteria for decision-making is provided and a reason for not taking additional actions based on that particular opinion. All the comments, proposals, recommendations, suggestions and opinions, as well as their resolutions, are made public.

3) Q5-1) We did not ask to see the Safety Assessment Report of the Cernavodă NPP, but the results of the nuclear safety analyses updated for the long-time operation of U1; based on your answer, we understand that these analyses are not ready yet. On what basis was the validity period of the operation license of the Cernavodă NPP U1 extended until 2061?

Answer:

The regulatory framework for the operation licensing process is following the nuclear law provisions (Law 111/1996 updated) and the CNCAN Nuclear Safety Norm 22 (NSN-22- see link - Licensing of Nuclear Facilities **) issued by CNCAN Order *no. 336/2018 for the approval of Regulations for licensing of nuclear facilities*. Specifically, within NSN-22, the actual operating license of U1 is in accordance with the provisions, limits and conditions stated generally in Section 6 "Operating License"**. There are specific requirements addressing operating license management within a long outage for unit refurbishment. The specific requirements following the NSN-22 provisions are detailed under the *General Limits and Conditions* section of the Operating License of U1.

The licensing decision is based on the demonstration of the compliance with the dose criteria in the regulations, using the conservative bounding analyses. In order for the licensee to maintain the licenses, the safety analyses need to be periodically verified and revalidated (i.e. shown to be still bounded by the licensing basis analyses), taking into account any design changes, new research results, operating experience and any new computational tools and methods that become available.

For the last operating period of Unit 1, until refurbishment, the safety analyses have been updated to account for the aging effects, to establish updated parameters for the safety systems settings and to reflect the current operating power level (which is lower than 100% full power as considered in the bounding licensing basis analyses).

The bounding safety envelope provided by the licensing basis analyses remains unchanged, but, at the same time, **the licensee is required by legislation to periodically review, revise and update the safety analyses and the operational limits and conditions, at least every 10 years and each time there are relevant modifications**, to demonstrate that design basis and licensing basis remain valid**. This approach is in line with the international standards.**

The validity period of **the operating license of the Cernavodă NPP U1 has been extended based on the bounding safety analyses, which are not affected by the refurbishment**. However, the final safety analysis report (**FSAR) is a living document and is updated on a continual basis**.

An updated FSAR for each unit is submitted to the CNCAN every two years, because design and process upgrades are implemented in accordance with the continuous improvement principle. The updated FSAR contains the safety demonstration for the nuclear power plant, taking into account the physical status of the installation, the impact of ageing, the safety upgrades performed and the current safety requirements, among other factors. **In addition, a PSR is also performed every ten years.**

Some additional considerations on the subject of safety analysis, are summarized below:

The design basis accident analyses for Cernavoda NPP, documented in the Final Safety Analysis Report, which is the main licensing basis document, include the following initiating events and combinations of events:

- loss of regulation / loss of reactivity control;
- LOCA events (large LOCA and small LOCA);
- single channel events (spontaneous pressure tube rupture, channel flow blockage, end-fitting failure, feeder stagnation break);
- fueling machine events;
- pipe breaks in HT auxiliary systems;
- loss of off-site power (complete and partial loss of Class IV electrical power, single heat transport pump trip and seizure of a primary heat transport system main pump);
- loss of heat transport system pressure and inventory control (pressurization events and depressurization events);
- loss of secondary circuit pressure control (pressurization and depressurization events)
- feedwater events (feedwater line breaks outside or inside containment, loss of steam generator feedwater flow);
- steam main breaks outside or inside containment;
- steam generator tube failure;
- multiple steam generator tubes failure;
- combinations of steam and feedwater system events with loss of class IV power (off-site power).
- moderator system events;
- end shield cooling system events;
- design basis earthquake,
- initiating events originating from shutdown state (loss of normal shutdown state heat sink – shutdown cooling system and design basis earthquake).

In accordance with the conservative safety philosophy and design basis approach of the reactor designer (AECL – Atomic Energy of Canada Ltd, currently known as CANDU Energy), the majority of the above-mentioned process systems failures (initiating events) were analyzed for the case in which the ECCS and the containment subsystems are available, and also in combination with various failures/impairments to either ECCS or containment subsystems. Feedwater events and steam main breaks were also analyzed in combination with loss of Class IV power. Large LOCA and small LOCA events are analyzed also in combination with loss of off-site power and with impairments to either ECCS or containment system functions.

The design basis accident analyses have 2 main purposes:

- to demonstrate to the nuclear regulatory authority the compliance with defence in depth and the dose criteria for accident conditions, as established in the national regulations and this includes demonstration of the prevention of severe accidents;
- to provide the basis for the operational limits and conditions, which include the safety systems settings and limiting conditions for operation.

For the first purpose, i.e. for the demonstration of compliance with dose criteria for accident conditions, bounding analyses have been prepared, considering conservatively the maximum inventory of fission products, for an equilibrium core. At the same time, for the second purpose, the safety analyses have been performed and revised at different moments during the operational lifetime of the nuclear power plant, taking into account different operating conditions, such as fresh core, equilibrium core, aged core, in order to adjust the safety systems settings as necessary (but still within the bounds of the design and licensing basis analyses).

After refurbishment, the reactor core will contain fresh nuclear fuel and a very low inventory of radioactive materials, but this is not of interest in the licensing basis analyses, which are done with the most conservative assumptions. What is of interest for the core with fresh nuclear fuel is the establishment of the safety systems settings, based on the calculations for the core reactivity. Before the core will reach equilibrium conditions, the safety analyses will be once again updated, considering all the relevant factors required in the regulations. However, these safety analyses will still remain bounded by the standard licensing basis analyses for a CANDU-6 unit, because the maximum inventory of radioactive materials in the reactor core considered for the equilibrium conditions is the same.

The current licensing basis analyses include also design extension conditions, among which severe accident scenarios and the updates to these analyses need to be performed whenever there are design changes with an impact on these analyses, or there are new computer codes or computational methods developed and validated or new relevant information becomes available.

4) Q6-1) Could you please provide more details (beyond those already provided in the EIAR) on the assessment of the cumulative radiological impact? More precisely,

a. please define the meaning of “minor negative impact” as used in Table 108;

b. please indicate the methodology used for estimating the significance of cumulated radiological impacts (as stated in Table 116).

Answer:

The cumulative impact assessment was carried out by a multidisciplinary team of about 18 experts with recognized competences according to the legislation in force, coming from organizations certified for environmental studies and certified by CNCAN.

The cumulative impact assessment considered the following aspects:

- ✓ Identification of existing and/or proposed projects in the project implementation areas with a potential cumulative impact in relation to the proposed project, on the environmental factors for which the proposed project may generate positive/negative effects;
- ✓ Analyzing the likelihood of these projects to generate cumulative forms of impact (to contribute with additional effects and/or synergistic effects with the project under analysis);
- ✓ Assessing the significance of the cumulative impact.

As defined in the General Guide applicable to the stages of the impact assessment procedure approved by Order No. 269/2020, **the significance of an impact is given by 2 components:**

- **The magnitude of the impact**, which is given by the characteristics of the project and the effects it generates
- **Sensitivity** is understood as the sensitivity of the receiving environment to change, including its capacity to accommodate the changes the Projects may bring about.

The importance of the impact or its overall significance is the result of multiplying the amplitude/magnitude of the impact *(small, medium, large)* by the sensitivity of the receiver *(low, medium, high)*.

The significance of an impact can be: *major (significant), moderate, minor, no impact (or insignificant)*.

As a result, the terms used in the EIA are in accordance with the applicable General Guidelines, respectively:

- **A "no impact or insignificant impact" project** means that the impact does not generate visible or measurable effects on the natural state of the environment.
- **A "minor impact" project** indicates that it has an impact of small magnitude, falls within standards and/or is associated with receptors of low or medium value/sensitivity.

and is determined as follows::

1 Small Magnitude + Low/Medium Sensitivity

2 Medium Magnitude + Low Sensitivity.

See attached Table 11 - *Determination of the significance of the impact according to the magnitude and sensitivity of the receptor*, from the General Guidelines Ord. 269/2020.

Regarding the radiological impact of the U1 refurbishment project implementation and the subsequent operation of the refurbished U1, as well as that associated with the extension and operation of the DICA with MACSTOR 400 modules, the following sensitive receptors were considered as sensitive receptors: the representative person from the population on the one hand

and the natural environment in the vicinity of the plant (with its components: soil, water, air and biodiversity) on the other hand. For the representative population representative person, the estimated annual effective dose due to exposure to radionuclides present in releases of radioactive effluents from the nuclear installation was used as an impact indicator, which was analyzed in relation to its associated dose constraint. From the retrospective analysis, for the whole period of U1 operation, it was observed that this indicator was below 10% of the corresponding dose constraint. For the implementation period of the refurbishment, the estimates were made in relation to predicted emissions based on the experience of other similar refurbishment projects, also resulting in falling, with a significant safety reserve, within the dose constraint set for U1 operation.

Regarding the radiological impact on the environmental factors, both the previous monitoring data and impact studies, as well as the results of the monitoring carried out by the authors of the assessment showed that, under the conditions of operation on the site of the Cernavodă NPP U1 for 27 years and U2, simultaneously with U1, for 15 years, no radionuclides specific to the operation of CANDU reactors, other than tritium, whose activity concentrations were low, could be detected in the environmental compartments in the vicinity of the plant, considering its very low radiotoxicity.

Why is the cumulative effect of all units in operation estimated to be "insignificant":

The assessment of the cumulative radiological impact on the environmental factors, as presented in Table 116 of the EIA, took into account the effects of the impacts presented in the regulatory acts, specific to each approved project that is being carried out or to be developed on the Cernavodă NPP site (e.g. environmental agreements and approval decisions - see Annex 5 to the EIA).

The EIA elaborator has assessed for each stage described in Table 116 whether the impacts of the project subject to this environmental assessment act together with the impacts of other projects to be carried out/developed on the site and whether they affect the same environmental factor or receptor (e.g. combined effect in the area of influence).

As a result, the assessment of the cumulative radiological impact has been carried out on the basis of the worst-case scenario in terms of impact.

According to the analysis, **the projects** described in the table, which are being implemented on the site, could have cumulative effects during the execution phase of the project with ***a temporary, punctiform, local character***, **the potential cumulative impact on the relevant environmental components being estimated as minor**.

The significance of the cumulative radiological impact during the operation of all the nuclear objectives on the Cernavodă NPP site, identified as ***insignificant***, is given by the sum of the positive effects of the CTRF commissioning with the effects of the simultaneous operation of 4 nuclear units on the site. Thus, since the four units are similar, it can be assumed that the impact of their normal operation would be at most double the impact of their current operation, unless the contribution of CTRF to maintaining a low tritium inventory in the active circuits of the four units is taken into account, with the consequence that the radioactive emissions of each unit would be lower than at present. In terms of the exposure of the representative person in the population, it will be at most double the current level, which is still less than 20% of the dose constraint for a single unit, so a minor impact. Also, as regards the impact on other environmental factors, the tritium concentration levels are expected to be at most double the current values (as tritium in the form of tritiated water does not accumulate in the environment), which is still insignificant, considering its very low radiotoxicity.

Regarding the definition of the minor negative effects referenced in Table 108:

The minor negative effects of an impact indicate a discomfort within acceptable limits, for which there are no effects on the health and quality of life of the population, as quantified in the multiple environmental studies approved by both the environmental authority and CNCAN over the last 20 years, studies that were the basis for the issuance of the operating permits for the operation of the Cernavodă NPP.

5) Q8-1) We did not ask to see the Safety Assessment Report of DICA, but the results of the safety analyses will give us the radiological consequences of the potential accidents; could you please provide the results and a description of the scenario used for analyzing the aircraft crash on the DICA event?

Answer:

Various types of aircraft, both civilian and military, were assumed to crash accidentally on the dry spent fuel storage, irrespective of the very low probability of such events. Deterministic accident analyses have been performed with conservative assumptions.

Dry spent fuel storage facilities are not vulnerable to loss of coolant because they are cooled by natural convection that is driven by the decay heat of the spent fuel itself. Thus dry-storage facilities differ from reactors in that their cooling is completely passive. To obtain a release of radioactive material, the walls of the fuel container, storage cylinder and storage module must be penetrated from the outside, or the container must be heated by an external fire to such an extent that the containment envelope fails. However, many dry-storage modules must fail or be attacked simultaneously to produce significant releases.

For the MACSTOR facility it is not physically possible that an aircraft crash would affect more than one storage module. For the purpose of conservative analyses, to support emergency planning for the worst-case scenarios, it was considered that an entire storage module is affected by an airplane crash resulting in a fire. Assumptions were made with regard to the quantity of the aircraft fuel consumed in the fire, the duration of the fire, the height of the release and the meteorological data. Although it is very unlikely that the entire storage module would be uniformly affected by a fire, for the purpose of calculating radiological releases it was conservatively assumed that all the fuel bundles in the storage module at full capacity are damaged.

The results of these deterministic analyses showed that the potential exposure to the population in the vicinity of the site would be below the generic intervention levels for sheltering (10 mSv) and evacuation (50 mSv), based on the average calculated doses. The doses calculated for different scenarios with over 99% confidence are of 100 mSv.

The analyses for various accident scenarios are considered security sensitive documents and are not public documents, therefore no further technical details can be provided. The legal provisions stating the legacy of such information classification are included in the CNCAN Safeguards Regulations (NGN-02-see link - *Detailed list of materials, devices, equipment and information for non-proliferation of nuclear weapons and other nuclear explosive devices*) and/or Government

Decision 916/2002 (updated) completed by provisions of NSN-22 section 2 article 7 ((**NSN-22-see link -** *Licensing of Nuclear Facilities*) **issued by CNCAN** ***Order no. 336/2018 for the approval of Regulations for licensing of nuclear facilities)*** **and the CNCAN Nuclear Security Regulations (NPF-01 – see link :** Nuclear Physical Protection Regulations).

6) Q9-1) A military aircraft crash on DICA is not necessarily a security event; a malfunction could happen and the crash could be unintentional. The fact that a no-fly zone over the Cernavodă site has been established is irrelevant in case of a war, and unfortunately, there is currently a war close to Romanian borders. Could you please provide the results and a description of the scenario used for analyzing the military aircraft crash on the DICA event?

Answer:

We have already mentioned that the structure of a concrete MACSTOR storage module is compact and robust, with significant resistance reserves with a high safety margin for the design loads. These characteristics limit the potential damage induced by an impact of an aircraft on DICA.

The probability of aircraft crash, for both civilian and military aircrafts, is lower than 1E-8 events/year.

Nevertheless, a conservative deterministic analysis has been performed for an event involving an aircraft crash on the dry spent fuel storage, for the purpose of emergency planning and preparedness. Various types of aircraft, both civilian and military, were assumed to crash accidentally on the dry spent fuel storage, irrespective of the very low probability of such events. Deterministic analyses have been performed with very conservative assumptions.

The results of the deterministic analyses showed that, in case of aircraft crash followed by a fire affecting the dry spent fuel storage, the potential exposure to the population in the vicinity of the site would be below the generic intervention levels for sheltering (10 mSv) and evacuation (50 mSv), based on the average calculated doses. The doses calculated for different scenarios with over 99% confidence are of 100 mSv.

These technical analyses for various accident scenarios are considered security sensitive documents and are not public documents. The legal provisions stating the legacy of such information classification are included in the CNCAN Safeguards Regulations (NGN-02-see link - *Detailed list of materials, devices, equipment and information for non-proliferation of nuclear weapons and other nuclear explosive devices*) and/or Government Decision 916/2002 (updated) completed by provisions of NSN-22 section 2 article 7 ((**NSN-22-see link -** *Licensing of Nuclear Facilities*) **issued by** ***CNCAN Order no. 336/2018 for the approval of Regulations for licensing of nuclear facilities)*** **and the CNCAN Nuclear Security Regulations (NPF-01 – see link:** Nuclear Physical Protection Regulations).

Cernavoda NPP emergency plan and procedures include the emergency measures and actions applicable to the DICA facility when it contains the MACSTOR 200 modules and will be extended to apply to a larger site that also contains an added number of MACSTOR 400 modules.

7) Q11-1) According to your answer, severe accidents' analyses have been performed in order to "support emergency planning and preparedness for the population in the vicinity of the site, taking into account lessons learned from the Fukushima Daiichi accident". The Nuclear Safety Directive requires the licence holders to provide for appropriate on-site emergency procedures and arrangements to deal with "accidents and severe accidents that could occur in all operational modes and those that simultaneously involve or affect several units". Could you please specify if such simultaneous accidents have been analysed, and if so, what the results were?

Answer:

Details on the severe accident analyses performed for Cernavoda NPP are provided in response to the last question. The scenarios analyzed cover all the states and modes of operation.

A scenario that would involve simultaneous severe core damage accidents in more than one CANDU unit of the Cernavoda NPP site is not credible. The reactor units are located at more than 150 m one from another, are fully independent (have no shared systems) and have substantial safety margins to cope even with extreme external events significantly beyond the initial design basis.

Notwithstanding, severe accident scenarios that could hypothetically affect both units have been analyzed. Several Station Blackout scenarios, Loss of Ultimate Heat Sink scenarios and the combination of these two categories of scenarios have been analyzed as part of the "Stress Tests" post-Fukushima for the operating units of Cernavoda NPP and safety upgrades have been implemented, as described in the public reports documenting these assessments http://www.cncan.ro/assets/Informatii-Publice/06-Rapoarte/RO-National-Report-for-2nd-Extraordinary-Meeting-under-CNS-May2012-doc.pdf ; https://www.ensreg.eu/EU-Stress-Tests/Country-Specific-Reports/EU-Member-States/Romania .

Accident scenarios that would affect both units are evaluated for the sole purpose of testing and validating the emergency preparedness and response arrangements, including the material resources and the qualified personnel needed for staffing the operating shifts and the shifts of the emergency response personnel, including the technical support group, firefighters, physical protection response force and other categories of personnel with roles and responsibilities in the management of emergency situations.

8) Ask the Romanian counterpart to revise the EIAR by including a section dedicated to the radiological impact assessment, where the radiological consequences of DEC including severe accidents should be presented in sufficient detail to allow a meaningful estimation of the potential transboundary impacts (i.e. with a description of the scenarios used, the source terms considered, and the analysis results in terms of doses to the population up to 1000 km from Cernavodă).

Answer:

According to the nuclear law provisions (Law 111/1996 updated) and the Nuclear Safety Norm 22 (NSN-22-see link - *Licensing of Nuclear Facilities*) issued by *CNCAN Order no. 336/2018 for the approval of Regulations for licensing of nuclear facilities*, completed by Law 292/2018 (regarding environmental assessment for public and private projects), the radiological impact assessment, where the radiological consequences of DEC including severe accidents should be presented in sufficient detail to allow a meaningful estimation of the potential transboundary impacts (i.e. with a description of the scenarios used, the source terms considered, and the analysis results in terms of doses to the population up to 1000 km from Cernavodă) are subject to Nuclear Regulator licensing requirements and developed within the Licensing Basics Documents within the nuclear installation authorization process. As mentioned also above, these detailed assessments and scenarios are not public information and are subject to review and approved by Nuclear Regulator within the licensing process. Therefore, EIAR, developed according with the provisions of Law 292/2018 (aligned to EU applicable Directive) presents only the available public information related to radiological impact assessments and potential impact as required in Appendix 4 of the previously mentioned law.

The following details summarize some information under the restriction of posting it to the public by any means:

The Design Extension Conditions (DEC) analyzed for the Cernavoda NPP units include the following categories:

- DEC–A – including sequences of events leading to limited fuel failures with preserved core geometry; these are scenarios with a frequency of f < 1E-5 events/reactor.year for which the severe core damage and fuel melting can be prevented;
- DEC–B – including sequences of events leading to fuel melt with lost core geometry, also known as severe accidents.

DEC-A

The most challenging scenarios in the category DEC-A include combinations of Large LOCA events (Large Loss Of Coolant Accident scenarios) and subsequent failures of the Emergency Core Cooling System (ECCS) functions and failures in other systems that would otherwise intervene to mitigate de consequences of a LOCA event.

Examples of event combinations analyzed in the DEC-A category:

- Large LOCA coincident with Loss of Class IV power
- Small LOCA coincident with ECCS failures
- Small LOCA coincident with Loss of Class IV power
- Pressure Tube Rupture coincident with ECCS failure
- Channel Flow Blockage coincident with ECCS failure
- End Fitting Failure coincident with ECCS failure
- Feeder Break with ECCS failure
- Main Steam Line Break coincident with ECCS failure
- Main Steam Line Break coincident with Loss of Class IV power

- Feedwater events coincident with Loss of Class IV power
- Design Basis Earthquake coincident with ECCS failure
- Large LOCA coincident with ECCS failure
- Feeder Break coincident with containment impairment

The event combinations in the DEC-A category have been analyzed with conservative assumptions and the two events resulting in the highest effective doses to the population in the vicinity of the Cernavoda NPP site are:

- An event sequence that includes the initiating event 100% ROH (Reactor Outlet Header) Break with Loss of ECCS Injection and Loss of Crash Cooldown, resulting in an effective dose of 164.58 mSv; the estimated frequency of occurrence for this combination of events is less than 1E-7 events/reactor.year;
- An event sequence that includes an End Fitting Failure Coincident with ECCS Impairments, resulting in an effective dose of 173.08 mSv; the estimated frequency of occurrence for this combination of events is less than 1E-6 events/reactor.year.

The doses calculated in the safety analyses for Cernavoda NPP Units represent the maximum effective dose to the most exposed person situated at the limit of the exclusion zone, over a period of 30 days.

The assumptions used in the licensing basis deterministic analyses were deliberately conservative, designed to maximize potential doses and ensure that scenarios requiring protective actions, such as evacuation and relocation, are adequately assessed.

It should be noted that the doses calculated for design basis accidents and for design extension conditions, using the conservative assumptions required in the regulations for the licensing basis analyses, are significantly higher than the doses that would result from calculations with realistic assumptions, because of the following considerations:

- It was assumed that the containment leak rate at maximum design pressure is 5 times higher than the acceptance criterion for the leak rate under periodic test conditions for the same pressure; it should be noted that the maximum design pressure of the containment has a significant margin over any pressure peak that could result from a Large LOCA event coincident with failure of ECCS and of the pressure suppression engineered safety features of the containment system; these assumptions were made to maximize doses, in order to compensate for any potential uncertainties;
- It was assumed that the reactor was operating with a large number of failed fuel elements and with a chronic steam generator tube leak, just for the purpose of maximizing the calculated doses for the population; these assumptions are overly conservative, because in practice any failed fuel is removed as soon as detected and operation with a steam generator tube leak is not permitted;
- The environmental conditions used in the calculation of the doses as part of the licensing basis analyses have been chosen as the most penalizing from the point of view of radiological consequences for the population and no credit was given for any protective measures, in order to yield results for the worst-case scenario and demonstrate that even in such conditions the most exposed members of the public would not suffer deterministic effects; this approach,

aimed at providing a conservative basis for emergency planning and preparedness, has been used in order to ensure that the estimations from the licensing basis analyses cannot be exceeded in case of a real accident, when dose calculations would be made using real time environmental conditions.

Therefore, the source terms used for the calculation of the radiological consequences for design basis accidents and DEC-A scenarios, as well as the effective doses estimated for the most exposed members of the population, are all artificially increased, more than 5 times, for the purpose of obtaining conservative estimates and enable the preparation of protection measures for the population in the vicinity of the plant site, including evacuation and relocation (which would not actually be required for such event scenarios if we would rely on calculations with realistic assumptions).

DEC-B

The scenarios in the category DEC-B include sequences of events initiated by failures in the core cooling systems, or by station blackout, or by total loss of the ultimate heat sinks.

Examples of event sequences analyzed in the DEC-B category:

- **Station Blackout (SBO) events, followed by other system failures:**
  - Loss of class IV & III power + loss of main & auxiliary FW + loss of ECCS + loss of LACs + loss of EWS & EPS
  - Loss of class IV & III power, EPS available, SG crash-cooldown available
  - Loss of class IV & III power, HTS loops isolation available, EWS available, SG crash-cooldown available, ECCS (HP & MP) available
  - Loss of class IV & III power, EPS & EWS available, dousing re-circulation available
  - Loss of class IV & III power, HTS loops isolation available, EWS available, dousing re-circulation available
- **Small Loss–of–Coolant Accident (SLOCA) event, followed by other system failures:**
  - SLOCA + Loss of class IV & III power + loss of main & auxiliary FW + loss of ECCS + loss of moderator & ESC cooling + HTS loops isolation available
  - SLOCA + loss of main & auxiliary FW + loss of ECCS + loss of LACs + moderator & ESC cooling not available
  - SLOCA + loss of main & auxiliary FW + loss of moderator & ESC cooling+ loss of ECCS-LP stage
  - SLOCA + SG crash-cooldown not available + loss of main & auxiliary FW + loss of moderator & ESC cooling + loss of ECCS
- **Feeder Stagnation Break (FSB) event, followed by other system failures:**
  - Loss of class IV & III power + loss of main & auxiliary FW + loss of ECCS + loss of LACs + loss of SG crash-cooldown + loss of EWS & EPS + moderator draining at 200 kg/sec
  - Loss of class IV & III power + loss of main & auxiliary FW + loss of ECCS + loss of LACs + loss of EWS & EPS + moderator draining at 30 kg/sec

    - Loss of main & auxiliary FW + loss of moderator cooling + loss of ECCS + loss of LACs + moderator draining at 200 kg/sec
    - Loss of main & auxiliary FW + loss of moderator & ESC cooling + loss of ECCS + loss of LACs + moderator draining at 200 kg/sec
    - Loss of main & auxiliary FW + loss of ECCS + loss of LACs + loss of moderator cooling + moderator draining at 200 kg/sec
    - Loss of class IV & III power + loss of EWS & EPS + loss of ECCS + loss of main & auxiliary FW + loss of moderator & ESC cooling + loss of LACs + loss of dousing + moderator draining at 200 kg/sec
- **Single Steam Generator Tube Rupture (SGTR) event, followed by other system failures:**
    - Loss of class IV power + loss of main & auxiliary FW + loss of ECCS + loss of LACs + loss of SG crash-cooldown + moderator & ESC cooling not available
- **Multiple Steam Generator Tube Rupture (MSGTR) event, followed by other system failures:**
    - Loss of class IV power + loss of main & auxiliary FW + loss of ECCS + loss of LACs + loss of SG crash-cooldown + moderator & ESC cooling not available

Summary of abbreviations:

EPS – Emergency Power Supply

FW – Feedwater (for the Steam Generators)

HTS – Heat Transport System

ESC – End Shield Cooling

LACs – Local Air Coolers

SG – Steam Generators

SGTR / SGTF – Steam Generator Tube Rupture / Steam Generator Tube Failure

FSB – Feeder Stagnation Break

LOCA – Loss of Coolant Accident

LLOCA – Large LOCA

SLOCA – Small LOCA

ECCS – Emergency Core Cooling System with 3 stages: HP (High Pressure), MP (Medium Pressure) and LP (Low Pressure – recirculation).

Bounding scenarios selected from the above-mentioned DEC-B event sequences have been analyzed deterministically, with conservative assumptions made on the performance of the containment system and on the operation of the Emergency Filtered Containment Venting System (EFCVS). The estimated source terms to the environment have been calculated based on conservative assumptions, including scenarios in which the containment isolation fails and scenarios in which the containment is overpressurized and the EFCVS system is not used (although it is available and it cannot be impaired by severe accidents), eventually causing the containment airlock seals to fail due to overpressure, resulting in unfiltered releases.

For example, the scenario resulting in the largest release of the Cs-137 radioisotope to the environment was an event sequence initiated by SBO (Station Blackout) with containment failure due to overpressure (no credit was given for the operation of EFCVS and the airlock seals were assumed to fail and result in unfiltered releases). The source term calculated for this scenario was 5.14E+02 TBq (or 0.514 PBq) of Cs-137 and the doses for the most exposed members of the population have been calculated for a period of 30 days. This represents a release of approximately 1% of the entire core inventory of Cs-137 of a CANDU-6 reactor. Such an accident scenario has a conservatively calculated frequency of occurrence of less than 1E-6 events/reactor.year.

The estimated doses to the population have been calculated based on the conservative assumptions that no protective measures were implemented (no sheltering, no administration of potassium iodide pills and no evacuation) and the most unfavorable environmental conditions were considered. Also, as required by the regulations, the estimated doses represented the highest 95th percentile individual doses to the most exposed individuals.

The purpose of the above-mentioned conservative deterministic analyses for DEC-B was to have a set of scenarios for emergency preparedness and response arrangements for the protective measures of the population in the vicinity of the plant site.

It is important to note that the hypothetical radiological consequences calculated with such overly conservative assumptions are not conceivable from technical perspective, because the results are overestimated in comparison with actual data from the operating experience with severe accidents. For example, the calculations for the estimation of the doses for the population at the boundary of the exclusion zone, using the above mentioned scenarios and conservative assumptions, resulted in values in the range of a few hundreds of mSv, while the effective doses actually measured for the emergency workers in Chernobyl and Fukushima accidents, were in the same range of a few hundreds of mSv, for source terms 30-150 times higher than the source term assumed in the CANDU safety analyses, and the effective doses measured for the members of the population were less than 100 mSv https://www.oecd-nea.org/jcms/pl_28312/chernobyl-chapter-iv-dose-estimates ; https://www.who.int/docs/default-source/documents/publications/health-effects-of-the-chernobyl-accident.pdf ; https://world-nuclear.org/information-library/appendices/fukushima-radiation-exposure . This demonstrates the excessive conservatism used in the estimation of the radiological consequences of reactor accidents as part of the licensing basis analyses.

General considerations regarding the calculation of doses for long-range distances

The current computer codes for dose dispersion and impact assessments are not designed to provide meaningful results beyond 300 km. This limitation is a constraint recognized at international level in safety analysis tools and methodologies. Validation of computer codes for the assessment of radiological consequences at distances beyond 300 km is challenging due to complexities like mesoscale and synoptic-scale weather systems, topography, and long-range transport mechanisms. The uncertainties associated with calculations of radiological consequences for distances beyond 300 km do not allow for a meaningful estimation of the potential transboundary impacts. Moreover, systematic validation beyond ~1,000 km cannot be achieved, because of the lack of consistent and comprehensive observational datasets. Studies for long-range dispersion are used for scientific research, not regulatory and decision-making purposes.

Nevertheless, in order to estimate the radiological consequences of severe accidents, in addition to the hypothetical scenarios covered by the licensing basis safety analyses for severe core damage events, the actual data collected from the measurements of the contamination levels and the effective doses resulted from severe accidents occurred in Chernobyl and Fukushima Daiichi can be used for comparison.

The amount of Cs-137 released from the Chernobyl-4 accident is estimated to be of approximately 85 PBq, which was considered to represent 20% to 40% of the total inventory in the RMBK-1000 reactor core. The RBMK-1000 used slightly enriched (2% U-235) uranium dioxide fuel. The Chernobyl reactors did not have a pressure-proof reactor containment. (https://world-nuclear.org/information-library/safety-and-security/safety-of-plants/chernobyl-accident ; https://www.oecd-nea.org/jcms/pl_28292/chernobyl-chapter-ii-the-release-dispersion-deposition-and-behaviour-of-radionuclides)

The total amount of Cs-137 released from the 3 affected units in the Fukushima Daiichi accident is estimated to be of approximately 15 PBq. The Fukushima reactors also used enriched uranium fuel. The Fukushima Daiichi reactors had Mark I containment buildings. (https://world-nuclear.org/information-library/appendices/fukushima-radiation-exposure ; https://www.oecd-nea.org/upload/docs/application/pdf/2021-09/7525_bsaf.pdf)

The total inventory of Cs-137 in the reactor core of the CANDU-6 design, which uses unenriched natural uranium, is of approximately 50 PBq, which is several times lower than the total inventory of the Chernobyl 4 reactor. The CANDU-6 reactors have robust containment buildings and have been backfitted with modern hydrogen mitigating systems and emergency filtered venting systems which prevent containment failure from severe accident scenarios. Even with the unrealistic assumption that the entire inventory of one CANDU-6 unit would be released to the atmosphere, a scenario that is not physically possible, the radiological consequences for Austria would be negligible, because of the large distance (the shortest distance between Cernavodă, Romania, and the nearest Austrian town is of more than 800 kilometers).

A scenario that would involve simultaneous severe core damage accidents in more than one CANDU unit of the Cernavoda NPP site is not credible. The reactor units are located at more than 150 m one from another, are fully independent (have no shared systems) and have substantial safety margins to cope even with extreme external events significantly beyond the initial design basis. However, Station Blackout scenarios, Loss of Ultimate Heat Sink scenarios and the combination of these two categories of scenarios have been analyzed as part of the "Stress Tests" post-Fukushima for the operating units of Cernavoda NPP and safety upgrades have been implemented, as described in the public reports documenting these assessments http://www.cncan.ro/assets/Informatii-Publice/06-Rapoarte/RO-National-Report-for-2nd-Extraordinary-Meeting-under-CNS-May2012-doc.pdf ; https://www.ensreg.eu/EU-Stress-Tests/Country-Specific-Reports/EU-Member-States/Romania . Accident scenarios involving both units are evaluated for the sole purpose of testing the emergency preparedness and response arrangements.

Based on international experience with exceptional situations of severe accidents occurred at nuclear power plants with releases to the environment, comprising data from the Chernobyl and

Fukushima accidents, radiological doses at distances greater than 300 km from the site of a severe nuclear accident are very low, in the range of microSieverts (µSv).

In accordance with the information provided in the following links https://pubmed.ncbi.nlm.nih.gov/2294074/ ; https://pubmed.ncbi.nlm.nih.gov/2094123/ ; https://www.nature.com/articles/pr1994202 ; https://www.ages.at/en/environment/radioactivity/caesium-137-in-austria the effective doses incurred from the radioactive fallout from the Chernobyl accident were lower than 1 mSv in the first year. Even if the Chernobyl accident resulted in a massive radioactive release, directly into the atmosphere, the doses in Austria were low because of the large distance from the point of release (the shortest distance between Chernobyl, Ukraine, and the nearest Austrian town is more than 1000 kilometers).

All the protective measures recommended in the IAEA publications cover distances up to a maximum distance of 300 km from the accident location; however, it is recognized that specific food restrictions may be considered for distances greater than 300 km if found necessary, but there is no specific recommendation available on this matter. https://www-pub.iaea.org/MTCD/Publications/PDF/te_953_web.pdf ; https://www-pub.iaea.org/MTCD/Publications/PDF/te_955_prn.pdf https://www-pub.iaea.org/MTCD/Publications/PDF/EPR-NPP_PPA_web.pdf ; https://www-pub.iaea.org/MTCD/Publications/PDF/EPR-Protection_Strategy_web.pdf

Average national doses in European countries, determined as results of the Chernobyl accident, were less than 1 mSv in the first year, with progressively decreasing doses in subsequent years. The average dose over a lifetime in distant countries of Europe was estimated to be about 1 mSv. These doses are comparable to an annual dose from natural background radiation (the global average is 2.4 mSv) and are, therefore, of little radiological significance.

Radiological impact assessments are typically constrained to a distance of 300 km, beyond which doses are expected to be negligible based on historical evidence from major accidents such as both Chernobyl and Fukushima. At such distances, even large source terms such as those resulted from Chernobyl and Fukushima accidents, which are not physically possible for CANDU-6 reactors, lead to potential doses below the 1 mSv/year regulatory limit, comparable to natural background radiation.

Moreover, to put things in perspective, it is worthwhile to compare the perceived risks associated with the nuclear industry with the demonstrated risks associated with other sources of potential exposure to harmful substances. For example, it is important to note that there are many other activities that present an exposure to harmful factors on a day by day basis and that put people at significantly higher risk (e.g. pollution, smoking etc.) than the hypothetical scenarios of nuclear accidents in EU countries: https://www.eea.europa.eu/en/analysis/maps-and-charts/austria-air-pollution-country-2023-country-fact-sheets ; https://www.meduniwien.ac.at/web/en/about-us/news/detailsite/2018/news-im-maerz-2018/doctors-against-smoking-six-million-deaths-a-year-from-smoking-14000-in-austria/ ; https://globalactiontoendsmoking.org/research/tobacco-around-the-world/austria/ .

Based on all the above considerations, we can affirm that even a hypothetical worst case severe accident scenario at Cernavoda NPP would not present a significant adverse transboundary impact for the Austrian population and environment.