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Consultation according to the Espoo Convention

Interim storage, encapsulation and final disposal of spent nuclear fuel in Sweden
Consultation meeting according to article 5 of the Espoo Convention
Stockholm, Sweden, March 21, 2016

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Appendices: 1 – Presentations
2 – Clarifying questions from Poland

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Introduction
Egon Enocksson, Swedish Environmental Protection Agency, welcomed everyone and opened the meeting, which has been announced as a consultation meeting according to article 5 in the Espoo Convention. The purpose of the consultation is to provide neighboring countries with an opportunity to obtain information and pose questions about possible transboundary environmental impacts from the facilities that the Swedish Nuclear Fuel and Waste Management Company (SKB) has applied for licences to build for the final disposal of spent nuclear fuel. This concerns a facility part for encapsulation and a final repository. In the notes from this meeting, discussions about factual matters and responses will be presented. Clarifying questions will not be noted.

Presentation of the basis for the consultation
Erik Setzman, SKB, gave a general presentation of SKB and of the assumptions that have led to the siting of the encapsulation part adjacent to the existing central interim storage facility for spent nuclear fuel (Clab) on the Simpevarp Peninsula in Oskarshamn Municipality and the final repository for spent nuclear fuel at Forsmark in the municipality of Östhammar. SKB carried out an extensive consultation procedure with all concerned parties during the feasibility study and the site investigations. Images 1 – 16 in appendix 1 and SKB's film on nuclear fuel's road to final disposal, "Final repository for spent nuclear fuel", were shown.
(The film is also available via YouTube: https://www.youtube.com/watch?v=xq1VJ0fbpIg.)

Martina Sturek, SKB, described how a facility part for encapsulation is intended to be linked to the existing central interim storage facility for spent nuclear fuel in Oskarshamn (Clab), after which the two facilities will be operated as one integrated facility called Clink. SKB explained the design of the facility and the safety requirements and protection barriers that govern the assumptions behind its construction. Images 17 – 31 were shown.

Niklas Heneryd, SKB, went through the investigations that were carried out of among other things geological, hydrogeological and geochemical aspects within the framework of the site investigations. The results served as a basis for the selection of the Forsmark site for the final repository for spent nuclear fuel. Images 32 – 43 were shown.

Allan Hedin, SKB, presented the work with and results from the assessment of post-closure safety of the final repository for spent nuclear fuel, SR-Site. SKB presented the laws and regulations governing this analysis. The risk criterion, set up by SSM, Swedish Radiation Safety Authority, is a central requirement to live up to. According to SSM's regulations, the assessment must cover a million years after closure. SKB's analysis shows that the repository will cope with the risk criterion with ample margin. An important conclusion is thus that potential releases to the Baltic Sea have insignificant consequences, even in the vicinity of the actual final repository and also during the long time spans that are relevant. SR-Site has, on the Government's initiative, been reviewed by an international expert group under OECD-NEA's auspices. The conclusion of the expert group is that SKB's safety assessment represents an adequate and credible basis from which to make decisions on licences to build a final repository. Images 44 – 59 were shown.

Mikael Gontier, SKB, presented the joint environmental impact statement (EIS) for Clab, Clink and the final repository for spent nuclear fuel. The presentation included methodology, limitations of the EIS, releases during operating time and after closure, and transport activities. The conclusions from the EIA work clearly show that all identified environmental effects and risks have a local or regional geographic impact, so no transboundary consequences are expected. Images 60 – 74 were shown.

Questions and Responses

Poland: How is the pool water from Clab handled?
Response: The pool water re-circulates within the facility after treatment via particle filters and ion exchange resins. Used ion exchange filters are sent to be disposed of in the existing SFR (Final repository for short-lived radioactive waste) in Forsmark.

The pool water is cooled by sea water via heat exchangers. The cooled water will never come into contact with the spent nuclear fuel and can thereby be returned to the sea.

Germany: How will you handle damaged fuel?
Response: All damaged fuel will be treated before final disposal. The treatment will consist of careful drying of the fuel rods that will secure that the fuel itself is dry. The fuel rods will thereafter be placed in water and gas tight containers, in which the fuel rods will not be exposed to water again, and prevented from leaking. The treatment of the damaged fuel in Sweden is on-going.

Prior to final disposal, damaged fuel is placed in copper canisters that are sealed in the same way as other spent nuclear fuel, so the differences compared to other fuel are negligible, viewed from a long-term safety perspective. In the assessment of post-closure safety for the Spent Fuel Repository, the Zircaloy cladding is not counted as a barrier, regardless of whether the fuel is damaged or intact.

The above response is slightly extended from that provided at the meeting.

Germany: Where do you check the canisters?
Response: Inspections of integrity of the canisters are carried out in Clink after the canister lid is welded solid. Before the canister leaves Clink, possible contamination on the canister surface is also inspected and if necessary the canister is cleaned. On arrival at the final repository in Forsmark the canister's identity is checked.

Finland: What happens after closure of the final repository?
Response: According to Swedish laws and regulations, SKB's mission is to build a final repository for spent nuclear fuel that does not require inspection after closure.

Poland: How will the temperature in the repository develop considering the heat output from all canisters?
Response: SKB will combine the fuel assemblies in the copper canisters such that the temperature on the surface of the clay buffer against the canister is less than 100 °C. The fuel's heat release is dependent on, among other things, burn-up and the time it is interim-stored in Clab. The temperature in the final repository is also dependent on the spacing between the canisters and on the rock's thermal conductivity, which is good in Forsmark. All these factors are included in SKB's calculations of the temperature evolution in the repository.

Germany: How will you handle drainage water that is pumped out from the final repository to the Baltic Sea? Can it contain radionuclides?
Response: The water is not expected to contain any radioactivity, since there will be no free activity in the final repository. The canister integrity is inspected in Clink. Drainage water will be monitored, after which it will be released to the Baltic Sea. The only source of radioactivity that can occur in the final repository is radon which occurs naturally in the rock, which is important to take into account for the personnel who will work in the facility.

Finland: How long is the spent fuel hazardous?
Response: The spent fuel is most hazardous during the first 1,000 years. The hazard decreases with time and, after about 100,000 years, the spent fuel has the same activity as the uranium that was once mined in order to produce the fuel.

Germany: Why is radium used as the design basis for post-closure safety in SR-Site whereas safety assessments in Switzerland and Germany at least partly point to other isotopes as the most critical?
Response: Radium-226 dominates the calculated dose because the few canisters that are assumed damaged are those present in the deposition holes with the highest flow rates, among the approximately 6000 canister positions in the repository. For these positions, the rock's retention properties are worse than for most other positions. In Switzerland and Germany, other types of geological formations (clay and salt) have been analyzed, and they behave differently in terms of retention.

Germany: Have you done calculations for the evolution beyond one million years? Does the dose continue to increase?
Response: Calculations beyond one million years are not included in the account of post-closure safety. We have, nevertheless, as an internal calculation example, performed simple analyses of what happens in the longer term, if we hypothetically assume that we can say something about the long-term conditions. The dose then continues to increase for a while since more canisters are assumed to fail and a larger portion of the fuel in the failed canisters dissolves.

Germany: Do you consider the fuel matrix as a barrier?
Response: No, we do not count the fuel matrix as a barrier in the final repository for spent nuclear fuel, but it is has low solubility and works in practice as a barrier.

Denmark: You have presented two scenarios that contribute to risk for dose, one with buffer erosion and copper corrosion, and one in conjunction with an earthquake (shear load). Have you combined these scenarios?
Response: Yes, firstly we assumed in the earthquake scenario that the clay buffer disappears sometime after the canister is damaged by the earthquake, and secondly, we have checked whether a partly corroded canister is more sensitive to earthquake movements.

Germany: How do you estimate the number of expected earthquakes one million years into the future?
Response: We have statistics from 100 years back in time. Earthquakes arise due to the movements of the tectonic plates. Their movements can be predicted by data analyses and measurements. This is explained in SR-Site, Section 10.4.5.

Germany: Does copper corrode in oxygen-free water?
Response: Sulphide in the groundwater is the entirely dominating cause of copper corrosion in the final repository. A group of researchers at Royal Institute of Technology in Stockholm have, however, claimed that copper corrodes much faster in pure water than established science suggests. Due to this fact, SKB has initiated several research projects over the past five years. The conclusions that we draw from these experimental and theoretical studies confirm SKB's standpoint that corrosion in oxygen-free water occurs only to the very small extent predicted by established science. The works thus support SKB's conclusion in the application that the canister will provide an adequate corrosion protection. The studies have been reported to SSM as supplementary information to SKB's licence application.

Germany: How do you handle gas evolution in the canister?
Response: The fuel is dried carefully before it is placed in the copper canister. In the safety analysis, we have assumed that there will be 600 grams of water left in the canister. The water can react with iron in the canister's insert and hydrogen is then formed. This, however, gives only a negligible

pressure increase in comparison with what the canister is designed to withstand. With time a certain amount of helium is also generated in the canister, but this also provides a negligible pressure contribution.

Lithuania: Can Sweden receive waste from other countries in Europe?
Response: No, Swedish law permits neither import nor export of nuclear waste. In addition, the relevant municipality, Östhammar, has stressed that they can only receive Swedish waste and nothing more. But it is possible for other countries to use our knowledge and experience to develop their own final repositories.

Germany: Why was Forsmark selected for the final repository instead of Simpevarp?
Response: The bedrock in Forsmark is homogeneous and fracture-poor with very low water flows at repository depth and offers very good opportunities to design and build a long-term safe repository. The bedrock in Simpevarp/Laxemar is much more heterogeneous, has higher fracture frequency and water flows and poorer thermal conductivity in comparison with Forsmark.

Germany: How do you categorize for example the event of a loss of cooling in Clab?
Response: That is dependent on the consequences that it could lead to. The road to such an event consists of a sequence of circumstances with different probabilities and consequences. A circumstance with high probability and large consequence is taken into account in the design. In the case of a loss of power supply, the passive system for coolant make-up comes into force, see image 31.

Germany: What is the worst possible incident that can occur at Clab?
Response: The worst that could happen at Clab is that we drop a fuel cassette, which at most could give a radiation dose of 0,39 mSv. This is the event with the greatest environmental consequence within the design, i.e. with a frequency larger than 10^{-6} per year.

SSM informed that the consequences for events that can conceivably occur must be presented in the EIS, whereas improbable events with low probability, but that have significant consequences, must be described in the safety analysis report that SKB handed in to SSM within the framework of licensing under the Act on Nuclear Activities. The latter category includes for example consequences due to an airplane crash and earthquakes.

Residual risks for Clab and Clink were discussed in connection with the visit to Forsmark, March 22, and SKB gave the following clarification:

> Disturbances and mishaps and potential consequences from residual risks for Clab and Clink are briefly presented and discussed in SKB's application according to the environmental code. Detailed information on those aspects has been submitted to the Swedish Radiation Safety Authority (SSM) within the licensing process for Clink and within the oversight of Clab according to the Act on Nuclear Activities. It is also important to consider that the licensing process according to the Act on Nuclear Activities is a stepwise process that requires that SKB submits new/updated safety analyses at different stages of the facility's life cycle (prior to construction, pre-operation, operation, etc.) where information on disturbances and mishaps is presented/updated.
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> In addition to the assessment of consequences of events that are taken into account when designing the facility (from expected events to events that are unlikely to occur) SKB has even assessed consequences from events that are very unlikely to occur – so called residual risks (with an occurrence of less than 10^{-6} per year). Such residual risks are presented and discussed with SSM within the licensing process according to the Act of Nuclear Activities. One example of a residual risk that has been calculated and analysed is the case of an earthquake causing great damage on the reception building of Clink. This scenario has been used as a so called umbrella case for residual risks. For the purpose of the calculation it has been pessimistically assumed that

a considerable amount of the spent fuel that is allowed to be stored in the reception building at the same time would be damaged. The results of those pessimistic calculations (without any retention of the radionuclides) shows that the effective dose at 500 meters from the facility would be approximately 90 mSv and that the dose would decrease rapidly with distance to be around 1 mSv at 20 km from the facility. This shows that even residual risks for the Clink facility will not cause transboundary impacts.

Germany: How will the construction of the encapsulation part affect the ongoing activities in Clab?
Response: Final design of the encapsulation part will be submitted to SSM for assessment of how construction of the new facility part will affect the existing facility and operations. Furthermore, it is worth noting that about 15 years ago Clab was extended with the second pool during ongoing operation in the first and without operational consequences. There exists in other words experience from similar rock works.

Germany: What does the continued process look like?
Response: In the process according to the Environmental Code a main hearing will eventually be held in the Land and Environment Court. The Court and SSM (under the Act on Nuclear Activities) then recommend that the Government either grant or decline the applications. The Government will also question the concerned municipalities, who have the right of veto on the issue: Östhammar Municipality when it comes to the Spent Fuel Repository and Oskarshamn Municipality for the facility part for encapsulation. After the Government has made its decision the issue goes back to SSM and the Court who impose conditions for the facilities, see image 12. After this, the process under the Environmental Code is concluded.

The continued process under the Nuclear Activities Act is stepwise and involves only the operator and the authority (SSM). The municipalities, however, have expressed a desire to participate in this process and SSM is considering how they can accommodate this.

Clarifying information that was not provided during the meeting:
In accordance with Euratom article 37, the Swedish state, via SSM, must report SKB's future facilities Clink and the Spent Fuel Repository to the EU. The documents shall present the material that is needed to determine whether operation of the facilities leads to consequences for our neighbouring countries.

Germany: Will a new safety analysis report be produced prior to each new step?
Response: Yes, SSM's regulations state that the development and licensing of nuclear facilities must take place via a stepwise process where requirements on the facility, its design and technical solutions are established gradually. The most important milestones are:

- **An application for a licence under the Act on Nuclear Activities and the Environmental Code to build a new facility** – in which SKB as a basis provides, for example, a preparatory preliminary safety analysis report where the requirements that the facility and operations must conform to are presented. How the requirements can be met with a suggested reference design and operation is also presented. Decisions on permissibility under the Environmental Code and a licence under the Act on Nuclear Activities are announced by the Government.
- **Approval of the safety analysis report prior to construction** – after a licence has been obtained under the Act on Nuclear Activities and the Environmental Code, a preliminary safety analysis report is approved by SSM before SKB can start building the facility. It should present the design of the facility, how activities are arranged and how the requirements are met.
- **Approval of the safety analysis report prior to trial operation and routine operation** – to take the facility into operation, the safety analysis report must be approved by SSM. The safety analysis report will show how the safety of the facility is arranged in order to protect

human health and the environment against radiological accidents and to prevent unauthorized handling of nuclear material or nuclear waste. The account should reflect the facility as built, analysed and verified and demonstrate how the requirements on its construction, function, organization and activities are fulfilled. In order to get approval for routine operation, the safety analysis report must be supplemented with experiences from trial operation.

As trial operation switches to routine operation, activities shift to an administration phase. In conjunction with the periodic safety evaluations every ten years, a survey will, if necessary, be carried out of the state of knowledge in essential safety areas.

The above response is slightly extended from that provided at the meeting.

Germany: Will there be a consultation prior to each new step?
Response: No, there will not be any further consultations. However, a dialogue with residents, politicians and officials in the concerned municipalities will continue. In addition, the municipalities, Östhammar and Oskarshamn, will have a right of veto regarding the establishment of the Nuclear Fuel Repository and the facility part for encapsulation.

Lithuania: Were the socioeconomic assessments part of the EIS?
Response: No, SKB carried out societal studies at the request of the municipalities during the time of the site investigations. The studies dealt with, among other things, the impact on tourism, employment and the property market. These studies are regarded as a basis, beyond the EIS, for the municipality to be able to judge the conditions for a final repository for spent nuclear fuel from a societal perspective. The work with the socioeconomic aspects is outside of the licensing process.

Lithuania: What questions did you get from nearby residents?
Response: Initially nearby residents' questions were largely about safety during operation and after closure of the final repository. Later in the process the questions were more about local environmental aspects such as transportation, handling of rock spoil, noise etc.

Lithuania: Have the concerned municipalities received any special advantages?
Response: Yes, in some sense. An added-value agreement has been signed between SKB, SKB's owners and the municipalities of Östhammar and Oskarshamn. The agreement was an initiative of the municipalities and was signed shortly before SKB selected the site for the final repository of spent nuclear fuel. The idea behind the agreement is that, in the long term, it will contribute to growth in the two municipalities and create good prospects for living and running businesses there. For SKB it is about being able to attract competence to the facilities we plan to build in the future. Areas that may be considered for investment are training, business sector development, infrastructure, widening of the labour market and commitment in the energy area.

Lithuania: Regarding the shipments of spent nuclear fuel from Oskarshamn to the final repository in Forsmark: What happens if the ship sinks?
Response: SKB presently has a licence for the transport of spent nuclear fuel from the nuclear power plants to Clab. The shipments have being going on for 30 years without any accidents occurring. The consequences of the ship sinking have been analysed. The analysis shows that the transport casks, which are licensed according to international standards, would hold.

SSM informed that SKB will, prior to commissioning of the final repository for spent nuclear fuel in Forsmark, license its transportation system for encapsulated fuel in accordance with both international requirements from the IAEA and national requirements according to the Act on Nuclear Activities.

Denmark: Is SKB building a final repository that permits that the retrieval of canisters in the future?
Response: SKB must build a final repository that does not require inspection. During the operating period, it will be possible if needed to retrieve individual canisters. From a purely technical perspective, it is possible to retrieve canisters even at a later stage, but this would entail a comprehensive effort at a high cost. Planning for this is not included in SKB's mission.

SSM informed that there is information in English on their website: www.ssm.se

Erik Setzman, SKB, thanked everyone for their involvement and interest and pointed out that affected parties have opportunity to send their final position till 15 of April 2016. Images 75 – 76 were shown.

On April 14, Poland sent five clarifying questions. The questions were answered by SKB during April and May. The questions and answers are found in appendix 2.