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Current Status of the Nuclear Waste Management Programme in Finland – 13441

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ABSTRACT

Pursuant to the Decision-in-Principle of 2001 the Finnish programme for geologic disposal of spent fuel has now moved to the phase of applying for construction licence to build up the encapsulation plant and underground repository. The main objective of former programme phase, underground characterisation phase, was to confirm – or refute – the suitability of the Olkiluoto site by investigations conducted underground at the actual depth of the repository. The construction work of the access tunnel to the rock characterisation facility (ONKALO) started in the late summer of 2004. The site research and investigations work aimed at the maturity needed for submission of the application for construction license of the actual repository in end of 2012. This requires, however, that also the technology has reached the maturity needed. The design and technical plans form the necessary platform for the development of the safety case for spent fuel disposal. A plan, "road map", has been produced for the portfolio of reports that demonstrates the safety of disposal as required by the criteria set by the government and further detailed by the safety authority, STUK.

INTRODUCTION

In the year 2001 the Finnish Parliament ratified the decision-in-principle on the disposal of spent fuel from the Finnish nuclear power reactors. According to the decision the repository would be located in crystalline bedrock at Olkiluoto in the municipality of Eurajoki on the western coast of Finland, and the disposal would be based on the KBS-3 concept. The decision means that Posiva, the implementer of the disposal facility for spent fuel in Finland, now sets the next major milestone for the research and technology development (RTD) activities at the submission of the application for the construction license. The guidelines of the Ministry of Employment and Economy (TEM) specify that the maturity for submission should be reached by the end of 2012.

One of the pre-requisites for the license application is the confirmation of the site suitability through underground characterisation of the intended repository host rock. The construction of an underground rock characterisation facility, ONKALO, has now been almost completed. About five kilometres of tunnel length has been excavated by autumn 2012 and the implementation of the underground investigations and demonstration programme is underway. The main characterisation level is at a depth of 420 meters below the ground level, but the excavations have continued down to the depth of 455 metres.

In parallel with the ONKALO design, construction and investigations progress is being made in the development of the technology needed for the encapsulation and disposal of the spent fuel. A lot of the work is now organised in joint projects with the Swedish SKB, pursuant to the agreement signed between SKB and Posiva initially in mid-2001. Both organisations now aim at licensing the construction of the disposal facilities in couple of years from now.

In addition to site suitability and technology development a third requirement for the successful license application is the proof of operational and long-term safety of disposal. The background reports have been made for the Safety Case that will accompany the application for the construction license.

In this paper the progress in Finland since the Decision-in-Principle in 2001 is summarised and the programme for the near future is outlined. A recent account of progress made since 2009 is also found in the three-year RTD programme published in 2012 [1].

NUCLEAR WASTE MANAGEMENT IN FINLAND

The Finnish nuclear power plants have been in operation for more than 25 years. Two BWR units are operated at Olkiluoto (2 x 860 MWe) by Teollisuuden Voima Oyj (TVO), and two PWR units at Loviisa (2 x 488 MWe) by Fortum Power and Heat Oy (Fortum). One PWR unit (1600 MWe) is under construction and one is at planning stage at Olkiluoto.

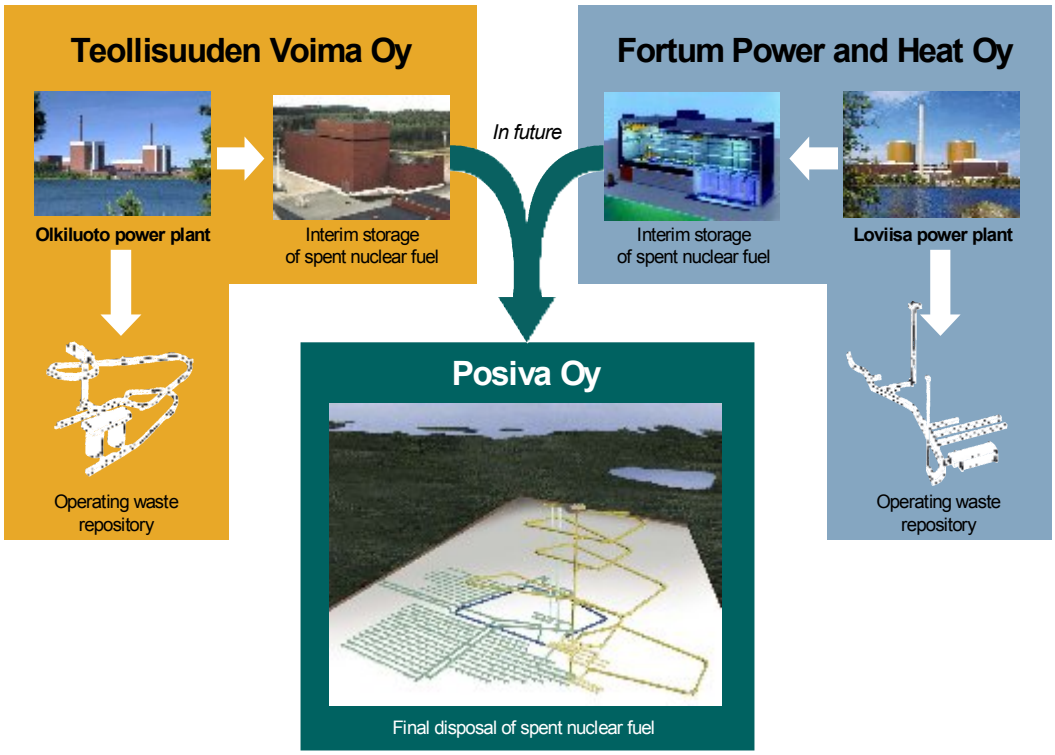

Fig. 1. Organisation of nuclear waste management in Finland.

According to the Nuclear Energy Act, all nuclear waste generated in Finland must be handled, stored and permanently disposed of in Finland. The two nuclear power companies, TVO and Fortum, are responsible for the safe management of the waste and for all associated expenses. TVO and Fortum established a joint company, Posiva Oy, in 1995 to implement the disposal programme for spent fuel, whilst other nuclear wastes are handled and disposed of by the power companies themselves (Figure 1).

Posiva is in charge of all the research, development and planning work required for final disposal, as well as of the construction and operation of the final disposal facility in the future. Posiva also provides expert services in the field of nuclear waste management to both the owner companies and external customers. Based on this the company will apply for the necessary licences and will later construct and operate the disposal facility.

Posiva possesses top expertise in Finland in the field of nuclear waste management and maintains extensive contacts with international organisations working in this field. Research and design related with nuclear waste management is carried out in universities, research institutes and consulting companies that represent state-of-the-art competence in various fields.

LEGAL FRAMEWORK OF WASTE MANAGEMENT

The Nuclear Energy Act regulates the implementation of nuclear waste management in Finland. According to the Act, the operators of the NPPs bear the responsibility for nuclear waste until final disposal has taken place. All nuclear waste generated in Finland, including spent fuel, must be handled, stored and permanently disposed of in Finland.

The principles of the policy on nuclear waste management were originally defined in a Government decision in 1983. This decision and the subsequent decisions of the Ministry of Employment and Economy (former Ministry of Trade and Industry (MTI)) provide a basis for both the practical implementation of nuclear waste management and for research and development related to the eventual development of a repository for spent fuel.

The Government grants construction and operation licences for nuclear facilities but, before actual licensing can take place, a policy decision referred to as the Decision-in-Principle (DiP) needs to be approved by the Parliament. The Government will only accept the application provided the Radiation and Nuclear Safety Authority (STUK) issues a favourable safety statement and the municipality where the disposal facility is to be built consents to it. STUK is responsible for the control and supervision of nuclear waste management activities.

The financial side of final disposal is also covered by legislation. The assets required for the management of wastes produced in nuclear power plants are collected in advance from the waste producers and transferred to the State Nuclear Waste Management Fund. The Fund is a reserve for future costs. It is not included in the budget of the state, but is an external fund controlled by the Ministry of Employment and Economy.

OVERALL SCHEDULE

Preparations for nuclear waste management were commenced in Finland already in the 1970s when the nuclear power plants were still under construction. In 1983, the Government confirmed a target schedule for spent fuel management, in which the construction of the final disposal facility was scheduled for the 2010s and the start of final disposal for 2020 (Figure 2).

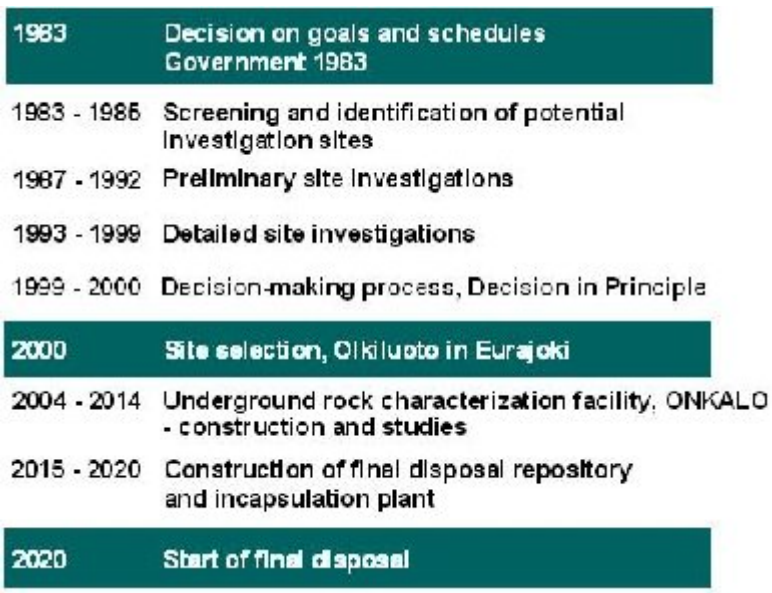

Fig. 2. Schedule of site selection and final disposal of spent fuel.

Potential sites for the disposal of spent fuel were screened in the 1980s, followed by detailed site investigations in the 1990s and an environmental impact assessment in late 1990. In 1999, Posiva submitted an application for a DiP to choose Olkiluoto as the site of the final disposal facility. The Government issued a DiP in favour of the project in December 2000, and the Parliament ratified the decision in May 2001.

Pursuant to the DiP the repository would be located in crystalline bedrock at Olkiluoto and disposal would be based on the KBS-3 concept. According to the target schedule, set by the Government in 1983, Posiva is submitting an application for the construction licence in the end of 2012.

One of the prerequisites for the licence application was the confirmation of the suitability of the site through underground characterisation of the intended host rock of the repository. For this purpose an underground rock characterisation facility, ONKALO, was constructed.

In parallel with the design and construction of ONKALO and the related investigations, progress is being made in the development of the technology needed for the encapsulation and disposal of spent fuel. Much of this work is organised into joint projects with the Swedish Nuclear Fuel and Waste Management Company, SKB, pursuant to a mutual agreement. Both organisations are steered by the need to demonstrate that the technology will be available when needed.

ONKALO

Constructing an underground characterisation facility, known as ONKALO, at Olkiluoto started in 2004. ONKALO will be used to obtain further information to plan the repository in detail and to assess long-term safety and construction engineering solutions. ONKALO will also enable final disposal technology to be tested under actual conditions. ONKALO is not intended solely for research premises it has also been designed to serve as an access route to the repository when constructed. Excavation of ONKALO took about 8 years to complete and the entire construction work will end in 2014. Investigations have been made from the start of construction in conjunction with excavation. Once ONKALO has been completed, the disposal project will progress to the next stage, where the construction licence is received and construction of the encapsulation plant and first disposal tunnels is started. The construction licence is expected to be given approximately in the end of 2014. Work on the entire disposal project is progressing so that disposal can commence in about 2020.[1]

The site characterisation programme already included the assumption that an underground rock characterisation facility would be required at the site confirmation stage to allow a detailed repository design to be developed and the preliminary safety assessment to be produced. The plans of the underground facility were realised after issuing the DiP. A decision was made to excavate the underground rock characterisation facility, ONKALO, at Olkiluoto. The approach adopted was that ONKALO facility shall be constructed in such a manner that it allows further characterisation and research work to be carried out without jeopardising the long-term safety of the repository site. In addition, it should be possible later to link the ONKALO to the repository so that they are integrated.

The location of the tunnel entrance is in the central part of the Olkiluoto island, some two kilometres away from the Olkiluoto nuclear power plant near the southern border of the existing site investigations area (Figure 3). The location was decided based on comparison between a number of alternatives. In this comparison one of the main criteria was the anticipated disturbance to the geological environment of the repository. In particular, the inflow of groundwater to the tunnel was to be kept to the minimum. After the systematic comparison of various alternative concepts, the decision was made in 2002 that the access to the repository depth would be provided by a combination of an access tunnel and a vertical shaft attached to it. The main aspects in favour of the combined tunnel-shaft concept were the increased flexibility as

regards the planned future use of the facility as a part of the planned repository, the logistic benefits as well as the greater opportunities for characterisation work during construction.

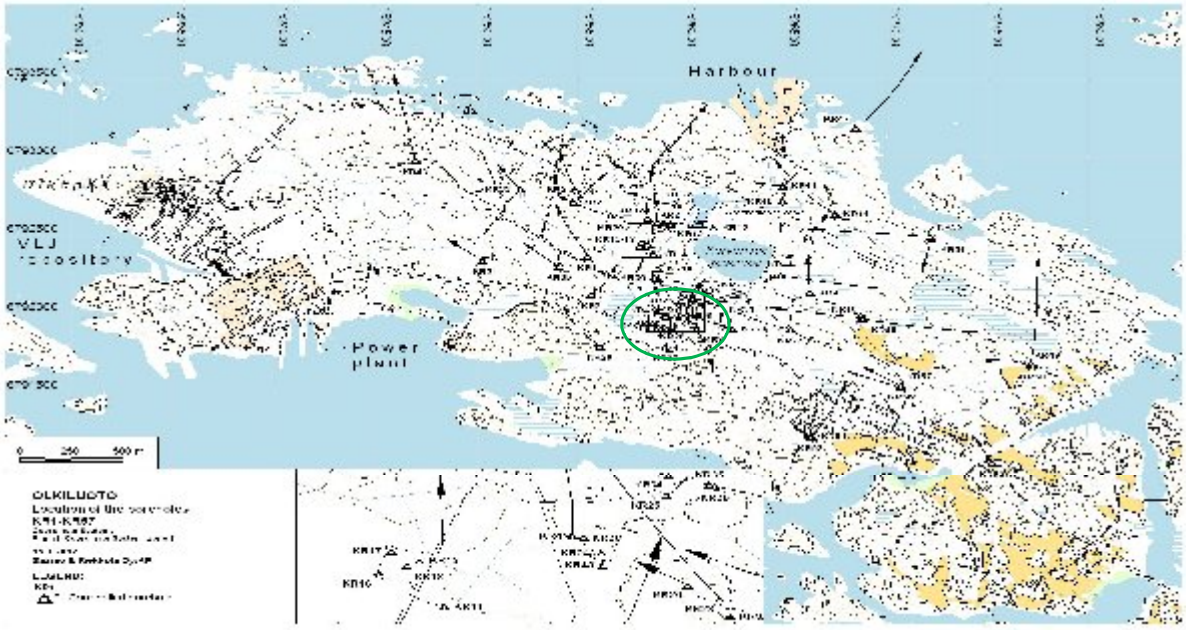

Fig. 3. Map of Olkiluoto site. Location of ONKALO is marked (green circle) together with the location of deep investigation boreholes.

The present design of the ONKALO is presented in Figure 4. The main characterisation level is at the depth of some 420 meters below the ground level. The inclination of the tunnel is 1:10, which means that the length of the access tunnel will be approximately 5 km. The total length of the tunnels and shafts will be about 8.5 km. A total of 420 000 m^3 of rock will be excavated. The site preparations for the facility were started in 2003 and the actual excavation work began in September 2004. The tunnelling work is carried out by traditional drill & blast techniques. Raise boring method has been used for the vertical shafts under construction [2].

By the end of November 2012 excavations of ONKALO were almost completed. The deepest part of ONKALO is situated 455 meters below the ground level. The excavated tunnel meets the specified quality requirements, the management of leakage waters being one of the most significant requirements. Total leakage to entire ONKALO is about 40 l/min. Due to the fractured nature of the rock, quite extensive grouting of the rock has been necessary.

The infrastructure of the site is constructed. The concrete walls of the tunnel entrance, the repair shop, the fuel distribution station and the asphalting of the machine field and roads are completed. The site office has been built, the site perimeter has been fenced and site surveillance has been organised.

The fact that the ONKALO is planned to become a part of the disposal facility means that it has to be designed and constructed according to the rules and requirements for nuclear facilities, for example, the quality assurance (QA) criteria posed by STUK. A specific graded QA programme for ONKALO, based on regulatory guidelines and IAEA safety guides, has been launched to complement the ISO 9001 (International Organization for Standardization) based QA applied by Posiva for its normal RTD activities.

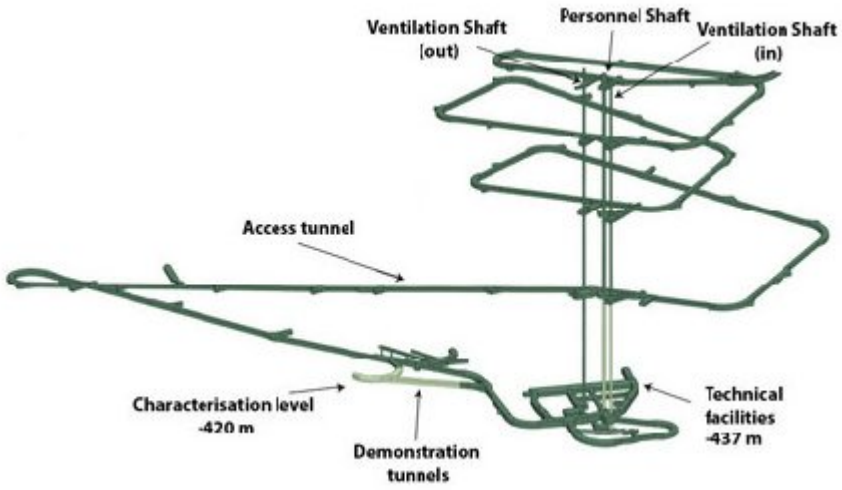

Fig. 4. Underground rock characterisation facility ONKALO.

SURFACE INVESTIGATIONS

In parallel with the construction of the ONKALO the fieldwork at surface continues, consisting of deep drillings, groundwater sampling, geophysical and geohydraulic measurements, geological mapping and various monitoring networks. The fact that the site investigations are focused on Olkiluoto makes it possible to employ new efficient methods for data gathering, e.g., investigations trenches, which nicely complement the lithological and fracturing data so far obtained only from the rather rare outcrops on the Olkiluoto island.

The number of deep cored drill holes at Olkiluoto had reached 57 by the autumn of 2012 [3]. New drillings from the surface is not planned in near future.

The modelling and interpretation of the field investigations data aim at building a consistent picture of the site. A special effort is made to integrate the site knowledge through the establishment of a specific Olkiluoto modelling task force. The purpose of the task force work is to coordinate and combine the expertise in different disciplines in such a way that a coherent picture of the site can be produced.

UNDERGROUND CHARACTERISATION AND RESEARCH

A programme for the underground characterisation and research (UCRP) to be carried out in the ONKALO has been established [4]. What Posiva expects to be achieved with the activities proposed for the ONKALO is, of course, that the general suitability of the site will be demonstrated as it is only with such confirmation that it will be possible to proceed to the application for a construction licence for the repository. The programme during the tunnelling stage includes mapping of the tunnel faces, drilling of characterisation holes with subsequent geological, geophysical and geohydrological studies, hydrogeochemical sampling and measurements, determination of fracture and flow data plus various rock-mechanics tests and measurements.

The further investigations to be carried out in ONKALO aim at further characterisation of the bedrock properties and groundwater characteristics and to help support decisions for selecting the most suitable locations for the first deposition tunnels and deposition holes for spent fuel canisters. Characterisation of the rock mass is already taking place using pilot holes core drilled along parts of the tunnel axis, prior to

its excavation, by tunnel mapping and by monitoring the impact of excavation works and in special investigation niches.

These studies aim to assess how the increased knowledge and experience gained from the construction of the ONKALO has enhanced the level of site understanding and the predictive capability of the modelling teams, as well as providing input and testing of the developing Rock Suitability Criteria (RSC).

The RSC is developed as a classification scheme to be applied for the repository layout, for defining suitable rock volumes for the repository panels, for assessing whether deposition tunnels or tunnel sections are suitable for deposition holes and for deciding whether a deposition hole is acceptable for disposal [5].

TECHNOLOGY DEVELOPMENT

The plans for the disposal of spent fuel are based on the KBS-3 concept, which was originally developed in the Sweden by SKB (Figure 5). In this concept, spent fuel elements are encapsulated in metal canisters with long expected life-times and emplaced at a depth of several hundreds of metres. A bentonite clay buffer is installed between the rock and the canisters and, after emplacement of spent fuel canisters is complete, all access routes from the surface to the disposal tunnels are backfilled and sealed, following which the repository needs no further control or maintenance.

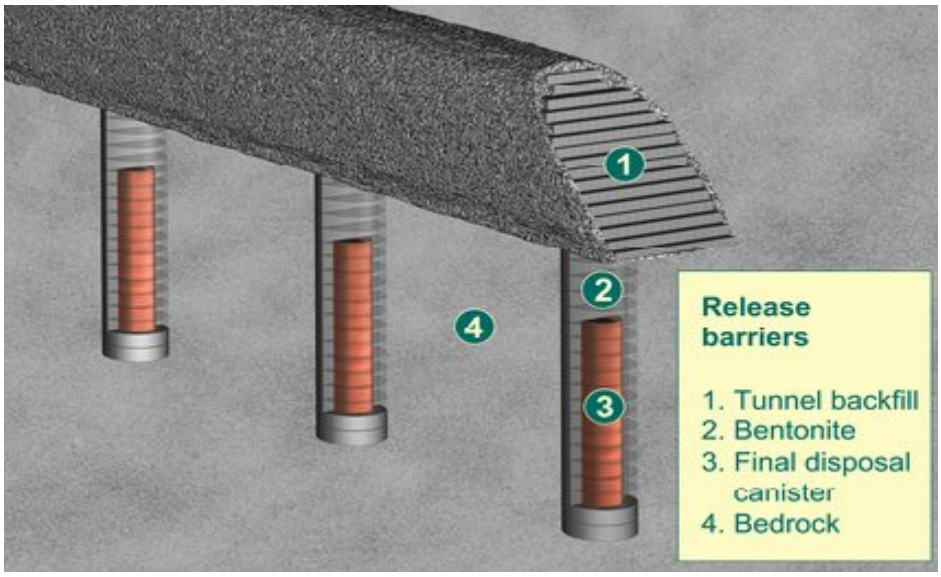

Fig. 5. KBS-3V concept.

In addition to the original concept of disposal in vertical deposition holes (KBS-3V), a “horizontal” variant of the concept (KBS-3H) is under development in a joint project between SKB and Posiva. In this alternative the canisters would be emplaced in horizontal position directly in the tunnels, buffered again by bentonite.

The main areas in the design and technical development programme are:

- encapsulation of spent fuel;
- canister development;
- the design of the repository together with its above ground facilities; and
- the development of buffer and tunnel backfill.

The present canister structure (Figure 6) consists of a massive nodular graphite cast iron insert and a 50 mm thick over-pack of copper. The basic canister design is the same for the BWR fuel elements of the Olkiluoto (OL) plant and the PWR fuel elements of the Loviisa plant, containing twelve fuel assemblies, and also for the future PWR fuel elements of the OL3 unit with four assemblies. The work on repository technology includes further development of site-specific layout alternatives for the repository panels, more detailed studies of thermal dimensioning of the repository, tests and comparisons for alternative backfilling materials and design of the technology for canister handling. Continuous progress is being made with the detailed location and layout plans for the repository. The repository will be built in several stages, which means that the excavation of the tunnels takes place in parallel with the canister emplacement operations.

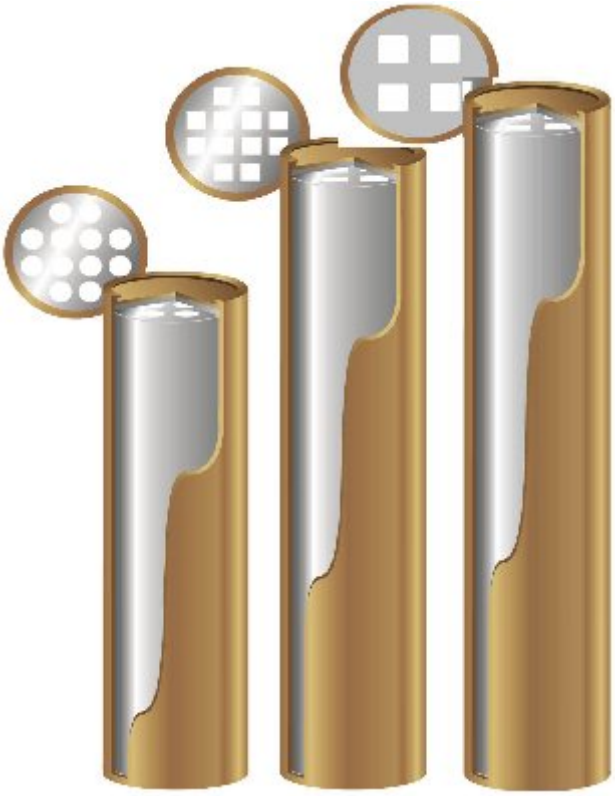

Fig. 6. Three canister designs.

SAFETY CASE

In addition to the site suitability and technology development a third requirement for the successful licence application is the proof of operational and long-term safety of disposal. The plans have been made for the Safety Case that will accompany the application for the construction licence. According to the plan, the safety case consists of several complementary reports (Figure 7) [6]. These reports cover topics related to long-term safety, such as developments at the final disposal site and in the repository as well as the changes occurring in the biotic environment for thousands of years from now.

The results will be presented for the safety case to be submitted in 2012 with the construction licence application.

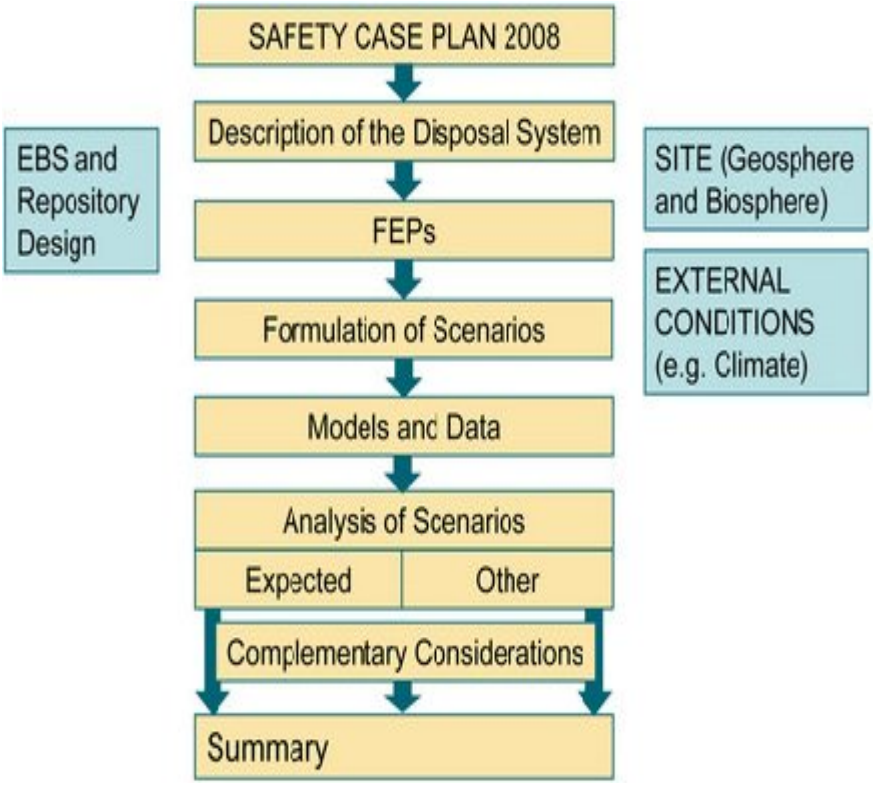

Fig. 7. Main reports of the safety case portfolio (in yellow) and the main input from supporting technical and scientific activities (in blue).
(EBS = engineered barrier systems and FEPs = features, events, and processes).

CONCLUDING REMARKS

With the finish of the excavation of the underground rock characterisation facility ONKALO, Posiva has taken an important step towards implementation of the plan for final disposal of spent fuel. The underground characterisation phase is required by the current regulations as a necessary step before the construction licence is granted, and should provide the ultimate proof – or refutation – of the suitability of the site for disposal. In addition, it has provided a lot of data for design and safety assessment purposes.

For Posiva, ONKALO is and has been also an important learning ground for the actual repository work; in particular, it has taught us how to combine investigations, engineering design and actual construction work to produce a safe repository. The experience gained so far indicates success in many aspects considered important, such as the management of ground-water inflow. However, experience also shows that our information about the bedrock is limited and it is necessary to prepare for the unexpected.

After the construction licence, the next major milestone is the operating licence, scheduled for about year 2020. The operational phase may continue over a long period. Taking into account the current plans for the operation of the nuclear power plants, the disposal facility will be closed sometime in the 2100's.

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