ONKALO - From Concept to Reality - 14494

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ABSTRACT

The programme for siting the deep repository for spent nuclear fuel was started in Finland in 1983 by screening potential candidate sites in the whole country. After the countrywide identification of potential sites and communication with local communities, five candidate sites were selected for investigation in 1987. Before a nuclear facility can be built in Finland the Government's Decision-in-Principle is required by the Nuclear Energy Act. The selection of the site was connected to this decision making and Posiva filed an application for the decision in 1999 to be able to build the disposal facility at Olkiluoto in Eurajoki municipality. In this process the host community and the Authority for Radiation and Nuclear Safety (STUK) have a right of veto. Since the local community Eurajoki was in favor for the disposal facility, as well as STUK, the Government made the positive decision in 2000 and the Parliament ratified the decision in 2001. The next step after site selection for Posiva was to prepare an application for a construction license and enter to implementation. The target for submitting the application to Government was set in 2012. Posiva decided to construct an underground rock characterisation facility from ground surface to the planned disposal depth. The purpose of this facility, called ONKALO, has been to produce detailed information for the design and safety assessment which cannot be obtained from investigation on the surface. The decision was made that ONKALO will later serve as an access to the repository.

INTRODUCTION

More than 25% of the electricity consumed in Finland is produced with nuclear power. There are four operative nuclear power plants in the country operated by two companies Teollisuuden Voima Oyj (TVO) and Fortum Power and Heat Oy (Fortum). In February 2005 the Government gave a construction license for the fifth nuclear power plant unit to TVO and current expectations are that the new reactor will be commissioned in 2016. In 2008 and 2009, three applications concerning new nuclear power plant units were filed to the Ministry of Employment and the Economy (TEM). On May 2010 the Council of State made two positive decisions on nuclear power plant units for TVO and Fennovoima Oy. The Parliament ratified these decisions on July 2010. The companies have entered to the bidding processes in their projects for the new reactors.

During the four decades of nuclear power generation, Finland has managed to build a system with clear responsibilities for nuclear waste management (Figure 1). Nuclear waste management is regulated by the Nuclear Energy Act and the Nuclear Energy Decree that came into force in 1988. These define, for example, the liabilities of a nuclear energy producer, the implementation of nuclear waste management, the licence procedures and the supervision rights. The Nuclear Energy Act was amended in 1994 so that all nuclear waste generated in Finland

must be disposed of in Finland. There is a distinct policy that Finland shall be responsible for its own wastes and no undue burden shall be left to future generations.

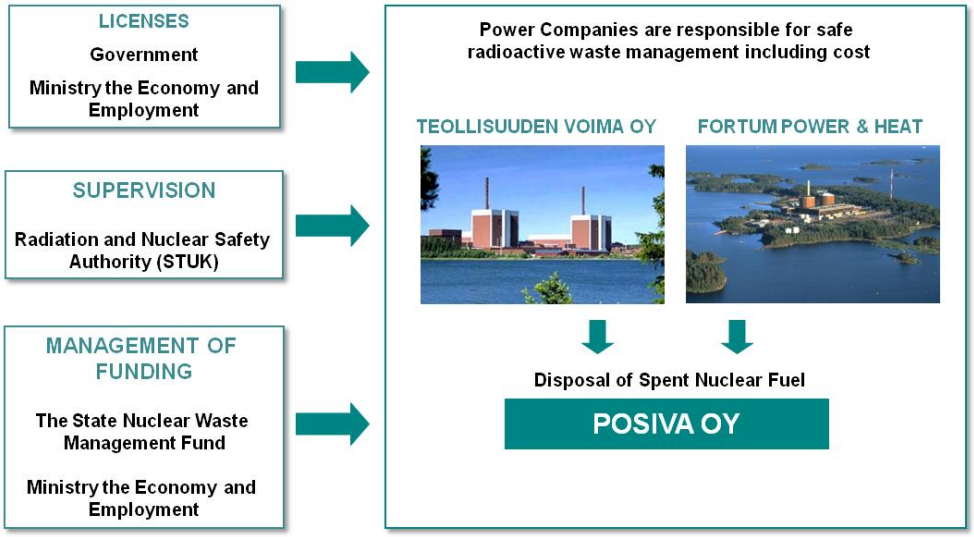

Fig. 1. Arrangement and responsibilities for radioactive waste management in Finland [5].

TVO and Fortum are responsible for the on-site storage, processing and disposal of operational waste generated in their own power plants. Both plant sites already feature an operational disposal facility into which the operational waste generated during the operation of the plant is placed. Waste generated from the eventual decommissioning of the power plant units is to be disposed of in the same facilities. In order to organise the management of spent nuclear fuel, TVO and Fortum established Posiva Oy (Posiva) in 1995 for the purpose of taking care of the disposal of its owners' spent nuclear fuel. Posiva submitted the construction license application to TEM at the end of 2012. The goal, presented in the application, is to start the geologic disposal of spent nuclear fuel at Olkiluoto in 2022 [1].

SHORT HISTORY

Nuclear waste management was not an important issue in 1970s when the construction of Finnish nuclear power plants was commissioned. In Government policy, final disposal was not considered as an alternative; the main option was to ship the spent nuclear fuel (SNF) abroad for reprocessing. Nothing was expected to come back. Fortum (at the time IVO), was successful in its efforts and had managed, in conjunction with the purchase of reactors, to negotiate the possibility to return SNF to the Soviet Union. This arrangement was in place until it was prohibited by amendment of the law in 1994.

TVO, which had bought reactors from Sweden, tried to seek possibilities for similar arrangements. This, however, appeared to be difficult since reprocessing companies wanted to return high-level waste (HLW) back to Finland. Largely for this reason TVO received the first operation license for its two units at Olkiluoto (OL1 and OL2) for only five years. This was an important impetus for TVO to start to develop alternative ways to manage SNF. In preparing for the appli-

cation for renewal of its operation license, TVO studied the possibility of geological disposal in Finland and drafted a proposal for a long-term programme covering all necessary steps from site selection research to implementation.

At the same time TVO made a decision to build an interim storage facility for SNF with such capacity that the company would not be forced into a hurried solution. TVO did receive the new operation license for the OL1 and OL2 reactors for a longer period but the Government urged the company to continue efforts for reaching an arrangement that would make it possible to export the SNF abroad permanently.

The power companies started to coordinate their waste management activities in 1977 to develop strategies for the management of short-lived low- and intermediate-level wastes (LLW and ILW). This work led to a conclusion that it would be more beneficial for both companies to build and operate their own LLW and ILW repositories at their plant sites. The site characterisation work at Hästholmen in Loviisa and Olkiluoto in Eurajoki was commissioned in 1978. Research and development work for LLW and ILW repositories was carried during the early 1980s and the repositories were excavated during late 1980s and early 1990s. The repositories at Olkiluoto and at Hästholmen have been operating successfully since 1992 and 1998, respectively.

The Government made a decision in 1983 that TVO should explore, in parallel with the export of SNF, possibilities for geologic disposal in Finland as an option. That being the case, it stipulated that a site should be selected by 2000 and disposal commissioned in 2020. The SNF would be cooled in the interim storage facility for 40 years and would then be suitable for disposal [1].

CHALLENGE OF SITING A REPOSITORY

The programme for siting the deep repository was started in Finland in 1983 since the efforts to ship the SNF abroad were not progressing for TVO. The work carried out in Sweden did give guidance for developing the disposal concept and planning the site selection research. Namely, in Sweden a law was passed in the mid 1970s which stipulated that before a reactor can be commissioned, a safe method for disposal should be presented for nuclear waste. This method is known today as the KBS-method and consists of multiple safety barriers.

The site selection work was started in 1983 by screening potential candidate sites in the whole country. After the countrywide identification of potential sites and communication with local communities, five candidate sites were selected for investigation in 1987 (Figure 2). Each site was subjected to an extensive programme of surface-based investigations and modelling studies. At least ten deep boreholes (up to 1000m deep) were drilled at each site. Finally in 1999 the Olkiluoto site in Eurajoki municipality (population 6000) was selected to host the deep repository. The site is located in the immediate vicinity of TVO’s power plant site which is close to the town Rauma (population 39000).

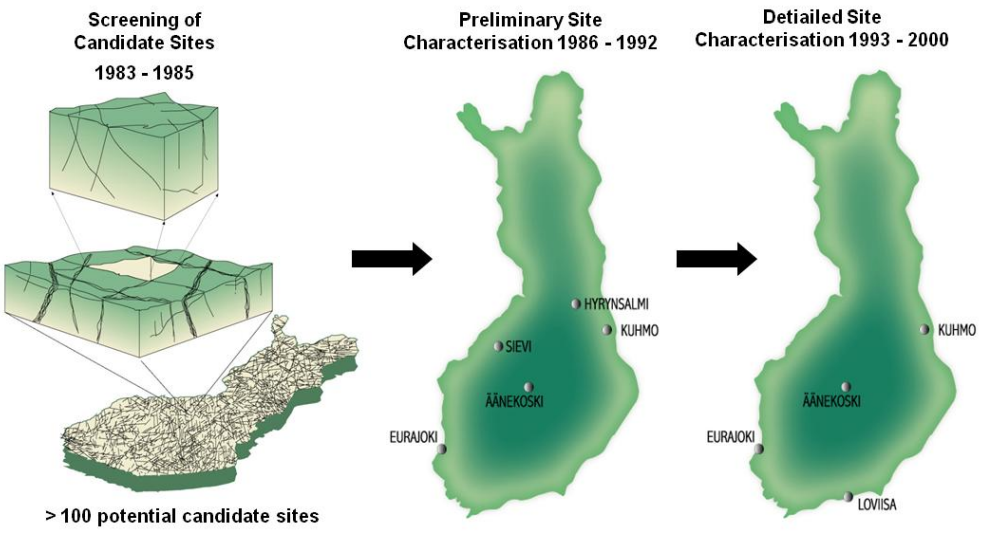

Fig. 2. Site selection process in Finland between 1983-2000 [5].

The site selection was based on the scientific material accumulated from 15 years of site characterisation and evaluation, and on an environmental impact assessment (EIA) conducted between 1997and 1999. An assessment on long term safety, TILA-99, was produced to support the EIA. Its main conclusions were that the regulatory, operational and transportation safety requirements could be met irrespective of the site selected. Hence the social impact and infrastructure of the sites gained more weight in the selection. Social acceptance was highest in nuclear communities Eurajoki and Loviisa and lower in Äänekoski and Kuhmo. It was found that the infrastructure of Olkiluoto provided the best support for a disposal facility and, in fact, most of the SNF accumulated would be at Olkiluoto [1].

Before a nuclear facility can be built in Finland a Government's Decision-in-Principle is required by the Nuclear Energy Act. The selection of the site was connected to this decision making and Posiva filed an application for the decision in 1999 to be able to build the disposal facility at Olkiluoto in Eurajoki municipality. In this process the host community and STUK have a right of veto. Since the local community Eurajoki was in favour of the disposal facility, as well as STUK, the Government made the positive decision in 2000 and the Parliament ratified the decision in 2001.

GAINING ACCEPTANCE FOR DECISION MAKING

The criticism towards nuclear power and especially towards nuclear waste started to grow internationally during 1970s. The disposal of radioactive wastes received very little understanding and was regarded to pose a significant risk to future generations. In early 1980s when the preparation of the Nuclear Energy Act was started in Finland it became obvious that the political decision on locating a nuclear facility would be required and that the local community would have a veto right in the decision making.

The planned duration of the siting was almost 20 years and this process, consisting of scientific and technical information, would end up in a social and political decision making. This would mean that decision makers have to, at the end, trust both the implementer and regulator when

making their informed decision. The decision making would be needed both on local and national levels. Therefore, when planning the siting programme it was considered that "honesty is the best policy" and the best way to build confidence would be open communication. It was also decided that the results accumulating from the programme would be public and available to all, the distribution of information would be based on multidisciplinary expertise and that the experts by themselves would be in the main role in the communication.

In the site selection process potential candidate areas were identified based on the scientific assessment of their geological suitability. The inventory of site candidates was published and the potential host communities were contacted for further negotiation on the possibilities to initiate site characterisation activities at the site. In this process several communities announced their willingness to join the site selection research programme and when field investigations were started in 1987 all five candidate communities had expressed their volunteerism and consent for investigation.

The environmental impact assessment procedure, which took place in all candidate municipalities in 1997-1999, was an important tool for communication. It also provided a means for local people to voice their concerns, and actually balanced the discussion bringing up not only the disadvantages but also the advantages of the project. Although public participation in this process remained limited, different views and opinions were presented on a broad spectrum during the assessment

According to Finnish experience, local acceptance played a key role when selecting the site for SNF disposal. This was due to the fact that the municipality had a veto right in the decision-making process and a possibility to stop the site selection process. In order to proceed with the final disposal preparations, local acceptance is required, but it cannot be created within a short period of time [2].

It is obvious that Posiva has not been the only contributor in gaining acceptance. The safety authority STUK (Finnish Authority for Radiation and Nuclear Safety) by being available for citizen and especially for communities provided an independent source of information. In building trust it has been also important that people have been able to rely on STUK as a supervisor of Posiva's work and results. In this respect it has been important how Posiva has conducted its work. Also the fairness of the decision making and the possibility to participate in the process has been an important issue.

PREPARATION FOR IMPLEMENTATION

The next step after site selection for Posiva was to prepare an application for a construction license and enter to construction of disposal facility. The target for submitting the application to the Government was set in 2012. During the period from year 2001 to 2012 conceptual designs of the deep repository and the encapsulation plant were developed to required maturity for the construction license phase.

The disposal system KBS-3 is based on engineered barriers with crystalline bedrock as a natural barrier. At the Olkiluoto site the bedrock consists of hard, crystalline rock. The main rock type is gneiss which is a metamorphic rock with a granitic composition (Figure 3). The engineered barriers are the copper-iron canister, where the copper works as a barrier against corrosion and

a cast nodular graphite iron insert gives the required mechanical strength. The buffer between the canister and the bedrock consists of highly compacted bentonite clay. Backfill in deposition tunnels is based on clay material with swelling capabilities.

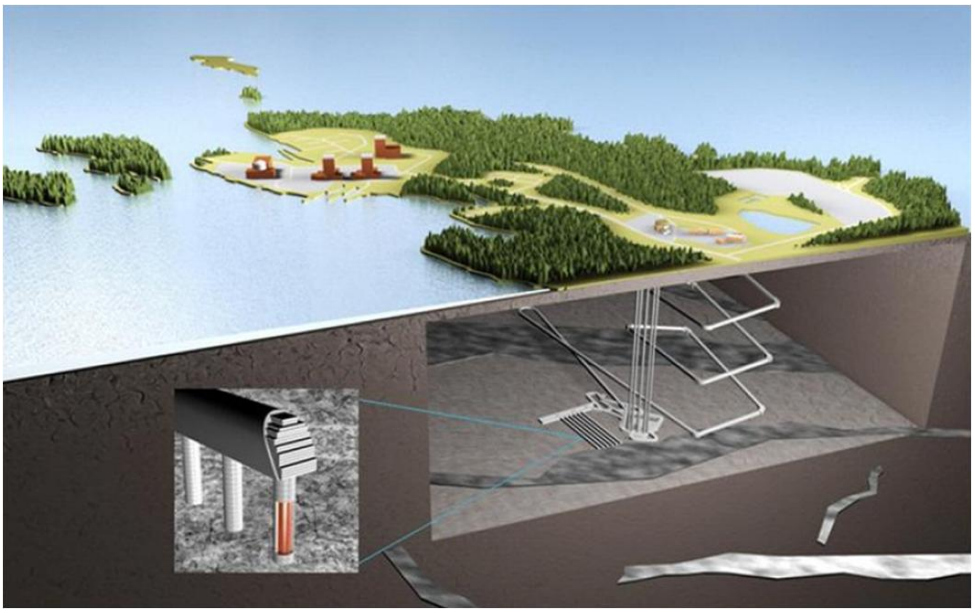

Fig. 3. Illustration of KBS-3 repository at Olkiluoto.

The main safety function of the canister is to ensure the complete containment of SNF for very long time periods. The safety assessment is usually stretched to 100,000 years and beyond. The safety function rests first and foremost on the mechanical strength of the canister insert and the corrosion resistance of the copper surrounding it. The safety functions of the buffer include the protection of the canisters from external processes that could compromise containment, and limitation and retardation of radionuclide releases in the event of canister failure. The safety functions of the host rock are to isolate the repository from the biosphere and normal human habitat, and to provide favourable and predictable mechanical, geochemical and hydrogeological conditions for the engineered barriers, protecting them from potentially detrimental processes taking place above and near the ground surface such that they contain the SNF. The rock also limits and retards both inflow and release of harmful substances from the repository. Other system components like backfill, plugs, structural and sealing components, have not been assigned safety functions. They are designed to be compatible with, and support the safety functions of the other barriers [3].

After the site selection, as part of site confirmation, Posiva decided to construct an underground rock characterisation facility from ground surface to planned disposal depth. The purpose of this facility, called ONKALO, has been to produce detailed information for the design and safety assessment which cannot be obtained from investigation on the surface. ONKALO also provides an opportunity to test and demonstrate processes for assessment of rock suitability, design of repository rooms and their excavation method. The decision was made that ONKALO will later serve as an access to the repository. For this reason STUK has supervised the construction in the same way as STUK supervises the construction of the new reactor at Olkiluoto.

The excavation of ONKALO was started in 2004 and was completed in 2012. The layout consists of an access tunnel and three vertical shafts (Figure 4). An extensive research programme has been conducted during the excavation stage. After reaching the planned disposal depth of -420 m (below the sea level) large scale tests and demonstrations were started in drifts especially constructed for this purpose.

Posiva submitted the application for the construction license at the end of the year 2012. The plan is to commence the construction of the encapsulation plant and first disposal tunnels after receiving the construction license in 2015. The final step to enter to operation of the repository is the application for an operation license, which Posiva plans to submit to Government in 2020. The disposal activities are scheduled to start in 2022. The disposal of the current inventory for four operating reactors and one under construction 5500tU (~2tU per canister) will take more than a hundred years. The thermal output of each canister is limited and SNF bundles must be cooled for 50 years. Since the reactors will be operated for at least 60 years, more than 100 years will be needed for disposal [3].

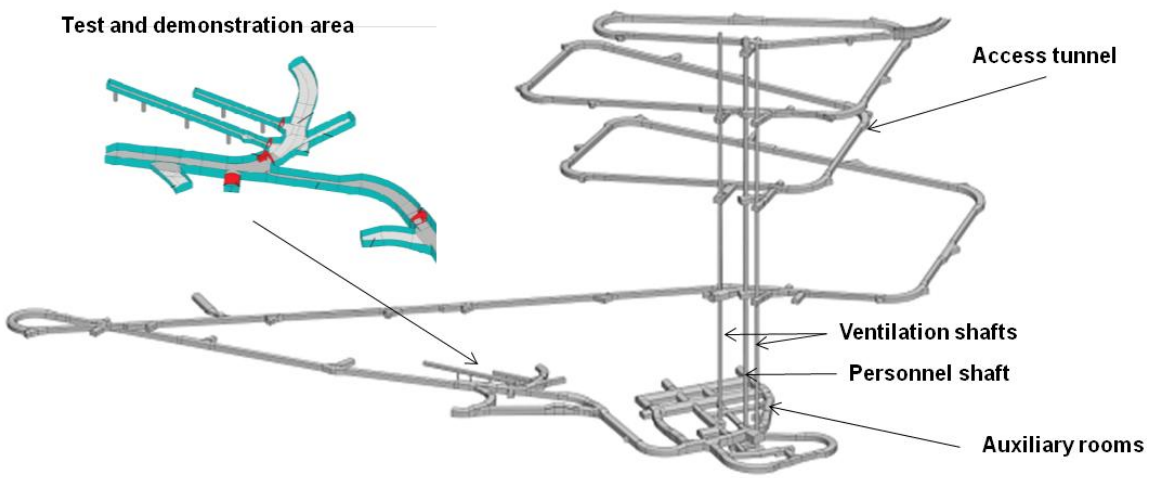

Fig. 4. Underground rock characterisation facility ONKALO at Olkiluoto.

COST AND FINANCING

The state nuclear waste management fund is a reserve for future costs which TVO and Fortum are liable for. The fund was introduced in the Nuclear Energy Act of 1987 and has been operating since 1988. The segregated fund is controlled by the TEM. The fund fulfils the two globally accepted principles for such funds: the funds are collected in the cost of the nuclear electricity production and the funds are available when the related waste management operations are carried out. The nuclear operators are entitled to borrow back, at market interest rates, 75% of the capital against full securities. The state has the right to borrow the remaining 25% at the same interest rate [4].

Based directly on realistic predictions of SNF inventory, waste management plans and technical designs Posiva has produced cost estimates for its owners for the SNF disposal. The total cost estimate for the construction, operation and closure of the SNF disposal facility presented is 3300 Million € (year 2009) for current four operating reactors and one under construction [4].

CONCLUSIONS

Nuclear waste has been generated for ca 50 years but only some of the less hazardous and short-lived radionuclides have been disposed of so far. This does not mean that the work for disposing of long-lived HLW would have been neglected. On the contrary, based on the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (opened for signatures in1997) all countries using nuclear power should proceed to develop safe solutions like permanent deep geological facilities for safe disposal of HLW. Geologic disposal in a mined repository is the most promising and technically accepted option available for safely isolating HLW for very long periods of time. This is stated in the European Union (EU) directive:"Council Directive on the Management of Spent Fuel and Radioactive Waste" which became effective in August 2013 within EU. This Directive requires a member country to develop a programme and submit it for EU review by 2015 whether the member country has nuclear power or not.

Finland, Sweden and France, have advanced to a licensing and implementation stage in their long-term programme and the target is set for commissioning repositories in the 2020s. Many programs, however, were very advanced at the time when the programme in Finland was started. Gorleben salt dome in Germany was selected to host a deep repository and the sinking of vertical shafts was started already during 1970s. The plans in the USA aimed at starting the disposal in late 1990. Other countries with an active R&D-programme for geologic disposal during the 1980s and 1990s were Canada, Switzerland, Belgium, Spain, Japan, UK and, of course, Sweden. The progress of these programs suffered, however, from the lack of political decision making related to selection of the site for the repository. Today in many countries the programs have been redesigned and started again. The siting is based on stepwise approach in which volunteerism plays an important role in the process. Meanwhile spent nuclear fuel has been stored in interim storage facilities. In 2020 the global inventory of SNF will be approximately 450000 tU but it keeps growing. In spite of the new possible technologies in a distant future there will be a legacy of SNF which needs to be safely disposed of.

ONKALO has started as an underground rock characterisation facility but it will also serve as a deep repository in the future. The success of ONKALO was based on a systematic long-term programme in which the site selection research received an emphasis. The programme has been successfully integrated into Finnish society by justifying its existence by political decision making in an early phase in 1983. During its course the programme has been guided by a "do and see" strategy which has made possible the flexibility in the consideration, based on science and technology, between the alternatives for SNF management. As the result deep geologic disposal has proved to be the preferred option as a permanent safe and secure solution. The future of the programme has been made possible by the licensing process in which the political consideration and decision making is made in an early phase thus making the commitment of the society possible. The continuity for the programme has been made possible by the respect paid by each new Government to earlier decisions.

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