Decommissioning and Disposal of the Decommissioning Waste at the Site of the Loviisa Nuclear Power Plant – 14254

Matti Kaisanlahti
Fortum Power and Heat Oy, Espoo, Finland

ABSTRACT

The planned lifetime of the Loviisa nuclear power plant is 50 years. The plan calls for the plant to be decommissioned over two periods: decommissioning of the main parts in 2027–2035 and decommissioning of the independent plant parts in 2066–2068, when all spent fuel has been transported to the Olkiluoto site for final disposal. The licensing of the decommissioning of the power plant and the repository of the decommissioning waste is designed to begin in the early 2020s with an environmental impact assessment. Immediate dismantling has been chosen as the decommissioning strategy of the power plant. Experienced plant personnel will still be available to lead the decommissioning work. Decommissioning waste will be disposed of in the underground disposal tunnels located at the site at a depth of about 110 m. Some of these tunnels have already been constructed for the power plant's operating waste, such as the maintenance waste tunnels and a solidified waste hall. The large and heavy components, e.g. reactor pressure vessels (RPVs) and steam generators, will be disposed of as they are, without cutting them into smaller pieces. Other decommissioning waste will be mainly packed into concrete and wooden containers. The latest cost estimate for the decommissioning of the Loviisa power plant is about 359 million euros, excluding Value Added Tax (VAT).

INTRODUCTION

The Loviisa nuclear power plant consists of two units. The first unit of the Loviisa NPP, Loviisa 1 (LO1), was commissioned in 1977 and the second, Loviisa 2 (LO2), in 1980. The originally designed technical life of the Loviisa NPP was 30 years. On the basis of the operating experience gathered at the plant, the preventive maintenance performed, and the modernization and power upgrading project carried out in 1995–1998, the operational life has been extended to 50 years, until 2027 for LO1 and 2030 for LO2.

The decommissioning plan for the Loviisa NPP is based on immediate dismantling after the final shutdown of the power plant. Experienced plant personnel will still be available to manage the decommissioning work. Only the radioactive power plant systems, components and structures are included in the decommissioning plan and cost estimate, and will be dismantled and disposed of. Later on, the non-radioactive parts will be dismantled and the power plant site will be released for industrial use. The estimated amount of radioactive decommissioning waste is based on calculations of induced activity, measurements during operation and use of a 3D computer aided design (CAD) model of the plant.

The existing repository for operating waste built in the bedrock of the plant site will be extended for the decommissioning waste. This part of the repository has not yet been licensed, and the required decisions and permissions will be applied for this enlargement part in the early 2020s.

The decommissioning waste will be mainly packed into concrete and wooden containers. Large components, such as RPVs and steam generators, will be disposed of in one piece.

DECOMMISSIONING AND DISMANTLING

Licensing Of Decommissioning

The licensing of the decommissioning of the power plant is designed to begin in the early 2020s with an environmental impact assessment. Also, a new operating license for the power plant units will be needed. The licensing of the final repository requires a decision in principle from the Government, a construction licence and a new operating license. All the licensing for decommissioning must be completed before the actual dismantling work can be started. The preliminary licensing schedule is shown in Figure 1.

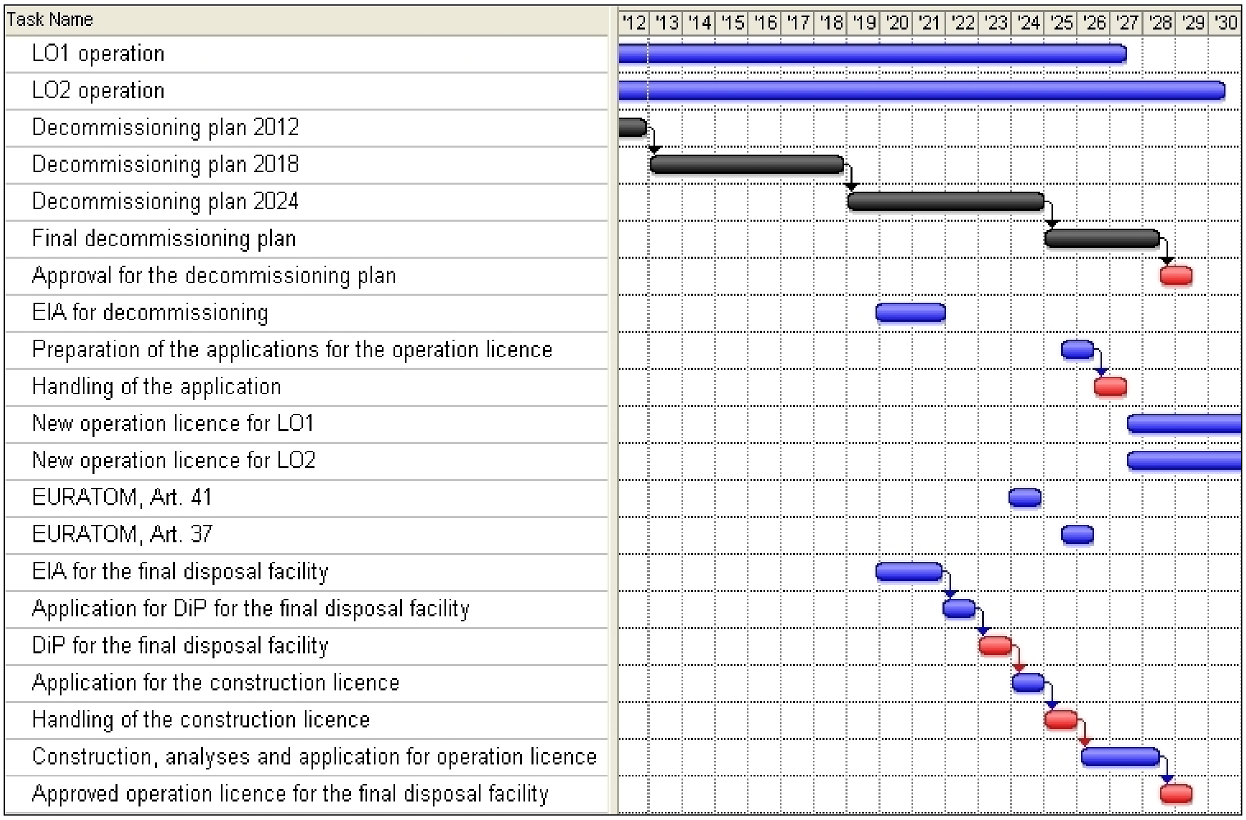

Fig. 1. Licensing schedule for the decommissioning of the Loviisa NPP [1].

Schedule For Decommissioning

The overall schedule for the decommissioning work is shown is Figure 2. It is based on the operating period of 50 years. The plant will be decommissioned in two phases. In the first phase, the decommissioning of the power plant units takes place in 2027–2035. In the second phase, the decommissioning of the facilities and systems intended for the storage of the spent nuclear fuel will be carried out in 2066–2068, when all spent fuel has been transported to Olkiluoto for final disposal.

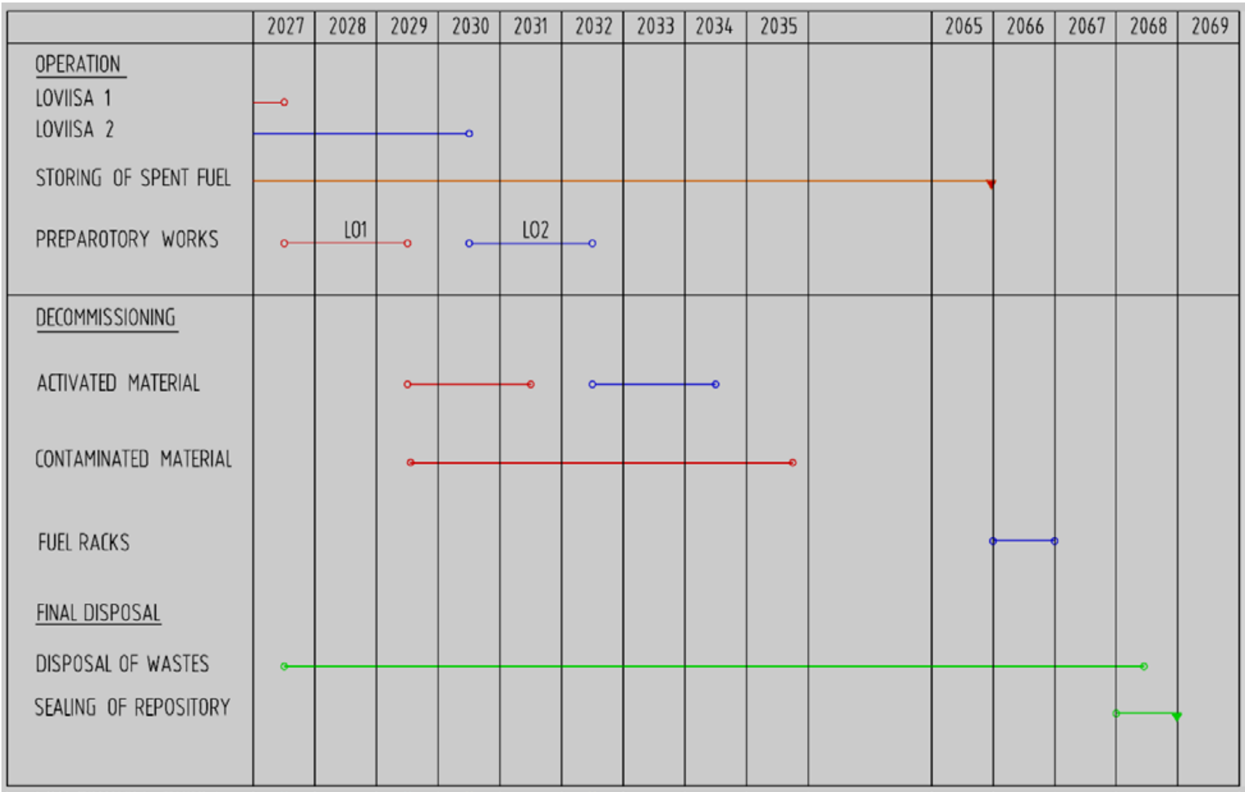

Fig. 2. Overall schedule for the decommissioning of the Loviisa Power Plant [1].

The Loviisa Power Plant decommissioning is designed to start with a two-year long preparation phase before the actual dismantling work begins. At the preparatory phase, the spent fuel will be transferred to spent fuel storage facilities, the process systems will be decontaminated, the liquid waste left in the storage and generated during preparatory phase will be treated and conditioned, and the ramp for the transfer of large components will be constructed.

Dismantling

The dismantling and treatment of the plant's radioactive components can be carried out with currently available technology and methods. The main point for the decommissioning of the Loviisa Power Plant is to dispose of the large components, such as the reactor pressure vessels and steam generators, as whole components. Other decommissioning waste will be mainly packed into concrete and wooden containers. The total volume of the decommissioning waste will be 30,000 m^3, when packed.

The plan calls for the reactor pressure vessel to be moved using a remotely controlled crane and a radiation shield which consists of concrete and steel (see Figure 4). The reactor pressure vessel will be lifted from the reactor shaft onto the main level of the reactor hall, where it will be put inside a radiation shield. The pressure vessel and a radiation shield will be lowered onto the transport carriage in the segment area of the reactor building for transporting to the repository.

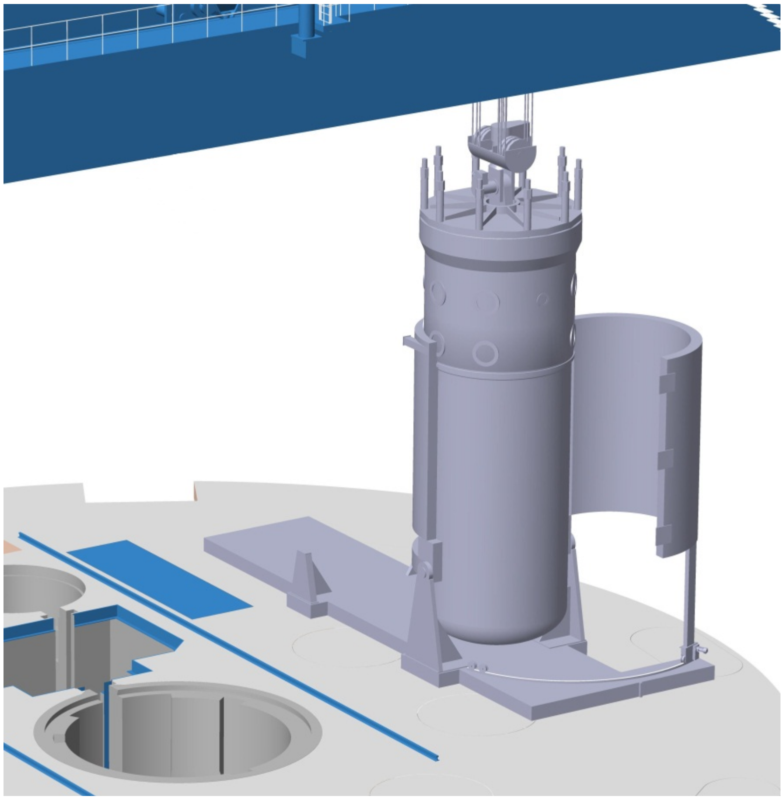

Fig. 3. The reactor pressure vessel is lifted onto the radiation shield [1].

The concrete structures near the reactor pressure vessel are activated and contaminated during operation of the plant. The dismantling of the concrete structures of the pool area and the reactor shaft will be done using diamond wire sawing. The work plan is based on the 3D model of the plant (see Figure 4).

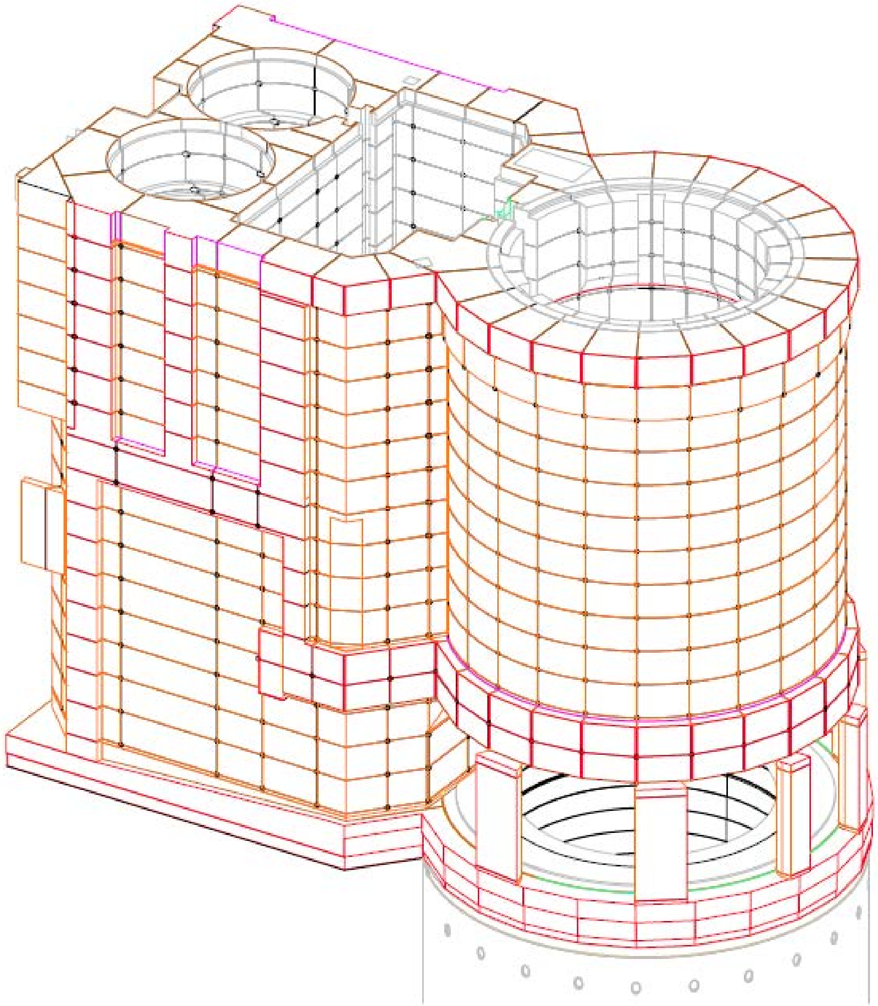

Fig. 4. Sawing plan for the pool area and the reactor shaft [1].

FINAL DISPOSAL

Repository For Operating And Decommissioning Waste

The low- and intermediate-level operating waste produced during operation of the Loviisa Power Plant and the decommissioning waste produced during the decommissioning works will be disposed of in the repository constructed in the bedrock of the power plant site. Some of the facilities for plant operational waste have already been completed and are in use. The facilities for the decommissioning waste consist of three halls and those will be constructed in the 2020s. The final disposal facility is located underground at a depth of some 110 metres and at a distance of some 400 metres south-west of the power plant units. Figure 5 shows the repository.

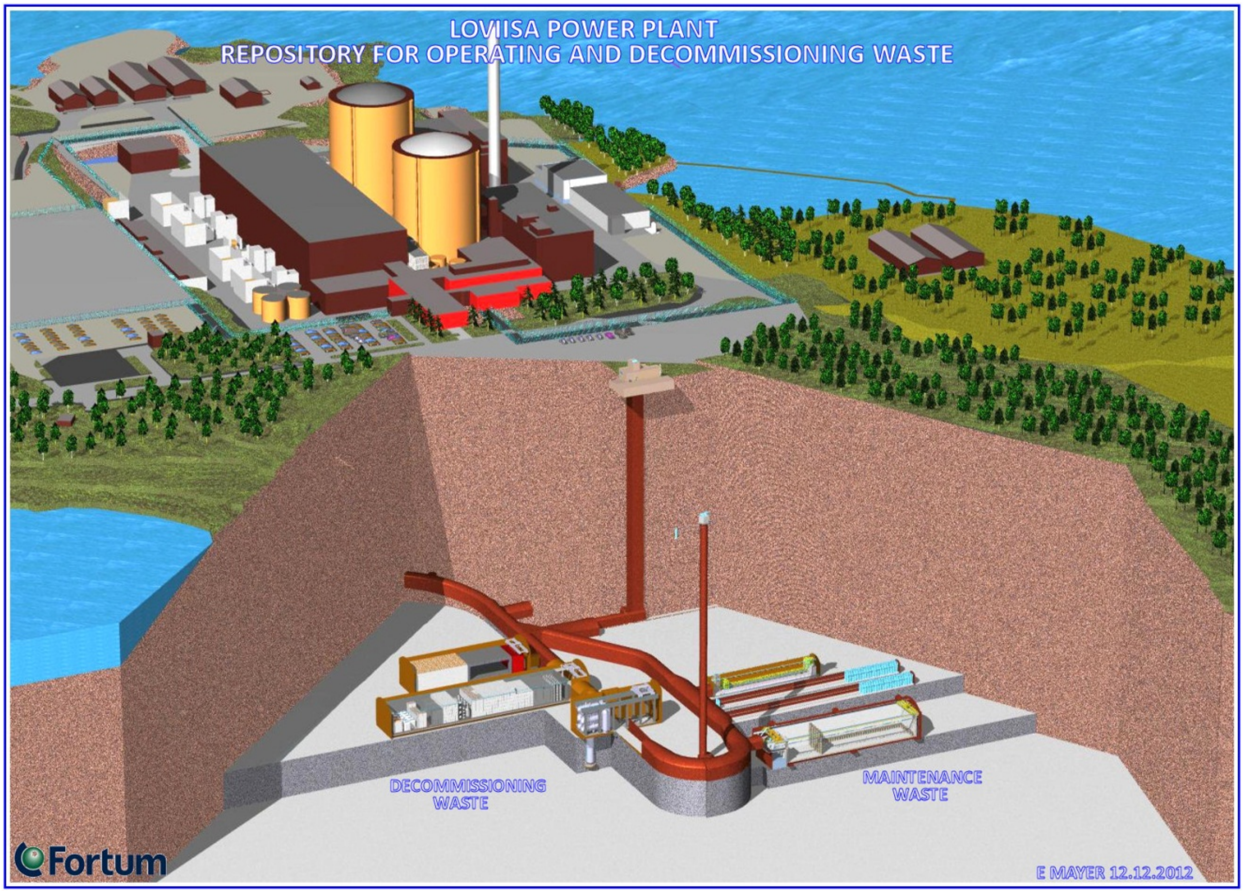

Fig. 5. LLW/ILW Repository at the Loviisa Power Plant [1].

The reactor pressure vessel will be brought to the hall along the transport tunnel, lifted with the aid of the bridge crane and lowered into the reactor silo. The pressure vessel internals will be transported inside a shielding cylinder to the repository and put into their places in the pressure vessel. The shielding elements will be transferred at the transport cask to the repository and placed into the positions of the fuel assemblies in the core basket. The protective tube unit of the control rod drives will be placed into the core basket. The sealed reactor silo is shown in Figure 6.

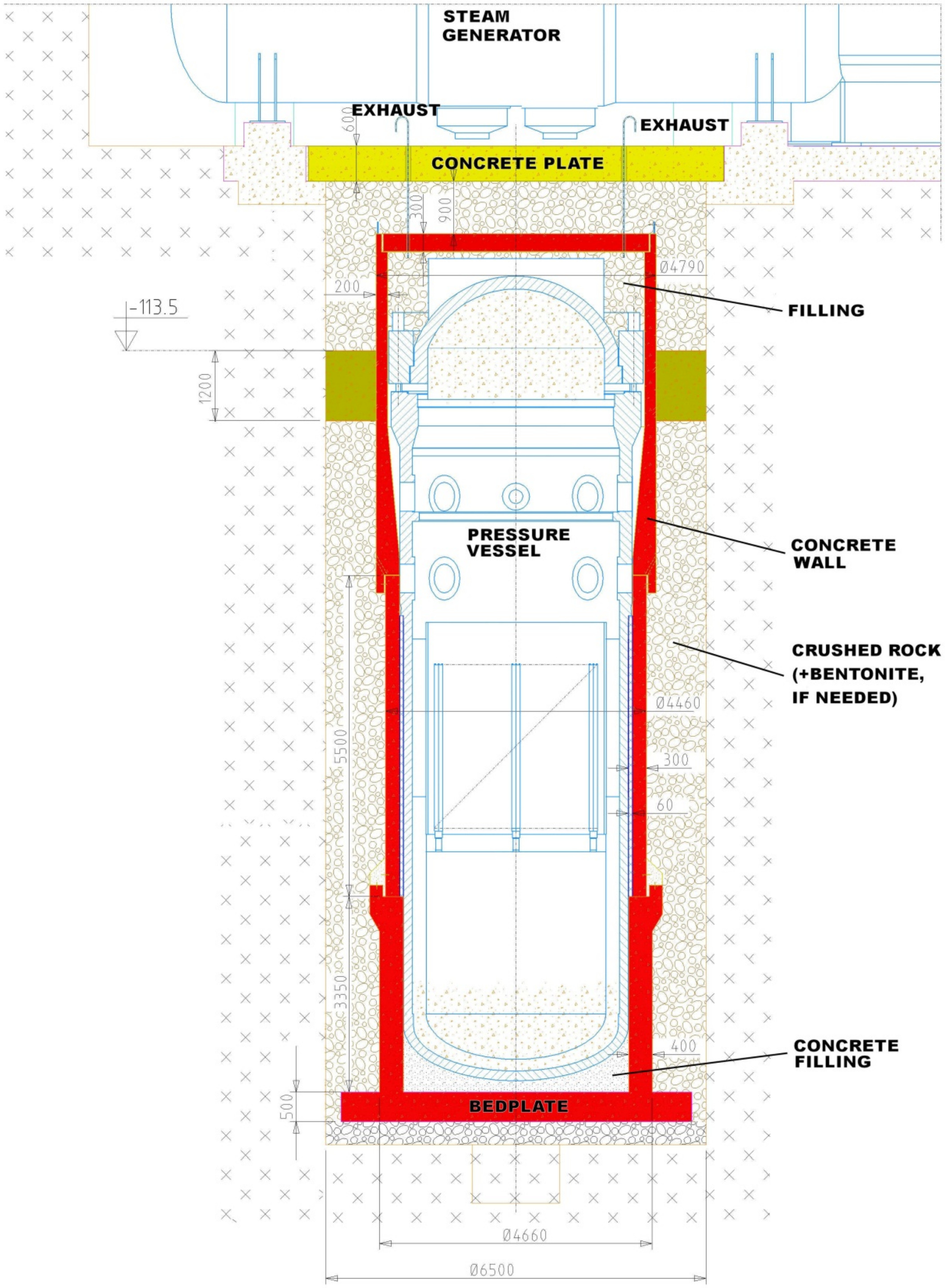

Fig. 6. The sealed reactor silo [1].

The large components of the primary circuit will be disposed of in the hall above the reactor silos. The steam generators will be piled in three layers at the far end of the hall. The pressuriser and the bubbler will be placed in the upright position in the middle part of the hall. In the sealing phase, the empty space remaining in the hall will be backfilled with crushed rock.

The waste packed in concrete and wooden packages will be disposed of in the second hall. A basin made of reinforced concrete will be built in the hall, with a bridge crane moving above it. The waste packages will be piled in the concrete basin by means of the bridge crane. In the sealing phase, the empty space remaining in the basin will be backfilled with crushed rock and a reinforced concrete slab will be cast on the basin. The empty space remaining beside and above the basin will be backfilled with crushed rock.

The waste from the reactor shaft, pool area, reactor hollow and used nuclear fuel racks will be placed in the third hall. The hall layout is similar to the second hall; only the waste basin is shorter.

The liquid waste produced during the decommissioning works will be solidified and disposed of to the exiting solidified waste hall of the repository. The solidified waste hall is shown in Figure 7.

Fig. 7. Solidified waste hall [1].

The maintenance waste produced during the decommissioning will be packed into 200-litre drums. The drums will be disposed of in the exiting third maintenance waste tunnel (HJT3). In the sealing phase of the repository, the tunnel will be separated from the connecting tunnel by a concrete wall. The maintenance waste tunnel is shown Figure 8.

Fig. 8. Maintenance waste tunnel [1].

The Long-term Safety Of The Repository

The safety of the repository after its closure is based on both natural and engineered barriers. The natural barrier system (NBS) consists of the bedrock as well as the physical and chemical behaviour of the radionuclides in the bedrock. The host rock of the island of Hästholmen is rapakivi granite, the most common variety of which is pyterlite. The rock between the main fracture zones is fractured cubically, and through this fracture system the repository is connected to the sea. As to sorption of radionuclides, rapakivi granite can be considered quite favourable. Radionuclides dissolved in groundwater diffuse into the micropores in the rock matrix and are retarded due to sorption in the rock material.

The engineered barrier system (EBS) constructed prior to and during operation and closure of the repository consists of waste packages, the sealing of the repository, and other engineered arrangements, which create conditions effectively limiting the release of radioactive substances from the repository. The large amount of concrete in the repository, especially in the reactor pressure vessel silo, creates long-standing alkaline conditions in which the corrosion of steel and dissolution of minerals is reduced. The pH will remain at an elevated level until all portlandite $Ca(OH)_2$ in the concrete is dissolved into the groundwater. Only after the portlandite has been dissolved does the pH gradually decline and other minerals start to dissolve efficiently. Therefore, the concrete environment forms an effective chemical barrier even after the concrete structures have mechanically lost their integrity.

The repository will be sealed with massive concrete structures, plugs, which reduce the water flow in and between the tunnels. The connection tunnel will also be sealed with a few plugs, and the rest of the tunnel volume will be backfilled with crushed rock. Ventilation and stairway shafts will also be plugged to prevent flow between the upper fracture zone and the repository. The plugs will be constructed below and above the intersection of the shafts and the fracture zone.

The bulk of the decommissioning waste activity is in the RPV silos. The release of the main radionuclides from the RPV silos into the biosphere in the case of the expected evolution case (a small well at a favourable location) is presented in Figure 9. The release rates are calculated using conservative corrosion rates and parameters. The release rates are averaged over periods of 1,000 years. All the release rates remain clearly below the nuclide-specific constraints (dashed lines). The other waste types contribute to the radioactivity release less than the ones in the RPV silos.

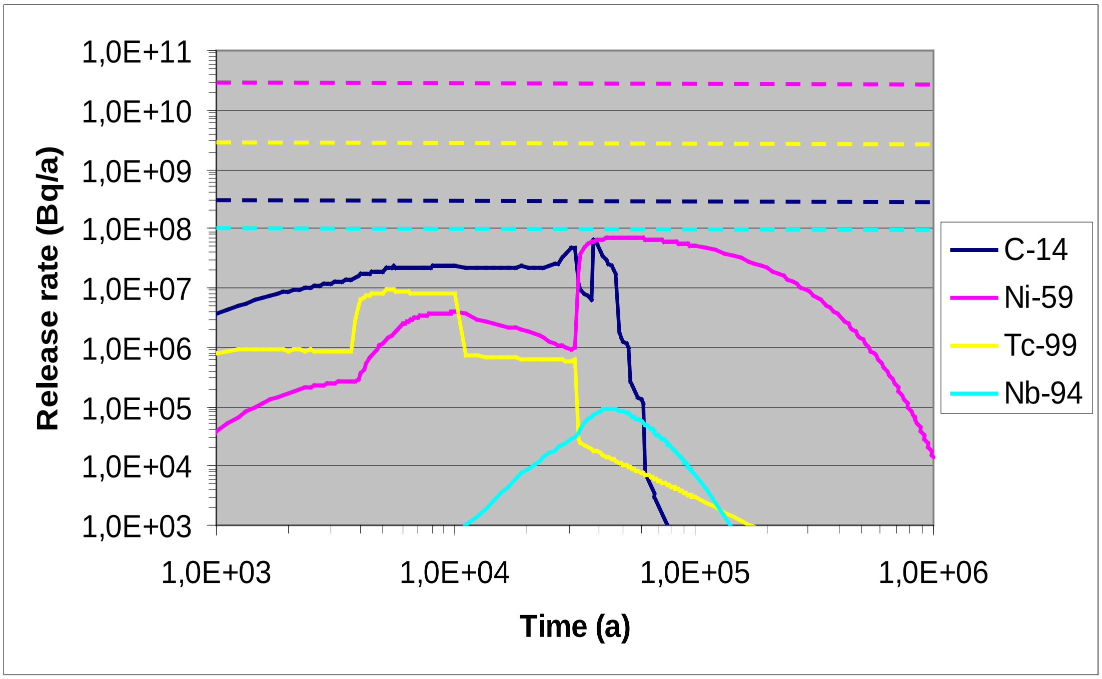

Fig. 9. Activity release into the environment from the RPV silos [1].

DECOMMISSIONING COSTS

The license holder is responsible for decommissioning costs. To guarantee that decommissioning can be carried out in all circumstances, the license holder has paid funds into the State Nuclear Waste Management Fund. The funding for the decommissioning the Loviisa Power Plant already exists.

The decommissioning costs of the Loviisa Power Plant have been assessed on the basis of the proposed plans and estimated workload. With regard to purchases of different types, the assessments are based on the empirical cost data gathered at Fortum during the operation of the Loviisa Power Plant and on the cost estimates obtained from equipment suppliers. On the whole, the decommissioning will be a very labour-intensive project; there are over 5 million working hours in the decommissioning plan. Table I shows the cost estimate for decommissioning the Loviisa Power Plant at December 2012 cost levels.

TABLE I. Decommissioning costs of the Loviisa Power Plant [1].

Cost item	**Cost in 1,000 euros**
Preparatory phase	53,223
Main equipment, construction and materials	19,362
Dismantling work (contracts)	125,662
Handling of waste and final disposal	27,497
Surveillance, guarding, maintenance and utilities at the site	9,780
Project administration and design	7,569
Other costs (personnel and insurance)	83,344
Costs in all	326,437
Reserve to cover unspecified costs, 10%	32,643
Total cost	359,080

The latest cost estimate for the decommissioning is about 359 million euros (excluding VAT). This cost estimate includes all costs of the decommissioning phases in 2027–2035 and 2066–2068, including the final disposal of the decommissioning waste, but not the cost for the management of spent nuclear fuel. The cost estimates have not taken into account any positive values linked with the decommissioned plant or plant site, such as the value of metals or components when recycled and reused, or the value of the plant site for industrial use.

CONCLUSIONS

The planned decommissioning of the Loviisa power plant units will start in 2027. So the licensing of decommissioning and the repository of the decommissioning waste should start in the early 2020s.

The dismantling and treatment of the plant’s radioactive components can be carried out with currently available technology and methods. Still, an important part of planning the decommissioning is to follow various technological improvements and decommissioning projects around the world.

The dismantling plans for the main objects are made by using the 3D CAD model of the plant.

The decommissioning waste will be disposed of in the facilities to be built in the bedrock of the island of Hästholmen at a depth of about 110 metres. These facilities will form an extension to the existing repository for operating waste, which has been in operation for several years now.

REFERENCES

1. Kaisanlahti M., Eurajoki T., Mayer E., Rämä T., Nummi O. Decommissioning of the Loviisa nuclear power plant, edition 2012, TJATE-G12-145, Fortum Power and Heat Oy, December 2012, ISBN 978- 951-591-086-8.