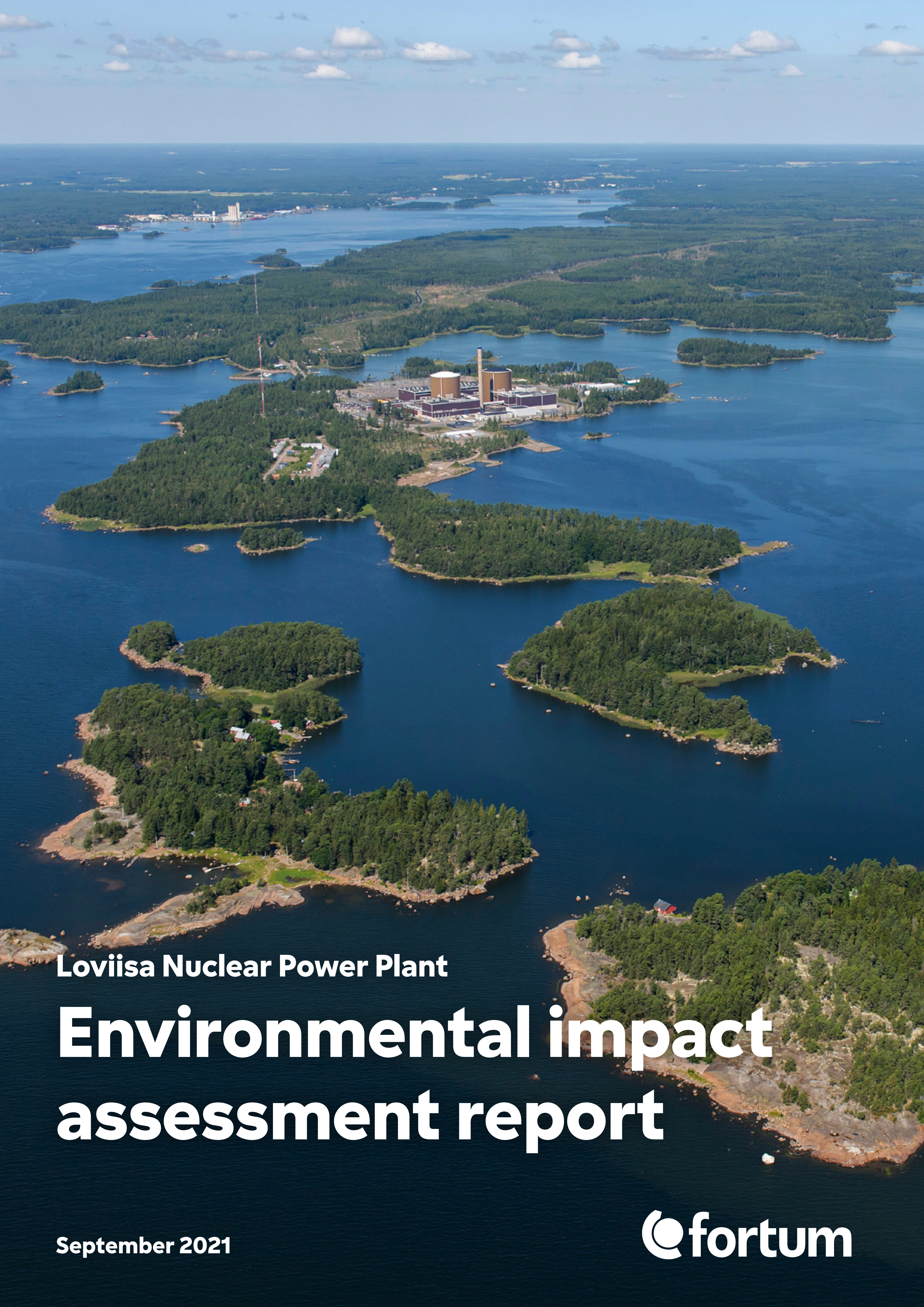

Loviisa Nuclear Power Plant

Environmental impact assessment report

September 2021

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Introduction

Climate change and transitioning to a low-carbon energy system make reliable and emission-free electricity production even more important than before. A steady supply of electricity is also important. In line with our vision, we want to promote development towards a cleaner world in the future as well.

At Fortum, we believe that this new world will also need nuclear power for a long time. As a carbon dioxide emission-free, reliable source of energy that is not dependent on the weather, nuclear power contributes to meeting today's need for energy and mitigating climate change – together with renewable energy.

Loviisa nuclear power plant has been producing clean electricity for over 40 years, and we have a long track record as a responsible producer of nuclear power. The impacts of and the added value provided by our operations can be seen locally, regionally and globally. We continuously work to reduce the impacts of our operations on the environment by applying the best practices and technologies.

Fortum initiated Loviisa nuclear power plant's Environmental Impact Assessment Procedure (EIA Procedure) in August 2020. The procedure covered the option of extending the power plant's operation for a maximum of 20 years and two different decommissioning options. An international hearing in accordance with the Espoo Convention will also be carried out in connection with the EIA Procedure.

The EIA Report you are reading includes the results of the environmental impact assessment of Fortum's Loviisa power plant. The EIA Report was prepared in cooperation with Ramboll Finland Oy.

The EIA Procedure concludes when the Ministry of Economic Affairs and Employment gives its reasoned conclusion on the EIA Report. The EIA Report and the coordinating authority's rea-soned conclusion to be issued on it are appended to any licence and permit applications.

The coordinating authority in the project's EIA Procedure is the Finnish Ministry of Economic Affairs and Employment, and the coordinating authority in the international hearing is the Ministry of the Environment.

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Arbets- och näringsministeriet

Ympäristöministeriö
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Summary

PROJECT OWNER AND THE PROJECT BACKGROUND

The project owner in the environmental impact assessment procedure (EIA Procedure) is Fortum Power and Heat Oy (hereinafter Fortum), part of Fortum Group and a wholly owned subsidiary of Fortum Corporation. In the Nordic countries, Fortum Group is the second-largest producer of electricity and the largest electricity seller. Nuclear energy plays a significant role in Fortum Group's carbon dioxide-free electricity production.

Loviisa nuclear power plant, owned and operated by Fortum, produces a total of approximately 8 terawatt hours (TWh) of electricity for the national grid per year. This is equal to approximately 10% of Finland's electricity consumption. For its part, Loviisa nuclear power plant supports the climate targets of Finland and the EU as well as a secure electricity supply.

Loviisa nuclear power plant consists of two power plant units, Loviisa 1 and Loviisa 2, as well as the associated buildings and storage facilities required for the management of nuclear fuel and nuclear waste. Loviisa 1 began its commercial operation in 1977 and Loviisa 2 in 1980. Loviisa power plant has been generating electricity reliably for more than 40 years. The current operating licence issued by the Finnish government to Loviisa 1 is valid until the end of 2027, and the operating licence issued to Loviisa 2 is valid until the end of 2030.

Fortum is in the process of assessing the extension of the commercial operation of Loviisa nuclear power plant by a maximum of approximately 20 years beyond the current operating licence period. Fortum will make the decision concerning the potential extension of the operation of the nuclear power plant and the application for new operating licences at a later date. The other option is to proceed to the decommissioning phase once the power plant's current operating licences expire.

Fortum has been investing in the ageing management of Loviisa power plant and has carried out improvement measures throughout the operation of the power plant. The power plant units were customised to meet western safety requirements as early as the planning phase. Over the years, Loviisa power plant has implemented several projects that improve nuclear safety. In recent years, extensive renewals have been carried out on the automation of the power plant, and ageing systems and equipment have been modernised. In 2014–2018, Loviisa power plant implemented the most extensive modernisation programme in the plant's history, in which Fortum invested approximately EUR 500 million. Thanks to the investments made and a skilled personnel, Loviisa power plant has excellent prerequisites with regard to the technical and safety-related requirements to continue operation after the current licence period.

POWER PLANT'S CURRENT OPERATION

Loviisa nuclear power plant is an electricity-generating condensing power plant, the plant units of which are pressurised water plants. Electricity generation in a nuclear power plant is based on the utilisation of thermal energy generated by a controlled fission chain reaction.

Loviisa power plant is used for the generation of base load electricity. The nominal thermal power of both power plant units is 1,500 MW, and the net electric power is 507 MW. The total efficiency of the power plant units is approximately 34%. The availability and load factors of Loviisa power plant have been excellent.

The low- and intermediate-level waste generated during the operation of the power plant is processed in the power plant and deposited in the final disposal facility for low- and intermediate-level waste (the L/ILW repository), located

110 metres underground in the power plant area. The spent nuclear fuel is deposited for interim storage in the pools of water in the interim storages for spent nuclear fuel in the power plant area. In due course, the spent nuclear fuel will be deposited for final disposal in Posiva Oy's encapsulation plant and final disposal facility at Olkiluoto in Eurajoki.

The volume of sea water used by Loviisa power plant for cooling is an average of 44 m^3/s. The cooling water is abstracted from the western side of the island of Hästholmen, using an onshore intake system, and the water, warmed by approximately 10 ºC, is discharged back into the sea on the eastern side of the island. The most significant environmental impact of the current operation of Loviisa power plant is the thermal load from the cooling water on the sea. The warming effect concentrates mainly in the vicinity of the cooling water's discharge location.

PROJECT DESCRIPTION AND THE OPTIONS REVIEWED

The implementation options reviewed in the EIA Procedure for the project include extending the power plant's operation after the current licence period by a maximum of approximately 20 years (Option VE1) and two different zero options (Option VE0 and Option VE0+) related to the power plant's decommissioning.

EXTENDED OPERATION (VE1)

Option VE1 covers an extension to Loviisa power plant's commercial operation after the current licence period (2027/2030) by a maximum of approximately 20 years. In the event of extended operation, the operation of the power plant would be similar to its current operation. There are no plans to increase the power plant's thermal performance. If the operation of the power plant is extended, new buildings and structures may potentially be constructed and modernisations may be carried out in the power plant area.

Potential modifications related to extended operation include replacing some old buildings in the power plant area with new ones; procuring the power plant's service water from the municipal plant and directing sanitary wastewater to the municipal sewage treatment plant; and increasing the interim storage capacity for spent nuclear fuel.

As part of Option VE1, the EIA Programme of Loviisa power plant investigated the possibility of carrying out water engineering projects in the area in front of the cooling water intake and the adjacent sea area. Based on the techno-economic investigations, the water engineering projects are no longer being planned, which is why they are not reviewed in the EIA Report.

Option VE1 includes the power plant's decommissioning after the commercial operation. The option of extended operation also includes investigating whether small quantities of low- and intermediate-level waste generated elsewhere in Finland could be received, handled, and deposited in interim storage and final disposal in the Loviisa power plant area. These operations are described in more detail below.

DECOMMISSIONING (VE0 AND VE0+)

Option VE0 reviews the power plant's decommissioning after the current licence period (2027/2030).

Decommissioning includes the dismantling of the radioactive systems and equipment of Loviisa power plant and the final disposal of radioactive decommissioning waste in the L/ILW repository. In addition, decommissioning includes making certain functions and waste management-related plant parts independent to ensure that the said independent plant parts can function without the power plant units.

Decommissioning – which includes the expansion of the L/ILW repository for the final disposal of radioactive decommissioning waste as well as the preparatory work and operation of the plant parts to be made independent – will be prepared for during the power plant's operation.

The decommissioning phase includes the following operations: the expansion of the L/ILW repository, the power plant's first dismantling phase, the operation of the plant parts to be made independent, the second dismantling phase and the closure of the L/ILW repository.

The transport of spent nuclear fuel to Olkiluoto will also be carried out during the decommissioning phase. At Olkiluoto, the spent nuclear fuel will be encapsulated and deposited for final disposal at Posiva Oy's encapsulation and final disposal facility.

Decommissioning will be based principally on Loviisa power plant's latest decommissioning plan, completed in 2018, which covers the dismantling of radioactive plant parts, waste treatment and the final disposal of radioactive waste. The plan is based on what is referred to as the brownfield principle, in which the buildings in the power plant area are not dismantled. Instead, the dismantling involves only the radioactive parts.

In decommissioning, Option VE0+ is similar to Option VE0. The difference is that it also takes into account the handling, interim storage and final disposal of the low-level and intermediate-level waste generated elsewhere in Finland and potentially received by Loviisa power plant.

In accordance with the recommendation of the National Nuclear Waste Management Cooperation Group set up by the Ministry of Economic Affairs and Employment (MEAE), the possibility of receiving and handling small quantities of low- and intermediate-level waste generated elsewhere in Finland in the Loviisa power plant area, and depositing it in interim storage and final disposal there, is considered as part of the options reviewed in the EIA Procedure. This radioactive waste could be derived from research institutions, the industrial sector, hospitals or universities. Since Loviisa power plant already has functions and facilities suitable for the handling and final disposal of radioactive waste in place, it would be natural and in line with the view of the National Nuclear Waste Management Cooperation Group that they would be available as part of the overall social solution for the management of radioactive waste.

Figure 1. Tentative schedules of the project options, to be specified as the plans progress.

PROJECT SCHEDULE

Tentative schedules for the project options to be covered in the EIA Procedure are provided in Figure 1.

ENVIRONMENTAL IMPACT ASSESSMENT PROCEDURE

In Finland, the requirement to carry out an EIA procedure is based on the Act on the Environmental Impact Assessment Procedure (252/2017). In addition, this project applies the Espoo Convention on the Environmental Impact Assessment in a Transboundary Context (the international hearing).

Based on section 7b of the list of projects in Finland's EIA Act, an assessment procedure pursuant to the EIA Act applies, among others, to nuclear power plants, including the dismantling or decommissioning of these plants. In addition, the EIA procedure applies to facilities designed for the final disposal of spent nuclear fuel, nuclear waste or other radioactive waste, or their long-term storage elsewhere than their production location.

The purpose of the EIA procedure is to promote the assessment and consideration of environmental impacts as early as the planning stage, as well as to increase access to information and opportunities to participate in the planning of the project.

The EIA Procedure has two stages. The first stage involved the preparation of the EIA Programme, on which the Ministry of Economic Affairs and Employment (MEAE), the coordinating authority in this project, gave its statement on 23 November 2020. The environmental impact assessment report was drawn up during the second stage of the EIA Procedure, based on the EIA Programme and the statement issued on it by the coordinating authority. The coordinating authority makes the assessment report available for public viewing in the same manner as the EIA Programme, and requests statements from various parties. As during the EIA Programme stage, an international hearing will also be held during the EIA Report stage.

Based on the EIA Report and the statements issued on it, the coordinating authority prepares a reasoned conclusion on the project's most significant environmental impacts, which must be considered in the subsequent licensing stages.

- The EIA Procedure was carried out interactively to provide different parties an opportunity to discuss and express their opinion about the project and its impacts.
- Pre-negotiations between the project owner, the coordinating authority and other key authorities were held prior to the commencement of and during the EIA Procedure.
- The EIA Programme's public event was held on 3 September 2020, and an equivalent event will be held during the hearing on the EIA Report.
- An audit group composed of authorities and the area's key stakeholders was established for the assessment procedure. The audit group convened twice.
- A resident survey was conducted during the EIA Report stage to study the attitudes of the area's residents toward the project.
- A small group event in which information about the project and the EIA Procedure was distributed, and people interested about the project were heard, was arranged during the EIA Report stage.

The EIA Programme and EIA Report are available on the MEAE's website in accordance with the coordinating authority's announcement. The EIA Programme and EIA Report are also available on Fortum's website. The website also contains up-to-date information on the project, the environmental impact assessment procedure, and licensing. In addition, Fortum provides information on the progress of the project and on the media and public events to be held, for example.

The EIA Procedure concludes once the coordinating authority has given its reasoned conclusion on the EIA Report.

DESCRIPTION OF PROJECT AREA AND ITS ENVIRONMENT

Loviisa nuclear power plant is located on the island of Hästholmen, at the boundary of the Gulf of Finland's coastal and outer archipelago, approximately 12 km from the centre of the town of Loviisa. The distance from the power plant to Helsinki is roughly 100 km. The power plant and the functions integrally related to it, such as the L/ILW repository and other waste management buildings, coolant water intake and discharge structures, as well as office and storage buildings, are located on the island of Hästholmen. The structures located on the mainland include an accommodation area. The functions related to the power plant's extended operation and decommissioning covered in the EIA procedure will be located in the existing power plant area and its vicinity.

The island of Hästholmen is located outside the structure of the built-up area. The power plant area is situated in the area of the Helsinki-Uusimaa Land Use Plan 2050. The Helsinki-Uusimaa Land Use Plan 2050 uses a site reservation symbol to designate an energy management zone on the island of Hästholmen where nuclear plants are allowed. The power plant area has a 5-kilometre precautionary action zone, indicated in the plan. In the master plan, the area of Hästholmen is indicated as an energy management zone. In the landscape province division, the power plant area belongs to the landscape province of the southern coastland and the coastal area of the Gulf of Finland. In addition to the power plant, the Port of Valko stands out as a clear exception to the landscape's natural state. In 2019, Loviisa's population was 14,772. Approximately 12,400 people live within a distance of 20 kilometres of the power plant. There are plenty of recreational settlements in the vicinity of Hästholmen.

The average daily traffic on the power plant's incoming route (Atomitie) has amounted to approximately 693 vehicles, of which heavy vehicles account for some 5%. Noise in the surroundings of the power plant area is currently affected by general traffic noise and the sounds of nature, in addition to the power plant. The noise levels have complied with the requirements of the environmental permit. Vibration in the power plant area is mostly the result of traffic and very local in nature. Emissions into air (including sulphur and nitrogen oxides as well as dust) on the island of Hästholmen are low, and the air quality in Loviisa is good. The operation of the power plant does not generate direct greenhouse gas emissions. Small amounts of radioactive substances from the power plant are released into the air and waterway in a controlled manner after purification. The discharges of radioactive substances into the air and waterway have remained significantly below the emission limits. The radioactive emissions resulting from the power plant's normal operation are so small that it is impossible to measure the radiation dose of members of the public attributable to them.

The power plant area has been in its current use since the 1970s, due to which there is no direct use of natural resources in the area. The quarry material generated in the quarrying of the L/ILW repository has been used outside the power plant area. The nuclear fuel is procured from a nuclear fuel supplier. Finland applies the principle of an open fuel cycle, in which spent nuclear fuel is enclosed in durable capsules deposited deep in the bedrock for final disposal. Natural uranium is a non-renewable resource, and according to current global consumption levels, the uranium reserves are expected to last for some 100–200 years in an open fuel cycle. Loviisa power plant's importance for the vitality of Loviisa's regional economy is significant, and up to 70.6% of all new investments in the Loviisa sub-regional area involve the energy sector.

The soil in the Hästholmen area consists primarily of stony and rocky moraine, and the bedrock consists of the rapakivi granite typical of the Loviisa area. There are no categorised groundwater areas in the vicinity of Hästholmen. A drop in the level of groundwater was observed in connection with the L/ILW repository's construction. The level dropped in varying degrees across the entire island.

Based on the monitoring results, cooling water increases the temperature of the seawater particularly in the vicinity of the discharge location in Hästholmsfjärden, where temperature stratification has been found to be stronger than normal. The ecological status of the bodies of water in Hästholmen's nearby sea areas ranges from bad to moderate.

The ichthyofauna in the sea area surrounding Hästholmen consists of both marine fish and freshwater fish species adapted to the brackish water, and its structure does not differ from observations made elsewhere in the Gulf of Finland to any notable degree. The region of Loviisa lies in the southern boreal zone. The Natura 2000 network site closest to the power plant area is the Källaudden–Virstholmen area in the southwest.

ENVIRONMENTAL IMPACT ASSESSMENT METHODS

IMPACTS TO BE ASSESSED

This environmental impact assessment assesses the environmental impact of the project under review in the manner and accuracy required by the EIA Act and EIA Decree. According to the EIA Act, the EIA procedure assesses the direct and indirect impacts of the operations related to the project which concern:

- the population as well as the health, living conditions and comfort of people;
- soil, ground, water, air, climate, vegetation as well as organisms and biodiversity, especially protected species and habitats;
- community structure, tangible property, landscape, townscape and cultural heritage;
- use of natural resources; and
- the mutual interaction between the aforementioned factors.

According to section 4 of the EIA Decree, the assessment report presents an assessment and description of the potentially significant environmental impacts of the project and its reasonable options as well as a comparison of the options' environmental impacts.

TIME OF THE IMPACTS AND REVIEW OF OPTIONS

The EIA Report reviews the operational phases included in the options, which involve extending operation by a maximum of 20 years after the current operating licences, decommissioning and the reception of radioactive waste generated elsewhere in Finland.

Extended operation is included solely in Option VE1. The operational phase of decommissioning is part of all the options (VE1, VE0 and VE0+). The reception of radioactive waste generated elsewhere in Finland may materialise in Options VE1 and VE0+, and is reviewed as a separate function.

The operational phase of extended operation in Option VE1 extends until approximately 2050. The operational phases related to decommissioning can be carried out either in 2025–2065 (VE0, VE0+) or in 2045–2090 (VE1). Radioactive waste originating from elsewhere in Finland can be received at Loviisa power plant for as long as the systems needed for the handling and treatment of the waste are available. In Option VE1, this is possible only until 2090 and in Option VE0+, only until 2065.

APPROACH TO AND METHODS OF IMPACT ASSESSMENT

The purpose of the environmental impact assessment is to systematically identify the impacts and their significance. "Impact" refers to a change in the status of the environment caused by the project, an option of the project or the operational phase of an option. The environmental impacts may be either negative or positive. They may also be neutral, in that no changes at all to the status of the environment can be observed.

In this EIA Report, "present state" refers to the current status of the power plant area's environment in which the power plant is in operation. The magnitude of a change can be influenced by, among other things, its scope, duration or intensity. Therefore, the change can be a direct impact on the environment caused by a change in the operations or an operation that continues for a long period of time, maintaining an impact on the environment.

The significance of an impact in the environmental impact assessment is determined by the affected aspect's capacity to tolerate the observed impact, i.e. its sensitivity, and the magnitude of the change. The significance of an impact in the assessment was determined by cross-tabulating the sensitivity of the affected aspect and the magnitude of the change in terms of the different operational phases in connection with the assessment of each impact. The significance of the impact is determined on a four-step scale: minor, moderate, high and very high. The significance of the impact may be negative or positive, or there may be no impact at all.

REPORTS AND OTHER MATERIALS USED IN THE ASSESSMENT

Environmental surveys and reviews have been carried out in the vicinity of the Loviisa power plant area since the 1960s. The EIA Report was drawn up with the help of the monitoring, studies and investigations carried out in the area. Separate investigations were also carried out to support the assessment work.

SUMMARY OF THE PROJECT'S ENVIRONMENTAL IMPACTS

ENVIRONMENTAL IMPACTS OF THE DIFFERENT OPERATIONAL PHASES

The impact assessment reviews the operational phases taking place after the power plant's current licence periods, which consist of either extending the operation by a maximum of 20 years or decommissioning, and the resulting environmental impacts. The handling, interim storage and final disposal of radioactive waste generated elsewhere in Finland is also reviewed as a separate function. The review accounts for the significance of the impacts impact-specifically, based on the affected aspects' sensitivity and the magnitude of the change. The impacts of the operational phase of extended operation were assessed at furthest until 2050. The assessment of the operational phase of extended operation accounts for the functions involved, all the way up to the closure of the L/ILW repository.

OPERATIONAL PHASE OF EXTENDED OPERATION

In the operational phase of extended operation, the impacts with the greatest positive significance involve the regional economy. Loviisa power plant's impacts on the regional economy are extremely high on the level of the Loviisa sub-regional area and also visible on the level of the entire country.

The energy markets and security of supply are also expected to be subject to positive impacts of a major significance. The extended operation of Loviisa nuclear power plant would support the security of supply of Finland's energy system and reduce the need to import electricity as its consumption grows in the future.

The impacts on greenhouse gas emissions and climate change are moderate and positive in significance. The extended operation of Loviisa power plant would support Finland's goal of being carbon neutral by 2035, because the use of nuclear power in the production of electricity does not generate greenhouse gas emissions.

The impacts on flora, fauna and conservation areas are expected to be minor and positive, particularly in terms of the avifauna, given that the power plant's cooling water would maintain, in the event of extended operation, Hästholmsfjärden's significance as regionally important wintering grounds for waterfowl.

The thermal effect on surface waters would continue at the current level in the operational phase of extended operation. The potentially warming climate combined with the thermal load of the cooling water could increase the thermal effect in the vicinity of the discharge location. This is expected to have an at most moderate and negative local impact in Hästholmsfjärden. A slight deterioration in the status of the Klobbfjärden body of water resulting from the combined impact of the thermal effect and the point source diffusion of nutrients cannot be excluded.

The impacts on the icthyofauna are expected to be moderate and negative. The continuation of the power plant's thermal effect would maintain a situation in the sea area that favours fish species adapted to warm water, such as pike-perch and cyprinids. Warmer waters could also allow non-native species to become more abundant in the area. The impact on fishing is expected to be minor and negative.

The operational phase of the power plant's extended operation is expected to have a negative impact of minor significance on land use, land use planning, the landscape, traffic as well as people's living conditions and comfort. Emissions of radioactive substances, radiation exposure and the accumulation rate of spent nuclear fuel as well as low- and intermediate-level waste would remain on their current level, with a minor and negative significance. The radiation dose caused to residents in the surrounding area by Loviisa power plant has been clearly below one per cent of the dose constraint set by the government, which is 0.1 mSv a year.

OPERATIONAL PHASE OF DECOMMISSIONING

Once the power plant is no longer in operation, its highly positive impacts on the regional economy will come to an end. Regional economy impacts which partly substitute for this will nevertheless be created for different operators and industries during the operational phase of decommissioning. The impacts on the sub-regional area of Loviisa are high and positive in terms of their significance. The impacts on the regional economy will end entirely once the decommissioning has concluded.

The impacts on surface waters will have a moderate and positive significance in the Klobbfjärden body of water close to the discharge location when the thermal load in the sea area comes to an end. At this point, the temperature and stratification conditions of the surface water and the length of the growing season will return to the natural state. The positive impacts may appear with a delay. The decommissioning will not weaken the category of the quality factors of the ecological status or prevent the body of water from attaining a good status.

The icthyofauna is expected to be subject to impacts with moderate and positive significance when the thermal load's impact on the marine ecosystem comes to an end. The fishing opportunities in winter will return to a better level, due to which fishing is expected to be impacted in a minor and positive way.

In addition, the decommissioning is expected to have minor and positive impacts on land use, land use planning, the landscape and the use of natural resources.

The power plant's decommissioning will have a highly negative impact on the energy markets and security of supply. The power plant's decommissioning will result in a need to procure electricity free of carbon dioxide emissions for Finland to achieve its carbon neutrality objective. This requires the construction of new electricity production capacity in Finland and the increased import of electricity. The possibilities for exporting electricity from Finland will also reduce.

The impact on greenhouse gas emissions and climate change is expected to be moderate and negative. The decommissioning of Loviisa power plant will lead to a need to increase other emission-free electricity production capacity to an equal degree.

Traffic impacts are expected to be at most moderate and negative. Traffic volumes will increase on a temporary basis during the dismantling phases, possibly impairing the smooth flow of traffic. The increase in traffic volumes could increase road safety risks, particularly on Atomitie and Saaristotie.

The impacts on people's living conditions and comfort are expected to be moderate and negative, given that the power plant's decommissioning will result in a significant and observable change in the operations taking place in the power plant area. The power plant's decommissioning and termination of electricity production may result in changes to the local identity and in both concerns about the effect that the change will have on the vitality of the Loviisa region and actual changes. All in all, the various phases of the decommissioning will take several decades.

The decommissioning is also expected to have minor and negative impacts on noise, vibration, air quality and on the flora, fauna and conservation areas.

The impacts on the soil and bedrock as well as groundwater resulting from the expansion of the L/ILW repository will be minor. The dismantling of radioactive parts and the handling of decommissioning waste during the decommissioning will result in radiation exposure, which will remain below the dose limits. Following the closure of the L/ILW repository, the final disposal will meet the long-term safety requirements.

RADIOACTIVE WASTE GENERATED ELSEWHERE IN FINLAND

The reception, handling, interim storage and final disposal of any low-level and intermediate-level waste generated elsewhere in Finland within the Loviisa power plant area would not have an impact for the most part.

However, the reception of radioactive waste generated elsewhere in Finland is expected to have a moderate and positive impact at the level of the entire country. The use of Loviisa power plant's existing functions and facilities applicable to the handling and final disposal of radioactive waste would support the overall social solution and the development of safe waste management at a national level.

The handling of radioactive waste generated elsewhere in Finland will result in minor radiation exposure. The waste handling and final disposal will be executed in such a way that their impact on the radiation doses of the personnel and members of the public in the environment is minor and that the long-term safety requirements will be met. There may also be minor negative impacts on people's living conditions and comfort.

COMPARISON OF OPTIONS AND CONCLUSIONS ON THE MOST SIGNIFICANT ENVIRONMENTAL IMPACTS

When reviewing and comparing the project's options (VE1, VE0 and VE0+), one must take into account that extended operation (VE1) would also include decommissioning to be carried out at a later stage and the reception of radioactive waste generated elsewhere in Finland.

The most significant difference between the options is the time at which the operational phases that would occur in the power plant area would be carried out (Figure 1).

The significance of the environmental impacts differs in the different operational phases. In all options, the final situation will ultimately be the same, in that operations such as they currently are in the power plant area will have ended.

In extended operation (VE1), the environmental impacts are in their entirety greater than in the other options, because the option includes the power plant's longer operating time and its decommissioning as well as the reception of radioactive waste generated elsewhere in Finland.

The option of extending the operation of Loviisa nuclear power plant (VE1) supports Finland's objective to be carbon neutral by 2035, in line with the Programme of Prime Minister Sanna Marin's Government. Extended operation would create significant economic benefits through the value chain and the multiplier effect, particularly on the local and regional level. The most significant negative impact up to 2050 in Option VE1 is the warming impact that the cooling water discharge side would have on the sea area, the significance of which was deemed at most moderate and negative.

In Option VE1, the impacts of the cooling water would end in 2050 as a result of the end of commercial operation, as would the major positive impacts on the regional economy resulting from the power plant's extended operation. The major negative impact that the end of the power plant's commercial operation will have on the energy markets and security of supply would also materialise in 2050. During the decommissioning of the power plant, partly substituting regional economy impacts will be generated for different operators and industries, but their impact will remain smaller than the impact of the commercial operation.

In Option VE1, the power plant's operation would continue in its current form for the next 20 years, and significant direct impacts on the regional economy would be accumulated during the additional years of operation. In addition, turnover would be generated for other industries in the Loviisa sub-regional area in 2030–2090 (2030–2080 in the regional economy modelling) in excess of EUR 800 million in the form of multiplier effects, while the value added would amount to more than EUR 460 million, and the need for labour to more than 8,900 person-years. Correspondingly, the regional economy's multiplier effects across Finland would amount to more than EUR 5,800 million in turnover, more than EUR 2,900 million in value added and more than 44,200 person-years in need for labour. Clearly more than half of the regional economy impacts would concern the period between 2030 and 2050. The regional economy impacts in Option VE1 would come to an end around 2090, when the decommissioning concludes.

In Option VE1, radioactive waste generated elsewhere in Finland can be received at Loviisa power plant until around 2090. While this will not have a significant environmental impact, the reception of radioactive waste generated elsewhere in Finland will have a moderate positive impact on the level of the entire country. This would benefit the interests of the entire society by providing a safe and cost-effective final disposal solution for radioactive waste originating from various sources.

In the decommissioning option (VE0/VE0+), Loviisa nuclear power plant's commercial operation will end as the current operating licences expire, at which point the at most moderate and negative impact that the cooling water discharge side has by warming the sea area would come to an end, as would the major regional economy impacts during the power plant's operation. A highly negative impact on the energy markets and security of supply would also materialise in 2027 and 2030.

In Option VE0/VE0+, the power plant's decommissioning, which would take place between the late 2020s and circa 2065, would generate new demand in the form of multiplier effects in the Loviisa sub-regional area to the amount of roughly EUR 300 million and value added in excess of EUR 170 million and need for labour in excess of 3,800 person-years. Correspondingly, the regional economy impacts across Finland would total more than EUR 2,200 million in turnover, more than EUR 1,100 million in value added and more than 17,500 person-years in need for labour. In Option VE0, the regional economy impacts would be focused on the 2030s.

In Option VE0+, radioactive waste generated elsewhere in Finland can be received at Loviisa power plant until around 2065. As in VE1, this would not have significant environmental impacts, but it would promote the interests of society as a whole.

Based on the assessments made, the project's options VE1, VE0 and VE0+ are feasible in terms of their environmental impacts. The means for preventing and mitigating the adverse effects presented in the assessment report allow for mitigating the potential environmental impacts, provided that they are accounted for in the project's further planning and implementation insofar as possible.

The operations of Loviisa nuclear power plant are very stable, and their environmental impacts are well known. The techniques, processes and the means by which to mitigate the impacts are well known. In extended operation, attention would be paid to the management of the plant's ageing. These measures serve to ensure the power plant's safe further use. The operations include monitoring the development of the best available technique (BAT), legislation's requirements for the industry and experiences from other nuclear power plants. The decommissioning plan will be updated and specified as the project progresses.

INCIDENT AND ACCIDENTS

In the event of a nuclear power plant incident or accident, radioactive substances detrimental to health could end up in the environment. The assessment on extended operation covered, in addition to a severe reactor accident, a major leak from the primary system to the secondary system, which is an INES level 4 event on the International Nuclear and Radiological Event Scale. The assessment also covered scenarios in which small quantities of radioactive substances would be released into the environment.

A severe reactor accident at a nuclear power plant is a highly unlikely extreme event that is also prepared for in the plant's design and operations. The assessment of the environmental impacts of a severe reactor accident is based on the postulation that 100 terabecquerels (TBq) of the caesium-137 (Cs-137) nuclide is released into the environment as referred to in section 22 b of the Nuclear Energy Decree (161/1988). The reviewed fictitious severe reactor accident would be equal to an INES level 6 accident. The assessment does not account for actions that aim to protect the population, such as seeking shelter indoors and changes in food intake.

Based on the results of the modelling of a severe reactor accident, the greatest radiation dose at a distance of one kilometre, accounting for all age groups, would be approximately 27 mSv during the first week. The doses would decrease as the distance increases. Health effects on humans resulting from the radiation caused by the reviewed severe reactor accident are highly unlikely. The magnitude of the annual radiation dose of an individual residing in Finland is approximately 5.9 mSv.

The impact of the release can be mitigated during the initial stage by various actions that aim to protect the population, such as the administration of iodine tablets, seeking shelter indoors and evacuations carried out at different times. The long-term consequences of the fallout would include the clean-up of the built environment, restrictions to the recreational use of the natural areas and arranging contamination measurements for the people residing in the area, up to a distance of less than 15 km from the power plant. The use of built-up recreational areas should also be restricted up to a distance of 80 kilometres. The authorities would likewise impose restrictions on the use of food products.

The impacts of other incidents and accidents would be significantly milder than those of a severe reactor accident.

MONITORING AND OBSERVATION OF IMPACTS

The project owner has various monitoring and observation programmes involving environmental impacts in place. The requirements for the programmes are provided in environmental legislation and in regulations and guidelines issued pursuant to the Nuclear Energy Act. In the event of extended operation, the operations of the power plant would be similar to their current levels, which is why the observation and monitoring is expected to continue in much the same manner as currently.

The precise emission measurements of radioactive substances ensure that the power plant's combined emissions into the air and discharges into the water do not exceed the emission limits confirmed by STUK, and that the environmental radiation doses fall below the limits specified in the Nuclear Energy Decree.

Fortum monitors the environment of Loviisa power plant in accordance with the environmental radiation control programme. The status of radioactive substances in the surroundings has been monitored for a long time. The environmental radiation control aims to ensure that the population's radiation exposure attributable to a nuclear power plant is kept as low as reasonably achievable and that the limit values specified in regulations are not exceeded. STUK also carries out its own independent radiation monitoring in the environment of Loviisa power plant.

The dispersion of radioactive substances released into the air during the power plant's normal operation or a possible accident is assessed with the aid of the meteorological measurements of Loviisa power plant's own weather observation system. During the power plant's operation, the radiation exposure of the population in the environment is estimated annually on the basis of the meteorological measurements and emissions.

The volume and quality of the cooling water and wastewaters conducted from the power plant into the sea is monitored in accordance with the valid monitoring programme. The impact monitoring conducted in Loviisa power plant's nearby sea area includes the monitoring of the quality (physico-chemical quality) of the seawater as well as biological and fishery economics monitoring.

The monitoring also covers the operations' flue gas emissions and noise and the keeping of records on radioactive and conventional waste, regular monitoring of rock mechanics, hydrology and groundwater chemistry, and the impacts on humans, which are investigated with the aid of discussion events and resident surveys, among other things.

THE PROJECT'S PERMIT PROCESS

The power plant units of Loviisa nuclear power plant have operating licences in accordance with the Nuclear Energy Act which are valid until the end of 2027 and 2030, respectively. The operating licence of the l/ILW repository is valid until the end of 2055. The L/ILW repository will require a new operating licence in both options (VE1 and VE0/VE0+). New operating licences must be applied for in terms of the power plant units should the power plant's operation be extended. The decommissioning of the power plant units requires the application of a decommissioning licence. The operating licence and decommissioning licence are issued by the government. The plant parts to be made independent require a separate operating licence once the operating licence of the power plant units expires, and they will begin to be dismantled as the decommissioning licence takes effect. In addition to the operating licence and decommissioning licence, the project options may require other licences in accordance with the Nuclear Energy Act.

Loviisa power plant's radiation practice other than the operation of nuclear energy requires a safety licence pursuant to the Radiation Act. The transport of nuclear fuel requires a transport licence pursuant to the Nuclear Energy Act. The prerequisites for such a licence include a transport plan, safety plan and, in some cases, a preparedness plan. Posiva is responsible for the transports of spent fuel for encapsulation and final disposal in Eurajoki, Olkiluoto. All transports of nuclear waste or radioactive substances are subject either to a notification to STUK or the application of a transport or safety licence in the manner required by the valid law.

The potential modification of buildings in the power plant area or the required infrastructure and the construction of any additional facilities require a building permit. The operation of a nuclear power plant requires an environmental permit pursuant to the Environmental Protection Act and a water permit pursuant to the Water Act for the water abstraction and discharge structures. Fortum has valid environmental and water permits.

Facilities engaged in extensive industrial handling and storage of chemicals require a chemicals permit granted by the Finnish Safety and Chemicals Agency (Tukes). Loviisa power plant has a valid permit for the extensive industrial handling and storage of chemicals, and the power plant is an institution subject to a safety assessment regulated by Tukes. The Tukes regulatory authority should be notified of the decommissioning of Loviisa power plant in accordance with the Act on Chemical Safety.

The extended operation and decommissioning of the power plant may also require other permits, licences and plans.

1. Project owner and the project background

1.1 PROJECT OWNER

The project owner in the EIA procedure is Fortum Power and Heat Oy, a wholly owned subsidiary of Fortum Corporation. The Government of Finland holds 50.8% of the share capital of Fortum Corporation. In the spring of 2020, Fortum acquired a majority interest in Uniper SE, based in Germany. The acquisition made Fortum one of the largest energy companies in Europe. Uniper was consolidated with Fortum Group as of April 2020, but it continues to operate as a separate listed company.

Fortum Corporation and its subsidiaries employ a total of nearly 20,000 people, a little more than 2,000 of whom work in Finland. In the Nordic countries, Fortum is the second-largest producer of electricity and the largest electricity seller. Fortum is among the largest producers of thermal energy in the world. Fortum also offers district cooling, energy efficiency services, recycling and waste solutions, as well as the Nordic countries' largest network of charging stations for electric cars. Fortum's subsidiary Uniper engages in large-scale global energy trading, and owns natural gas storage terminals and other gas infrastructure.

Nuclear energy plays a significant role in Fortum's electricity production that is free of carbon dioxide emissions. With Uniper, Fortum is the third largest nuclear power company in Europe. In 2020, the combined electricity production of Fortum and Uniper was approximately 142 TWh, of which 20% was based on the production of nuclear power. Thanks to its large-scale nuclear, hydro- and wind power, Fortum is Europe's third largest producer of emission-free electricity. In 2020, electricity production free of carbon dioxide emissions accounted for 73% and 45% of all electricity production in Europe and across the globe, respectively.

The electricity generated by Loviisa nuclear power plant, owned and operated by Fortum Power and Heat Oy, is used as an uninterrupted, year-round source of energy. Annually, Loviisa power plant produces a total of approximately 8 terawatt hours (TWh) of electricity for the national grid. It accounts for approximately 10% of the electricity consumption in Finland. For its part, Loviisa nuclear power plant supports the climate targets of Finland and the EU as well as a secure electricity supply.

In Finland, Fortum also holds a 26% share in the current nuclear power plant (Olkiluoto 1 and 2) of Teollisuuden Voima Oyj, and a 25% share in the nuclear power plant unit (Olkiluoto 3) currently in its commissioning phase. In addition, Fortum participates in the nuclear power plant project of Fennovoima, with a share of 6.6%. With Teollisuuden Voima Oyj, Fortum owns Posiva Oy, which is tasked with conducting studies on the final disposal of spent nuclear fuel of its owners, the construction and operation of a final disposal facility, as well as the closure of the facility. Fortum owns a 40% share in Posiva Oy.

1.2 PROJECT BACKGROUND

Fortum's Loviisa nuclear power plant was built in 1971–1980. It consists of two power plant units, Loviisa 1 and Loviisa 2, as well as the associated buildings and storage facilities required for the management of nuclear fuel and nuclear waste. Loviisa 1 began its commercial operation in 1977 and Loviisa 2 in 1980. Loviisa power plant has been generating electricity reliably for more than 40 years. The current operating licence issued by the Finnish government to Loviisa 1 is valid until the end of 2027, and the operating licence issued to Loviisa 2 is valid until the end of 2030.

Fortum is in the process of assessing the extension of the commercial operation of Loviisa nuclear power plant by a maximum of approximately 20 years beyond the current operating licence period. Fortum will make the decision concerning the potential extension of the operation of the nuclear power plant and the application for new operating licences at a later date. The other option is to proceed to the decommissioning phase when the power plant's current operating licences expire.

Fortum invests in the ageing management of Loviisa power plant and has carried out improvement measures throughout its operation. Over the years, Loviisa power plant has implemented several projects that improve nuclear safety. In recent years, extensive reforms have been carried out on the automation of the power plant, and ageing systems and equipment have been modernised. In 2014–2018, Loviisa power plant implemented the most extensive modernisation programme in the plant's history, in which Fortum invested approximately EUR 500 million. Thanks to the investments and skilled personnel, Loviisa power plant has excellent prerequisites with regard to the technical and safety-related requirements to continue operation after the current licence period.

In addition, the quantity of such radioactive waste generated in the operations of Loviisa power plant that requires final disposal has been considerably reduced, and the efficiency of the use of nuclear fuel has been improved. The radioactive waste from the power plant is processed and deposited in the final disposal facility for low and intermediate-level waste (the L/ILW repository), located in the power plant area. In due course, the spent nuclear fuel generated by the power plant will be deposited for final disposal at Posiva Oy's final disposal facility, currently under construction at Olkiluoto in Eurajoki, Finland. Solutions therefore exist for the processing and final disposal of all nuclear fuel generated by Loviisa power plant.

This environmental impact assessment procedure (the EIA procedure) covers the extension of Loviisa nuclear power plant's operations or its decommissioning. In both cases, the project requires a licensing procedure in accordance with the Nuclear Energy Act and an environmental impact assessment procedure in accordance with the EIA Act (section 3, subsection 1 of the EIA Act; points 7 b and d on the list of projects). The EIA report and the coordinating authority's reasoned conclusion to be issued on it are appended to any licence and permit applications. In this project, the coordinating authority is the Ministry of Economic Affairs and Employment.

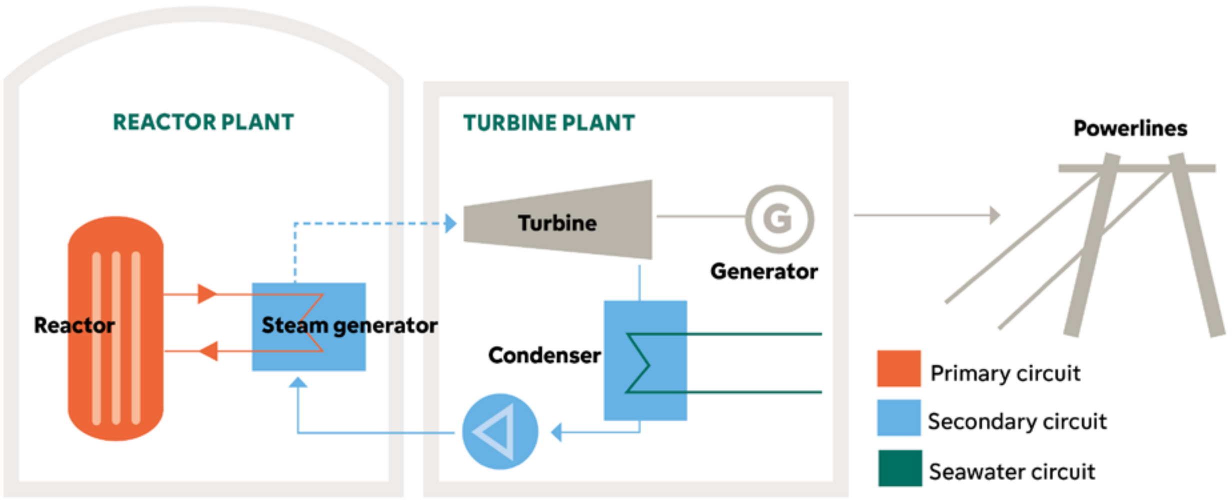

Figure 1-1. Operating principle of a pressurised water plant.

1.3 CURRENT OPERATION OF THE POWER PLANT

1.3.1 Operating principle

Loviisa nuclear power plant is an electricity-generating condensing power plant. Instead of a fossil fuel (such as coal, natural gas or peat), Loviisa nuclear power plant uses uranium dioxide (UO_2) made from enriched uranium as its fuel. The use of uranium as fuel is primarily based on the splitting of the nucleus of the atom of the uranium isotope uranium-235 or fission. In the fission reaction, a heavy atomic nucleus splits into two or more lighter atomic nuclei when hit by a free neutron. The reaction also releases some neutrons and energy. Electricity production in a nuclear power plant is based on the utilisation of the thermal energy generated by a controlled chain reaction.

In nuclear power plants, heat is generated in a reactor. In Loviisa power plant's reactors, the nuclear fuel is in the form of small pellets with a diameter of approximately one centimetre. The pellets are encased in hermetically sealed fuel rods approximately 2.5 metres in length. The fuel rods are arranged in fuel bundles, with 126 fuel rods in each. A reactor contains 313 fuel bundles.

The reactors of Loviisa power plant are light water reactors in which regular water is used for cooling and as a moderator in the reactor core. The power plant units are pressurised water plants; in other words, the pressure of the water used as the coolant and moderator of the reactor is kept high to prevent it from boiling.

The power plant units of Loviisa nuclear power plant are based on the Russian VVER -440 pressurised-water plant. The designs were subject to a great number of modifications during the power plant's design phase to ensure the key principles would meet western requirements. Numerous projects that aim to improve nuclear safety have also been carried out over the years. Imatran Voima Oy, which preceded Fortum, acted as the principal planner and project coordinator, coordinating the work of the main supplier, V/O Atomenergoexport, and other key suppliers such as Westinghouse and Siemens/KWU.

A pressurised water plant contains separate primary, secondary and seawater systems. The controlled fission reaction that takes place in the reactor core of the primary system generates heat, and the water circulating in the reactor under high pressure cools the fuel bundles in the reactor core. The water heated in the reactor is conducted to the steam generators, from where the thermal energy is transferred to the secondary system's water which is of a lower pressure, evaporating it. The generated steam is conducted to the turbines. A generator that shares the same shaft with the turbines generates electricity for the national grid and for the power plant itself. From the turbine, the steam is conducted to a condenser, where it condenses to water. The condensed water is pumped back to the steam generators. The condenser is cooled by a separate seawater system. The seawater used for the cooling warms up and is led back to the sea. Radioactive water from the primary system does not mix with the cooling water at any point.

Figure 1-1 shows the operating principle of a pressurised water plant, and Table 1-1 presents the key details and indicators of Loviisa's power plant units.

Table 1- 1. Loviisa power plant's power plant unit-specific details and key indicators.

Details of the power plant units	
Start-up/commercial operation	1977/1977 (Loviisa 1) 1980/1981 (Loviisa 2)
Reactor type	Pressurised water reactor (VVER-440)
Net electric output	507 MW
Thermal power	1,500 MW
Efficiency	34%
Annual electricity production	approximately 4 TWh
Thermal power to be conducted to the water systems	approximately 1,000 MW
Primary system pressure	122.5 bar
Secondary system pressure	44 bar
Need for cooling water	22 m³/s
Fuel volume	37.4 tonnes of uranium
Number of fuel bundles	313
Height and diameter of reactor core	2.42 m and 2.73 m
Number of steam generators	6
Number of turbogenerators	2

1.3.2 Production

Loviisa power plant is used for the production of base load electricity; in other words, the power plant units are usually operated steadily at full power to meet the continuous minimum requirement for electrical power. The original nominal electrical power of the power plant units was 440 MW. In 1997, the modernisation project carried out at Loviisa power plant included power uprating, which increased the nominal thermal power of the reactors from 1,375 MW to 1,500 MW. This increased the nominal electrical power of the plant units to 488 MW. The efficiency of the power plant units has been improved several times, and today the net electric output of each unit is 507 MW. The total efficiency of the power plant units is approximately 34 %. Since the power uprating of 1997, the production of Loviisa power plant has been approximately 8 TWh per year. This accounts for approximately one-tenth of the annual electricity consumption in Finland.

The planned annual operating time of the power plant is approximately 8,000 hours. The aim is to keep the power plant units running continuously at full power. The plant units can also be run at a lower power should the need for this arise. An operating period is usually interrupted by an annual outage, held once a year between July and October. The annual outage includes modifications and maintenance, inspections and refuelling. The outage is carried out on one plant unit at a time and it lasts for 2–8 weeks. Typically during the outage of one unit, the other plant unit is kept in operation. Both power plant units undergo more extensive maintenance every four years. The most extensive annual outages, which are also the longest, take place every eight years.

The availability and load factors of Loviisa power plant have been excellent. In 2020, for example, the load factor for Loviisa 1 was 83.8%, and the load factor for Loviisa 2 was 91.7%. The load factor describes the actual production's share of the theoretical maximum, or in other words, of a situation in which the power plant would be operated at full power for the entire year. Figure 1-2 shows the load factor and electricity production during the power plant's operating history.

In terms of safety and availability, Loviisa power plant is one of the best nuclear power plants in the world. The key indicators used to measure safety and reliability have been good throughout Loviisa power plant's operating history. The operation of Loviisa power plant has been certified to the ISO 14001 Environmental Management and the ISO Occupational Safety and Health Management System standards.

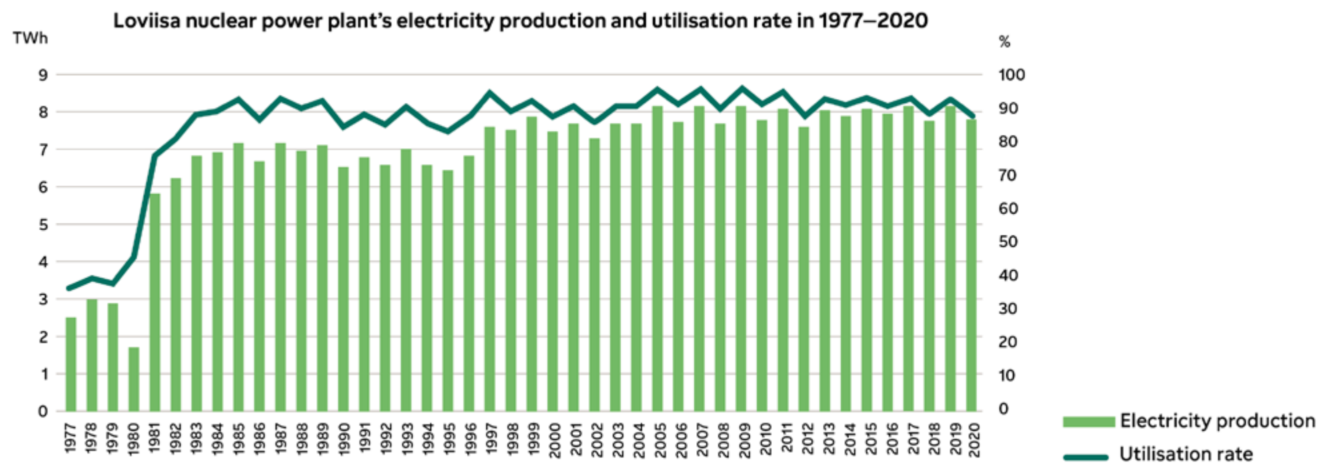

Figure 1-2. The electricity production and load factor of Loviisa power plant during the plant's operating history.

1.3.3 Location

Fortum's Loviisa power plant is located approximately 12 kilometres from the centre of the town of Loviisa, in the village of Lappom, on the island of Hästholmen (Figure 1-3 and Figure 1-4). The buildings and structures required for the power plant's support functions, such as security and temporary accommodation for workers employed for annual outages, are located on the mainland. The functions related to the extension of the power plant's operation and its decommissioning covered in the EIA procedure are located in the existing power plant area and its vicinity.

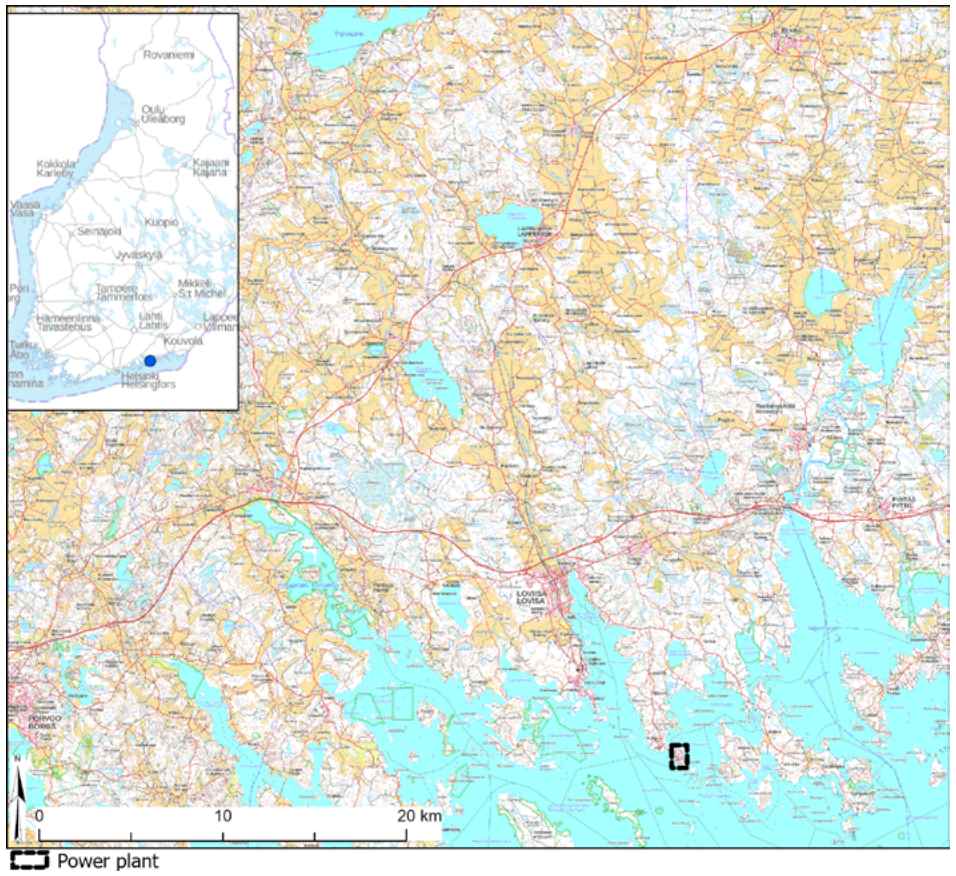

Figure 1-3. Location of Loviisa power plant.

Figure 1-4. Aerial photo of the Loviisa power plant area.

1.3.4 Functions in the power plant area

The illustration depicting the Loviisa power plant area (Figure 1-5) shows the most central buildings and functions in the area.

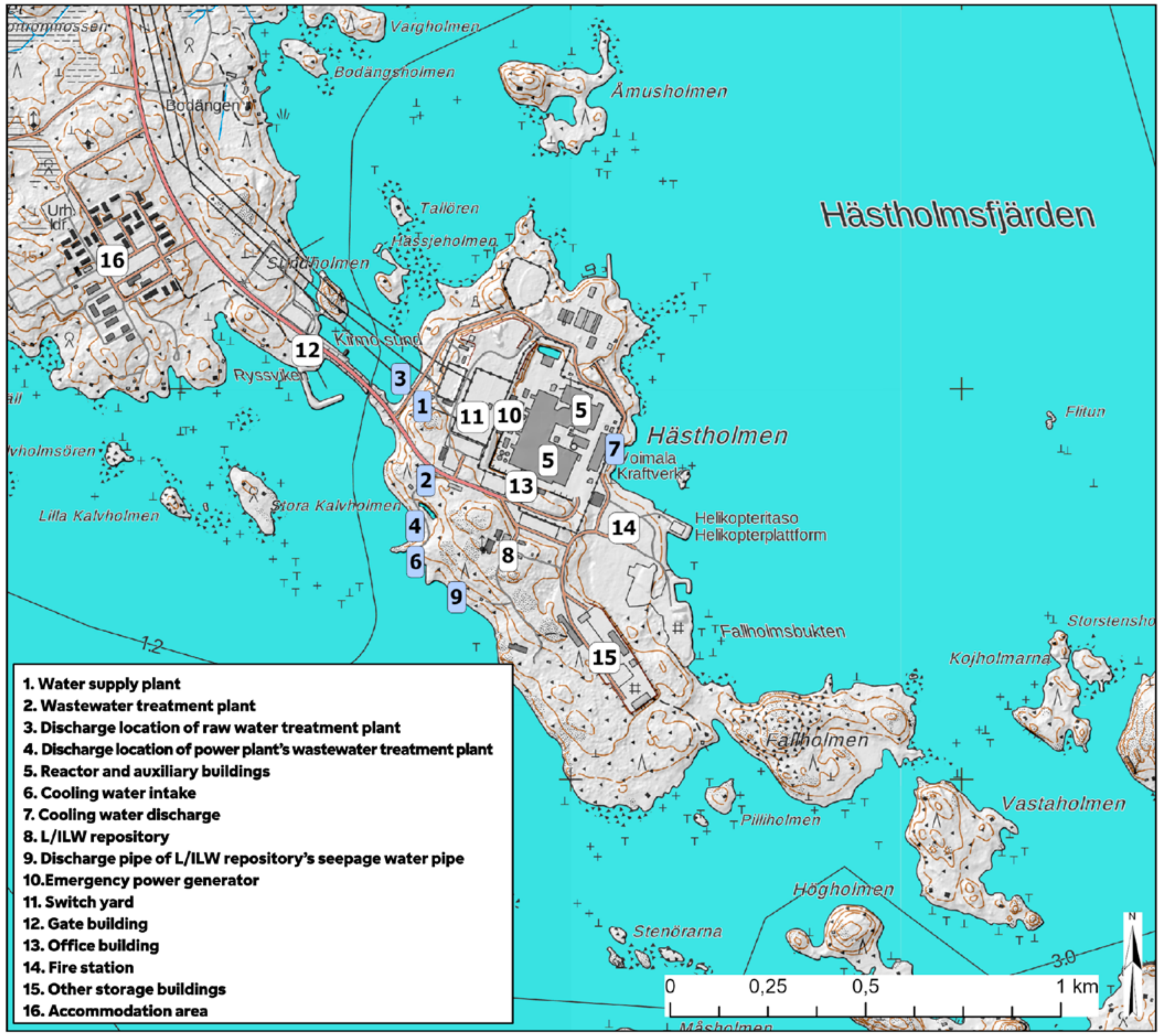

Figure 1-5. The most central buildings and functions in Loviisa power plant area.

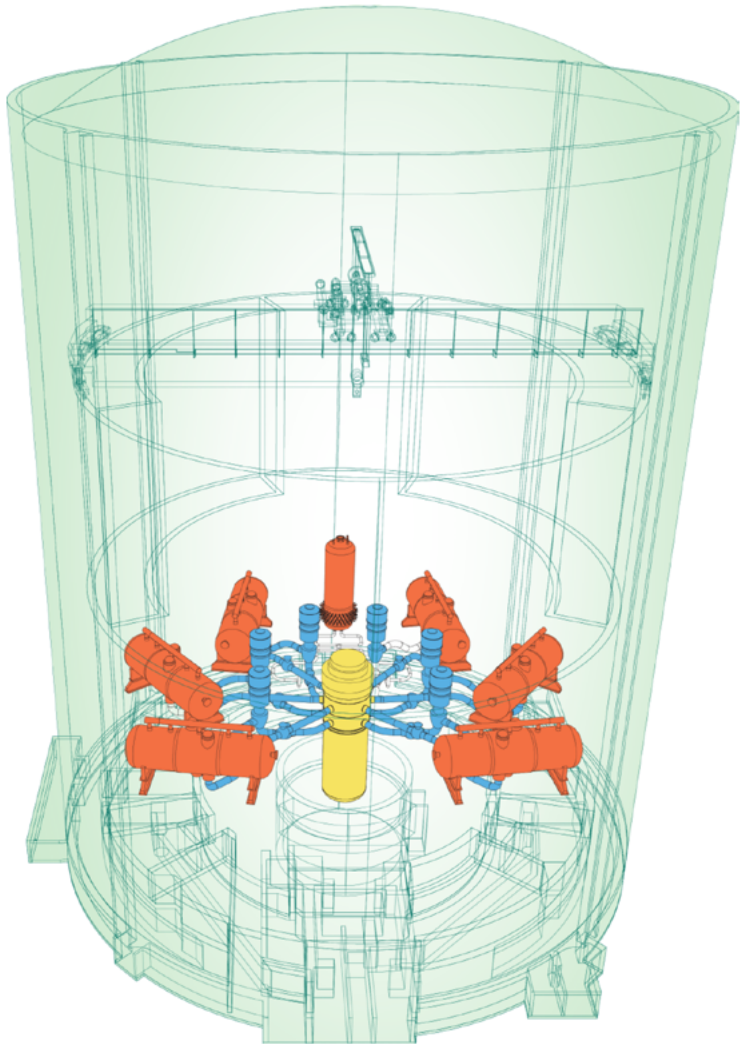

Figure 1-6. Illustration of reactor building and the location of the primary system's main components. The reactor pressure vessel is shown in yellow, the six steam generators and the pressuriser in red, and the main coolant loops of the reactor's cooling system in blue.

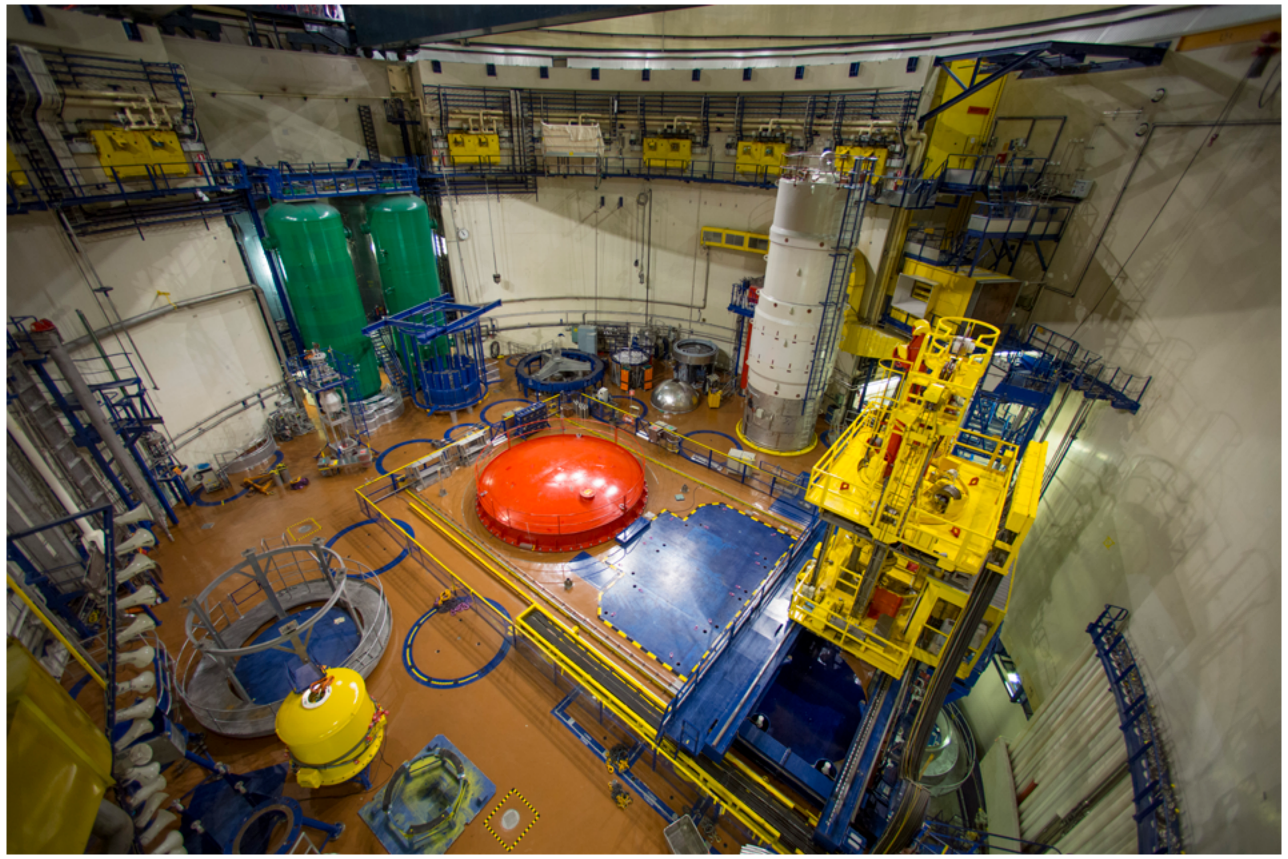

Figure 1-7. The interior of the containment building. The green hydro accumulators can be seen on the left. The reactor's red cover can be seen in the middle and adjacent to it the refuelling pool, covered with blue plates. The yellow refuelling machine can be seen on the right-hand side of the picture.

1.3.4.1 Reactor and containment building

Both of the power plant units have their own reactor and containment buildings, which house, among other things, the main coolant loop (primary system) and the related components, including the reactor pressure vessel, steam generators and the pressuriser.

The containment building housing the reactor's primary system is pressure containing and gas-tight. The containment building consists of a hemispherical dome, a cylindrical mid-section and a bottom plate. The wall structures of the cavity, or "reactor cavity", in the bottom plate's mid-section support the reactor pressure vessel. The containment building is divided into an upper and lower compartment as well as the main service level separating them. Figure 1-6 is an illustration of the reactor building and the containment building within it, including the containment building's main components. Figure 1-7 depicts the interior of the containment building.

In addition to the primary system, the containment building houses the treatment system for primary water, for example, as well as the hydro accumulators of the low-pressure emergency cooling system, ventilation equipment, the ice condenser system, refuelling pool, the refuelling machine, and lifting gear and transport equipment for maintenance work and fuel transports. The containment building is enveloped by the reactor building, which protects the containment building from external phenomena and in the event of an accident, would function as a radiation shield. The reactor building's cylindrical section is built from reinforced concrete. In addition to the containment building, the reactor building houses the emergency cooling systems and the cooling system for the containment building's refuelling pool.

Materials and personnel enter and exit the containment building through material and personnel air locks, in addition to which there is one emergency personnel air lock. The air locks are equipped with two separate doors.

1.3.4.2 Auxiliary building and covered tank area

Both power plant units have their own auxiliary buildings, which house, among other things, the systems for treating the primary system's discharge waters, part of the ventilation systems, radioactive gaseous waste treatment systems, thenon-active and radioactive intermediate cooling system, part of the service seawater system, part of sampling, the make-up water systems, the piping and equipment of other systems, repair shops and warehouses. The auxiliary buildings of Loviisa 1 and Loviisa 2 are connected by a walkway which provides access to the units' shared staff building. The exhaust airs from all the ventilation systems in the radiation controlled area are led to the roughly 100-metre-high vent stack in the immediate vicinity of the walkway.

The covered tank areas are next to the auxiliary buildings of Loviisa 1 and Loviisa 2. The boron solution tanks and the tank rooms for radioactive water are in the covered tank area.

The auxiliary buildings of Loviisa 1 and Loviisa 2 differ slightly from one another in terms of the systems they house. For example, the auxiliary building of Loviisa 1 houses the storage for fresh fuel, whereas the auxiliary building of Loviisa 2 houses the units' shared interim storage for spent fuel. The control room for serious accident management is also located next to the auxiliary building of Loviisa 2.

1.3.4.3 Turbine and control room building, and other buildings related to the secondary system

The turbine building houses the steam turbines, generators and condensers, including the auxiliary systems, of both power plant units. The turbines have been placed lengthwise in relation to the reactor building. The generators are located after the turbines along the same line, and the condensers are located in the spaces underneath the turbines. The seawater pumping station of Loviisa 1 is also next to the turbinebuilding, and the four tanks of the plant's make-up water system are in the yard close to the pumping station. The seawater pumping station of Loviisa 2's plant unit is a separate building from the turbine building. It is located within the power plant area. The seawater pumping stations house the pumps of the circulating seawater systems and the service seawater systems.

The control room building adjacent to the turbine building houses the units' main control rooms as well as the facilities for the units' electrical and automation equipment. The functions related to the primary and secondary system, as well as electricity production, are controlled and directed from the main control rooms, which also serve as the entire power plant's communications centre. The power plant's feed water tanks, from which the main feed water pumps pump water to the steam generators through the preheaters, are above the main control rooms. The new automation buildings have been built next to the control room building.

The pumping station of the backup residual heat removal system is in the vicinity of the control room building, and the air-cooling system, or "cooling towers", have been built on top of the pumping station. The system can be used to transfer the residual heat generated in the reactor plant to the atmosphere in a situation in which the primary heat sink – i.e. seawater – would not, for some reason, be available for the reactor's cooling.

1.3.4.4 Intake and discharge of cooling water

Seawater is used for various cooling purposes at Loviisa power plant. The primary use is the condensation of steam in the turbines. The cooling water for the power plant is taken from Hudöfjärden, west of the island of Hästholmen, using an onshore intake system, and is discharged back into the sea at Hästholmsfjärden, on the east side of the island. The intake and discharge of cooling water is described in more detail in Chapter 4.2.

1.3.4.5 Interim storage for spent nuclear fuel

The spent nuclear fuel removed from the reactor is stored in the reactor building's refuelling pool initially for 1–3 years, and thereafter until final disposal, in the pools of water in interim storages (interim storages for spent fuel). The interim storages for spent fuel 1 and 2 are located in Loviisa 2's auxiliary building. The transfers of fuel between the reactor building and fuel storage are carried out with a radiation protected transfer cask filled with water.

According to the original plan, spent fuel was to be held in interim storage at Loviisa power plant for three years before it would be returned to the Soviet Union/Russia. The original plan was therefore for the power plant to have one interim storage for spent fuel. A subsequent agreement set the minimum storage period at five years, due to which the interim storage capacity for spent fuel was increased with the construction of another interim storage for spent fuel in 1984. Following the amendment made to the Nuclear Energy Act in 1994, all nuclear waste generated in Finland has had to be stored and deposited for final disposal in Finland. As a result of this amendment, interim storage 2 for spent fuel was expanded with four additional pools in 2000.

In operational terms, the interim storages for spent fuel have two areas: the fuel handling area and the actual storage area. In both storages, the transfer cask is lifted to the handling area and the reloading pool with a crane. Interim storage 1 for spent fuel has two storage pools, in which the fuel bundles are stored in transfer baskets. The fuel transfer baskets are lifted completely from the transfer casks with a crane and transferred to the storage pool. Interim storage 2 for spent fuel has seven storage pools, and the fuel bundles are stored in fuel racks. The fuel bundles are transferred from the transfer casks one at a time to the fuel rack with the help of a fuel handling machine.

1.3.4.6 Liquid waste storage and solidification plant as well as the dry waste handling facility

Liquid radioactive waste is initially placed in interim storage in the liquid waste storage, which houses eight 300-m^3 storage tanks. From there, the waste is transferred via pipelines to the solidification plant. At the solidification plant, the radioactive waste is processed and solidified into a tight waste container, which is deposited for final disposal in the solidified waste hall of the final disposal facility for low and intermediate-level waste (the L/ILW repository), located in the power plant area.

The dry waste handling facility is located in an auxiliary building. The interim storage spaces for dry waste are in separate halls within the power plant, the L/ILW repository and the power plant area. The halls are used primarily for the interim storage of waste that is to be cleared from regulatory control.

1.3.4.7 Final disposal facility for low and intermediate-level waste (L/ILW repository)

The low- and intermediate-level waste generated during the operation of the power plant is deposited for final disposal, at a depth of approximately 110 metres in the power plant area's bedrock on the island of Hästholmen (the L/ILW repository). The L/ILW repository is a separate nuclear facility as referred to in the Nuclear Energy Act and Decree, but it is used regularly in connection with Loviisa power plant and is integrated in the power plant's operations. The halls of the L/ILW repository are located on the island in such a way that no part of them is under the sea, or the existing power plant units or sites reserved for units. The final disposal halls have been designed in such a way that any significant water-bearing zones of fragmented rock occurring naturally in the bedrock do not intersect with the final disposal halls. The L/ILW repository was built in the 1990s, and expanded between 2010 and 2012.

Currently, the L/ILW repository is composed of the following halls and their related operations (Figure 1-8):

1. three (3) halls for maintenance waste
2. solidified waste hall
3. vehicle access tunnel
4. connecting tunnel
5. personnel shaft
6. ventilation shaft.

Plans are in place to expand the final disposal halls by excavating a final disposal hall for the decommissioning waste of Loviisa power plant. This expansion would allow for depositing all radioactive waste generated by the decommissioning of the power plant for final disposal in due course. The decommissioning and expansion of the L/ILW repository are described in more detail in Chapter 5.

1.3.4.8 Diesel generators and engines

The AC supply for equipment important for the safety of both power plant units is backed up by four 2.8 megawatt (MW) emergency diesel generators. The use of the emergency diesel generators is limited to the weekly test runs and the 10-hour test run carried out in connection with annual outages.

The separate 9.7 MW diesel-operated emergency power plant in the power plant area functions as a reserve supply connection independent of Loviisa's external connections. This unit would secure the nuclear power plant's safety functions in

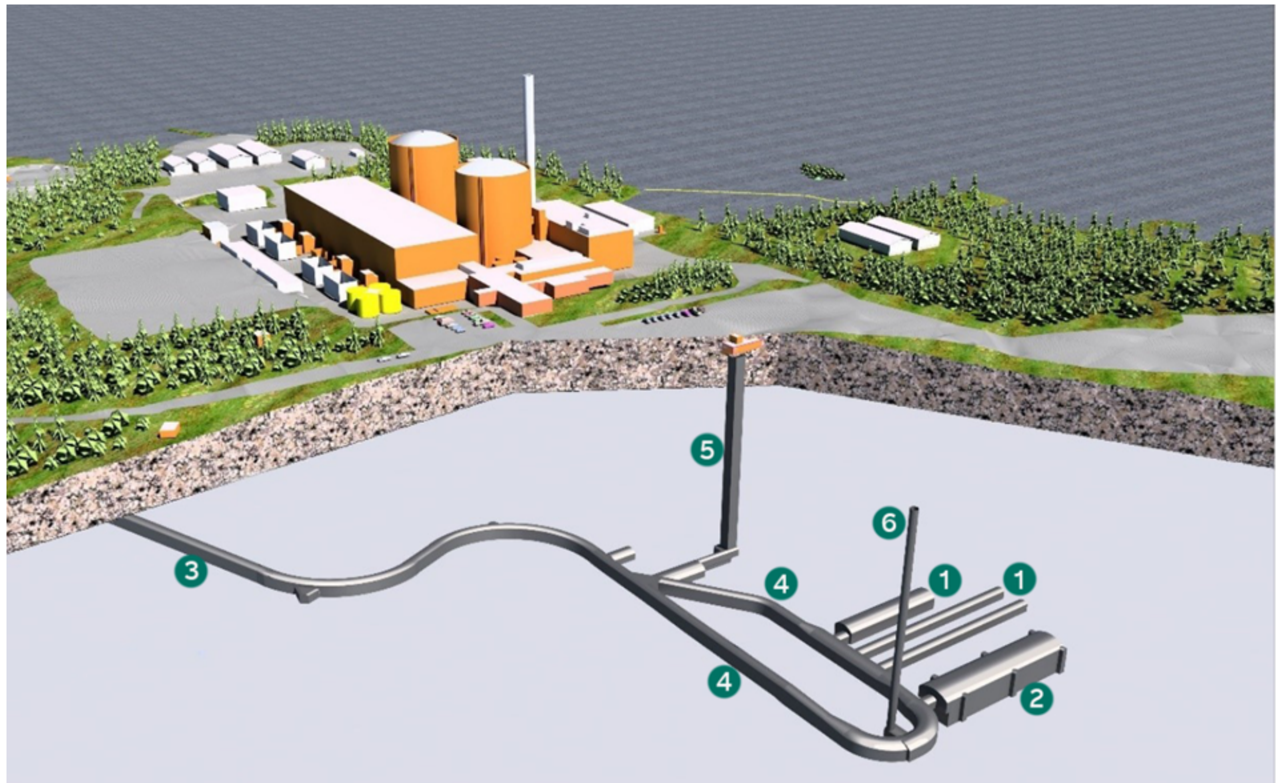

Figure 1-8. Loviisa power plant's final disposal facility for low- and intermediate-level waste (L/ILW repository) in its current size. Layout: Timo Kirkkomäki, Fortum.

the event that the emergency diesel generators and the power supply from the national transmission networks be unavailable. The diesel-operated emergency power plant undergoes a test run every six weeks, for about an hour at a time.

In addition to the aforementioned, there are, in the power plant area, diesel generators for a severe reactor accident and small diesel generators in the auxiliary emergency feed-water system and in the fire water pumping stations.

The 20 kilovolt (kV) connection from the nearby Ahvenkoski hydropower plant also serves as an alternative power supply for the emergency diesel generators.

1.3.4.9 Water supply plant and wastewater treatment plant

The power plant's service water is produced at the raw water treatment plant, or "water supply plant", located within the power plant area. The service water produced from the raw water is used as the power plant's process, fire, cleaning and rinsing water as well as its domestic water. The water treatment at the water supply plant is based on chemicalisation, flotation clarification and sand filtration. The treated water is kept in two domestic water tanks, the volumes of which are 140 m^3 and 160 m^3, as well as in two underground fire water pools, both with a volume of 1,500 m^3.

The power plant area also has a chemical-biological wastewater treatment plant for the treatment of the sanitary wastewater of the power plant area and the related accommodation area. The sanitary wastewater processed at the treatment plant is led to Hudöfjärden via a discharge channel.

Small amounts of the service water produced at the water supply plant are also supplied to Oy Loviisan Smoltti Ab and the Svartholma fortress, and the wastewaters of the aforementioned are likewise led to the power plant area's wastewater treatment plant for processing.

1.3.4.10 Other buildings and functions in the area

The **laboratory building** of Loviisa 1 houses the radiochemistry laboratory, the oil and water laboratory, the water and oil laboratory, and equipment spaces. The samples taken from the processes of both power plant units are subject to chemical and radiochemical analyses which function as a basis for controlling the plant's water chemistry, as well as for monitoring and controlling the status of the plant's processes, emissions and waste. The **maintenance building** is in the equivalent section of Loviisa 2. The maintenance building houses the warehouse, repair shop and equipment rooms.

People enter the power plant through the **main office building**. In addition to the working spaces of the power plant's personnel, the building has facilities for a variety of service functions, such as a kitchen and cafeteria, conference rooms, archives and an emergency preparedness centre. The area also has other office buildings. Facilities suitable for training are located in the **training building** and in the simulator buildings within its vicinity.

The **staff building** is located between the power plant units' auxiliary buildings. During annual outages, this building houses a great number of contractors' workspaces. The building also provides access to the radiation controlled area in which the systems containing radioactive substances are located.

The power plant's own fire brigade, which is on round-the-clock standby, is based in Loviisa power plant's **fire station**. In an emergency, the fire brigade is charged with initiating and directing firefighting and rescue operations until such time as the emergency authorities arrive and take charge. The separate fire water pumping stations are also located in the power plant area.

The transformers and **switch yard** are behind the turbine building. The electricity produced by the power plant is transmitted to the national grid via the switch yard. Transmission to the national grid is carried out with 400 kV power lines. A 110 kV power line connection is used to supply power from the national grid to the power plant.

The power plant's **gate building** is on the mainland, by the Kirmussalmi roadside and bridge. Access to the power plant area is controlled at the gate. The small craft harbour intended for the use of power plant personnel is located by the power plant's gate building.

The power plant's **accommodation area** is on the mainland, northwest of the gate building. The accommodation area is intended for people working in the power plant area temporarily, during annual outages, for example.

2. The options to be reviewed

The implementation options reviewed for the project include extending the power plant's operation after the current licence period by a maximum of approximately 20 years (Option 1, VE1) and two different zero options (Option VE0 and Option VE0+) related to the power plant's decommissioning. In most EIA procedures, the zero option is the non-implementation of the project, but since this EIA procedure concerns existing operations, non-implementation is not possible. In the zero options of this EIA procedure, the operation of the power plant would not be extended, instead of which the power plant units would be decommissioned after the current operation licence period. A brief description of the options being reviewed is provided in Table 2-1 and Figure 2-1.

Table 2-1. Options to be reviewed in the EIA procedure.

Option	Description
Extending the operation (VE1)	**Extending the operation** of Loviisa nuclear power plant by a maximum of approximately 20 years after the current operating licence period, followed by decommissioning. The option also entails: • Modifications related to the extension of operations (including new buildings in the power plant area, service water and wastewater connections, and increasing the capacity of the interim storages for spent nuclear fuel or expanding interim storage for spent nuclear fuel 2). • Operations related to decommissioning, such as VE0 and VE0+. • The possible receiving, processing, placing in interim storage and depositing for final disposal of radioactive waste generated elsewhere in Finland.
Decommissioning (VE0)	The **decommissioning** of Loviisa nuclear power plant after the current licensing period (in 2027/2030).
Decommissioning (VE0+)	The **decommissioning** of Loviisa nuclear power plant after the current licensing period (in 2027/2030). • The possible receiving, processing, placing in interim storage and depositing for final disposal of radioactive waste generated elsewhere in Finland.

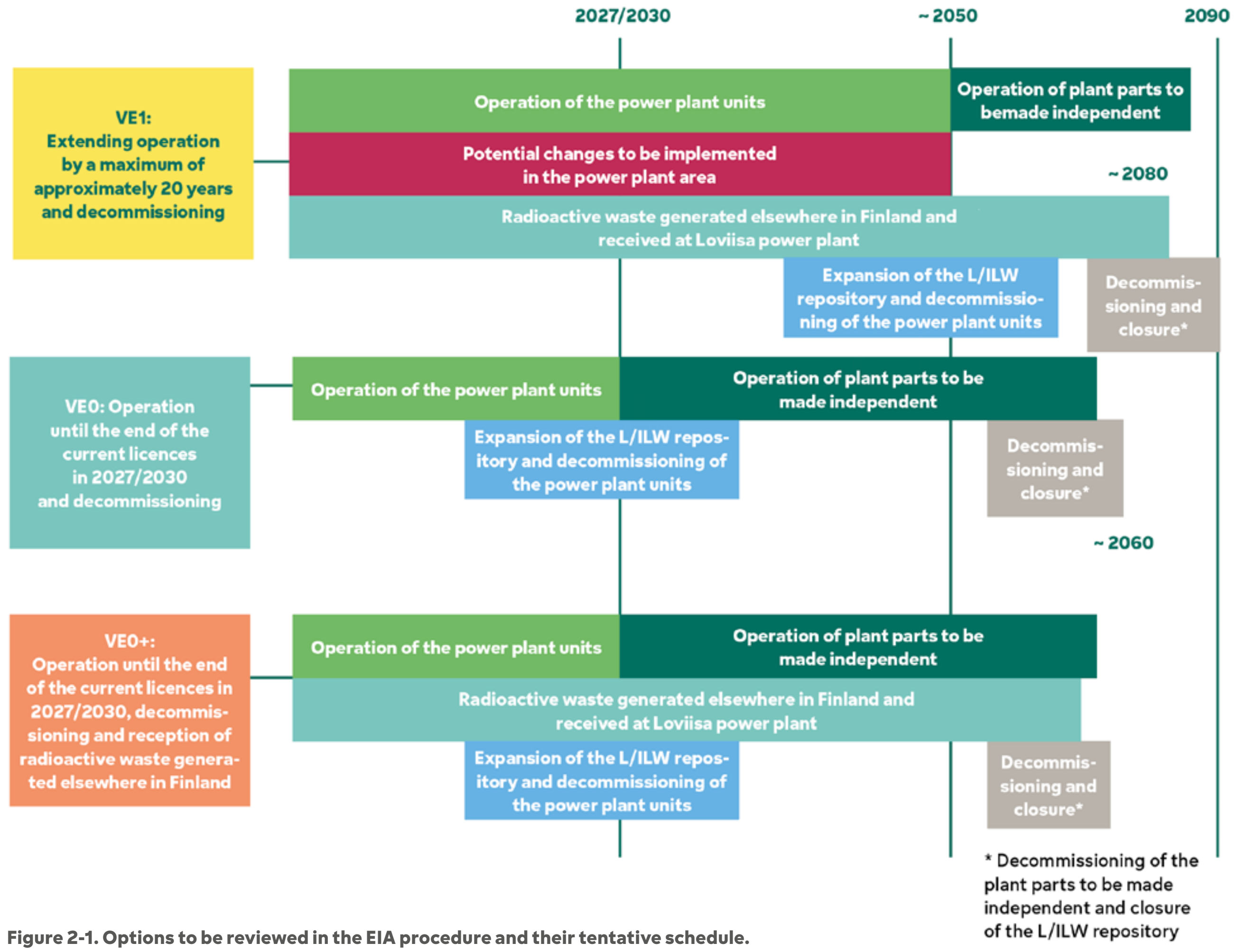

Figure 2-1. Options to be reviewed in the EIA procedure and their tentative schedule.

2.1 EXTENDING THE OPERATION (VE1)

Option VE1 covers an extension to Loviisa power plant's commercial operation after the current licence period (2027/2030) by a maximum of approximately 20 years. During the extension, the operation of the power plant would be similar to what it is currently; increasing the thermal power of the plant, for example, is not being planned. If the operation of the power plant is extended, new buildings and structures may potentially be constructed and modernisations may be carried out in the power plant area.

Potential modifications related to extended operation include:

- Replacing some old buildings in the power plant area with new ones. These would include an inspection or reception warehouse, a cafeteria building, a wastewater treatment plant, welding hall and a waste storage hall.
- Procuring the power plant's service water from the municipal plant and directing sanitary wastewater to the municipal sewage treatment plant. The power plant's current service water and wastewater connections would nevertheless be preserved alongside the new arrangement.
- Expanding the interim storage for spent nuclear fuel or increasing the capacity of the current interim storage (by placing more nuclear fuel in the pools of the existing interim storage, for example).

As part of Option VE1 for extending operations, the EIA programme of Loviisa power plant investigated the possibility of conducting water engineering projects in the area in front of the cooling water intake and the adjacent sea area. Based on the techno-economic investigations, the water engineering projects are no longer being planned, which is why they are not reviewed in the EIA procedure.

Option VE1 includes the power plant's decommissioning after the commercial operation. The functions related to decommissioning would be implemented in 2045–2090. Chapter 2.2 describes the functions included in the decommissioning.

One aspect of the option of extended operation (VE1) being considered, in accordance with the recommendation of the National Nuclear Waste Management Cooperation Group set up by the Ministry of Economic Affairs and Employment (MEAE 2019), is the possibility of small quantities of radioactive waste generated elsewhere in Finland being received, processed, placed in interim storage and deposited for final disposal in the Loviisa power plant area. Such waste could be generated in research institutions, industry, hospitals or universities, for example. Since Loviisa power plant already has the functions and facilities suitable for the handling and final disposal of radioactive waste in place, it would be natural and in line with the view of the National Nuclear Waste Management Cooperation Group that they would be available as part of the overall social solution.

The reception of radioactive waste generated elsewhere in Finland at Loviisa power plant is assessed waste batch-specifically, taking into account the handling, packaging, storage and final disposal methods required by and available for the waste. As a rule, the methods are suitable for waste that is similar to low and intermediate-level operational waste in terms of its radioactivity and other properties.

2.2 DECOMMISSIONING (VE0)

Option VE0 reviews the power plant's decommissioning after the current licence period (2027/2030).

Decommissioning includes the dismantling of the radioactive systems and equipment of Loviisa power plant and the final disposal of radioactive decommissioning waste in the L/ILW repository's current halls, and new halls to be built as required. In addition, decommissioning includes making certain functions and waste management-related plant parts independent to ensure that the said independent plant parts can function without the power plant units. In Option VE0, the operation of the L/ILW repository would continue approximately until the 2060s.

During the operation of the power plant, preparations are made for decommissioning, including the following:

- the operation and expansion of the L/ILW repository to ensure that the radioactive decommissioning waste generated in the decommissioning of the power plant can be deposited in the L/ILW repository for final disposal;
- the preparations required by and the use of the buildings and structures to be made independent (including the interim storage for spent nuclear fuel, the liquid waste storage and solidification plant.

The decommissioning phase includes the following:

- power plant dismantling, with the main focus on the dismantling of radioactive plant parts and systems;
- the handling of radioactive decommissioning waste and its final disposal in the L/ILW repository;
- the handling and reuse of conventional dismantling waste;
- the operation and dismantling of the plant parts to be made independent;
- closure of the L/ILW repository.

The transport of spent nuclear fuel to Olkiluoto in Eurajoki, Finland, will also be carried out during the decommissioning phase. At Olkiluoto, the spent nuclear fuel will be encapsulated and deposited for final disposal at Posiva Oy's encapsulation and final disposal facility (Posiva Oy 2008).

The decommissioning will be based principally on Loviisa power plant's latest decommissioning plan, completed in 2018, which covers the dismantling of radioactive plant parts, waste treatment and the final disposal of radioactive waste (the "brownfield principle").

2.3 DECOMMISSIONING (VE0+)

Option VE0+ is the same as Option VE0, except that it also takes into account the handling, interim storage and final disposal of potential radioactive waste generated elsewhere in Finland and received by Loviisa power plant (see Chapter 2.2).

3. Project phases and schedule

The tentative schedule estimates for the project options to be reviewed in the EIA procedure are provided in Figure 3-1. In the case of the extension of the power plant's operation (Option VE1), commercial operation would be extended by a maximum of approximately 20 years, making the total service life of the power plant units about 70 years. In this scenario, the expansion of the L/ILW repository related to the preparation for the power plant's decommissioning would take place in the 2040s. In addition, preparatory measures would be taken in terms of the plant parts to be made independent of the power plant (the interim storage for spent nuclear fuel, liquid waste storage and solidification plant). The power plant's decommissioning would take place roughly between 2050 and 2060. The operation of the plant parts to be made independent would continue roughly until the 2080s, which is when their decommissioning would begin, and their radioactive dismantling waste would be deposited in the L/ILW repository for final disposal. The use of the L/ILW repository would continue until approximately 2090.

If the operation of Loviisa power plant ends when the current licensing periods come to an end in 2027 (Loviisa 1) and 2030 (Loviisa 2), the preparation for the decommissioning of the power plant (Options VE0 and VE0+) should be initiated within the next few years. In the zero options, the expansion of the L/ILW repository for decommissioning waste is scheduled to start in the mid-2020s. This is also when the preparations and required plant changes for the operation of the plant parts to be made independent will be implemented.

Among other things, the service life of the plant parts to be made independent depends on when the final disposal of the spent nuclear fuel from Loviisa power plant is begun at Posiva Oy's encapsulation and final disposal facility at Olkiluoto in Eurajoki. According to the current estimate, the final disposal of Loviisa power plant's spent nuclear fuel would begin within the framework of the current operating licence period in the 2040s, meaning that the operation of plant parts to be made independent would continue until the 2060s. The decommissioning of the plant parts to be made independent will begin after this, and the resulting radioactive decommissioning waste will be deposited in the L/ILW repository for final disposal. The L/ILW repository will be closed after all the radioactive decommissioning waste has been deposited in the repository for final disposal.

Radioactive waste originating from elsewhere in Finland can be received, in Options VE1 and VE0+, at Loviisa power plant during the operation and dismantling of the plant parts to be made independent for as long as the functions needed for the handling and final disposal of waste are available.

Figure 3-1. Tentative schedules of the project options, to be specified as the plans progress.

4. VE1: Extending operation

The project's Option VE1 covers the extension of the operation of Loviisa nuclear power plant by a maximum of approximately 20 years after the current licence period. During the extension, the operation of the power plant would be similar to what it is currently; increasing the thermal power of the plant, for example, is not being planned. The power plant's operating principle and production would continue in the same fashion as in its current operation (see Chapter 1.3). The modifications related to the extension of operation are described in the following chapters.

Option VE1 also includes the power plant's decommissioning after the extended operation. The decommissioning is described in Chapter 5, and insofar as the decommissioning is subject to changes in the case of extended operation, it is described in Chapter 5.9. In addition, Option VE1 includes the receiving, processing, placing in interim storage and depositing for final disposal of small amounts of radioactive waste generated elsewhere in Finland, described in Chapter 6.

The extension of Loviisa power plant's operation requires, among other things, an operating licence pursuant to the Nuclear Energy Act. The licensing process is described in more detail in Chapter 12.

4.1 AGEING MANAGEMENT AND MAINTENANCE

Attention has been paid to the ageing management of Loviisa power plant throughout its operation. Well-managed and professional ageing management and maintenance are prerequisites for ensuring the safe, reliable and profitable operation of a nuclear power plant. The ageing management programme and procedures cover the entire Loviisa power plant. The plant parts have been divided into ageing management categories based on their significance in terms of safety, as well as in terms of parts that limit the plant's service life, and their significance for availability. The equipment of these plant parts has been categorised according to its criticality. The measures and monitoring methods to which a piece of equipment is subject are determined on the basis of the criticality classes, and the equipment's failure and ageing mechanisms. The monitoring, maintenance programmes and tasks of plant parts and equipment that have a high criticality class are the most extensive in scope. Ageing management also entails the monitoring of technical ageing and ensuring an adequate reserve of spare parts.

The basic principle is that the equipment is kept in good condition, and if a piece of equipment does break down, it is repaired. Loviisa power plant's maintenance organisation and maintenance functions are responsible for ensuring that a system, piece of equipment or structure that is in operation or operable meets the requirements set for the operating conditions under normal operation. They should also meet the requirements for operating conditions pursuant to the technical specifications regarding safety, which enable preparedness for incidents and accidents. As the failure rate of a piece of equipment increases, the measures are determined on the basis of observations or other considerations, and in such cases, one option is to replace the piece of equipment with a new one. An increase in failure rate may also have an effect on the probabilistic safety analysis, described in Chapter 7.8.

During the power plant's extended operation, the ageing management and the related procedures, as well as maintenance, would continue in the same manner as during the power plant's current operation, under the supervision of the Radiation and Nuclear Safety Authority (STUK). The measures are primarily carried out during annual outages to ensure the safety impact during work is as small as possible.

The following assessment, development and improvement targets have been identified on the basis of the power plant's operation and ageing management:

- measures resulting from the ageing of some automation systems, such as ensuring the availability of spare parts or a system's modernisation;
- ensuring the safety margins of the primary system and the reactor pressure vessel, particularly the safety margins applicable during operation;
- renovation of the existing buildings in the power plant area and the possible construction of new buildings;
- the potential modernisation of the low-pressure turbines, which would also increase the power plant's efficiency.

Their possible related measures and their timing are to be decided at a later date.

The aforementioned management of the reactor pressure vessel's ageing has been identified as a key measure for extending the power plant's service life. Over time, radiation embrittles the weld seam which is at the height of the bottom half of the reactor pressure vessel's core. A brittle fracture of the weld seam could occur if the reactor pressure vessel was exposed to a great change in temperature during an incident or accident. Safety margins have been defined for a brittle fracture of the weld seam, and the reduction of these margins is assessed on the basis of a research programme and analysis. In relation to this, the materials of the reactor pressure vessel, for example, are studied by irradiating them and studying their safety properties.

If the power plant's operation is extended, measures aiming to prevent the radiation embrittlement of the reactor pressure vessel's weld seam must be carried out. Such measures would include:

- limiting the weld seam's radiation dosage to decelerate the radiation embrittlement;
- the annealing of the weld seam;
- the reduction of any thermal load to which the weld seam would be subject during an incident or accident.

The radiation dose accumulated by the weld seam can be decelerated in various ways, for example, by the placement of fuel and adding dummy elements to the reactor core.

Loviisa power plant has experience of the annealing of a reactor pressure vessel's weld seam, given that the procedure in question was carried out on Loviisa 1's reactor pressure vessel in 1996. As a result of the annealing, the material properties of the embrittled area of the weld seam returned nearly to the original level.

Table 4-1. The environmental aspects of the power plant's extended operation in terms of cooling water.

Environmental aspect	Current operation of the power plant	Extending operation
Cooling water	Average consumption, 1,300 million m^3 (max. 1,800 million m^3)	No change.
	Average thermal load, 57,000 TJ (max. 60,000 TJ)	No change.

The thermal loads of the weld seam were reduced in the automation modification carried out in 2019. The goal of the modification was to avoid the use of cold water in the spray system used for the containment building's pressure control when the spraying begins. Thermal loads can be further reduced with insulation, for example.

The measures presented above are examples of methods that allow the controlling of the reactor pressure vessel's ageing, thereby ensuring the power plant's safe extended operation. The investigations related to the measures will be continued, and the measures will be determined at a later date.

4.2 COOLING WATER

Seawater is used for various cooling purposes at Loviisa power plant. The primary use is the condensation of steam in the turbines. If the power plant's operation is extended, cooling water would continue to be used in the same manner as it is currently. The cooling water for the power plant is taken from Hudöfjärden, west of the island of Hästholmen, using an onshore intake system, and is discharged back into the sea at Hästholmsfjärden, on the east side of the island (Figure 1-5). The thermal load to which the sea area is subject due to the cooling water would remain unchanged. Table 4-1 presents the environmental aspects of the power plant's extended operation in terms of cooling water.

4.2.1 Cooling water intake

There are no plans to make changes to the cooling water intake. The cooling water will be taken from the sea as is done currently, and the volume taken will remain unchanged.

The upper and lower edges of the cooling water intakes are at a depth of 8.5 metres and 11.0 metres, respectively. The intakes' combined cross-sectional area is approximately 80 m^2. The calculated flow velocity at an intake varies, being around 0.5 m/s in the winter and around 0.63 m/s in the summer. Beyond the intake, the seawater is led to the power plant units along a shared rock tunnel, which bifurcates further into two separate tunnels, each leading to a different power plant unit.

The volume of cooling water used by Loviisa power plant is, on average, 44 m^3/s. The flow of the cooling water is at its maximum at the end of the summer, when the temperature of the cooling water taken from the sea is at its highest (Figure 4-1). At that time, the cooling water flow may be approximately 55 m^3/s. According to the power plant's environmental permit, the limit value for the flow is 56 m^3/s. According to the environmental permit and water permit, the power plant may use a maximum of 1,800 million m^3 of cooling water a year. In 2019, the power plant's use of cooling water totalled 1,380 million m^3.

The temperature of the cooling water taken by Loviisa power plant varies according to season. The average monthly temperatures of the cooling water taken for power plant unit Loviisa 1 in 2012-2020 are shown in Figure 4-2. The cooling water is at its coldest in January–March, when its average temperature is roughly 1.5˚C. The temperature of the cooling water rises towards the summer months; it is at its warmest in August, when its average temperature is roughly 17.3˚C. After August, the temperature falls towards the end of the year.

Fish, algae and other screenings carried with the cooling water to the power plant are removed from the water by means of coarse and fine screens and travelling basket filters. The screenings accumulated by the power plant alongside cooling water amount to roughly 25–30 tonnes a year, with fish accounting for approximately 10–20 tonnes of this amount. The screenings consist mostly of organic biowaste, which is taken to an external waste management company for appropriate processing.

4.2.2 Cooling water discharge

There are no plans to make changes to the discharge of cooling water. The cooling water will be discharged into the sea as is done currently, and the volume discharged into the sea will remain unchanged.

The temperature of the cooling water taken to the power plant increases by 8–12 °C in the turbine condensers, or by an average of 9.8 °C.

The warmed cooling water is led to the cooling water discharge, where the flow spreads over an approximately 90-metre submerged weir near the surface of the water (at a level of -0.5 m) (Figure 4-3). The submerged weir spreads the water to the sea's surface layer, thereby accelerating the release of the excess thermal energy into the atmosphere. Despite this, some warm cooling water ends up in the intake side as a result of recirculation.

The temperature of the discharged cooling water and the temperature of the seawater in front of the discharge area are monitored continuously. The data buoys measuring the

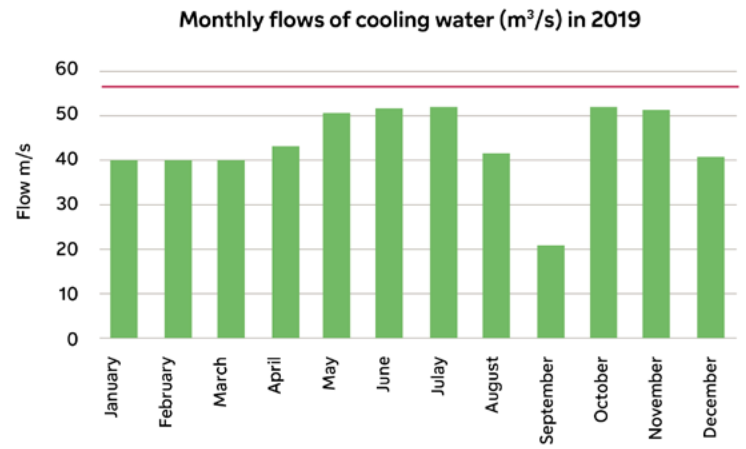

Figure 4-1. Monthly flows of cooling water in 2019 The environmental permit's limit value (56 m^3/s) is indicated with a red line.

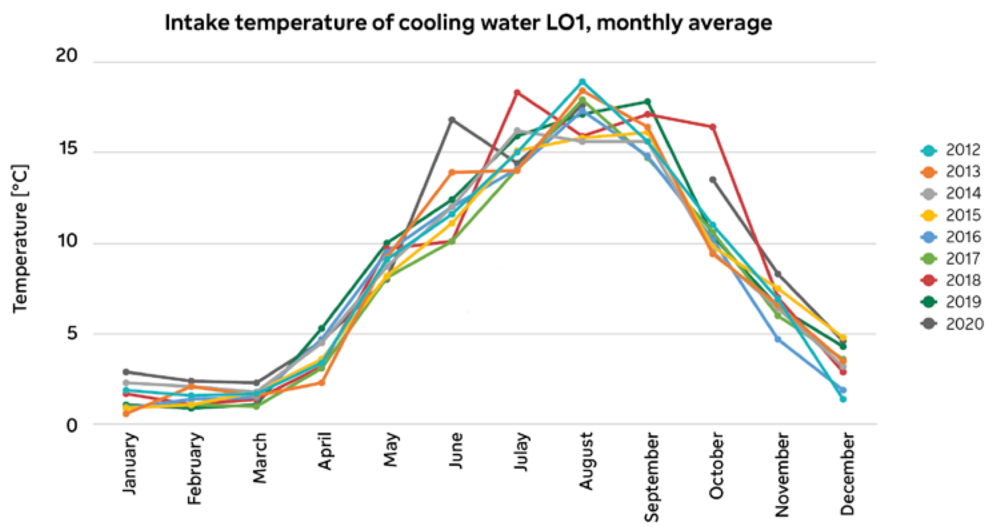

Figure 4-2. The average monthly temperatures of the cooling water taken for power plant unit Loviisa 1 in 2012-2020.

Figure 4-3. Discharge of cooling water into Hästholmsfjärden.

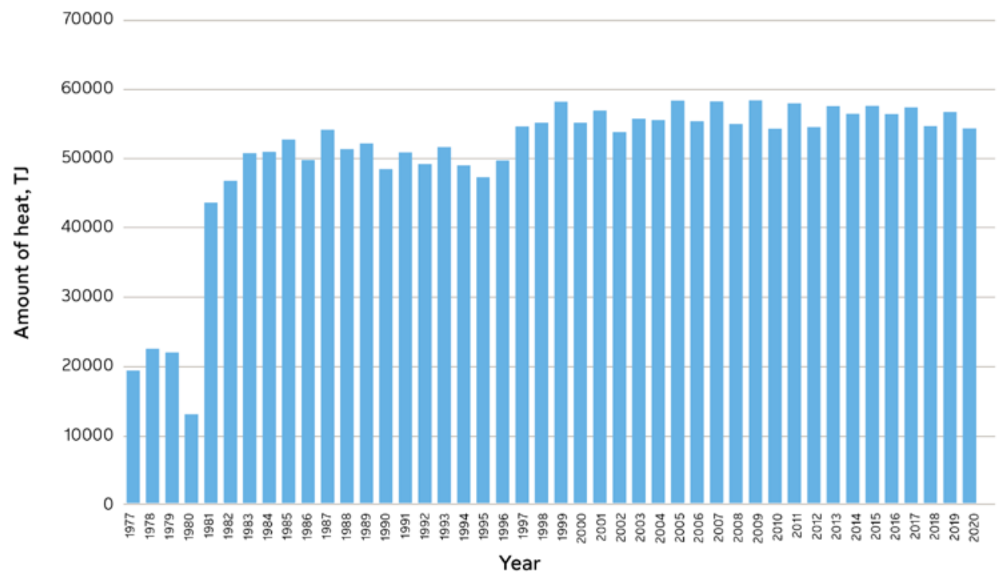

Figure 4-4. Loviisa power plant's thermal load (TJ) into the sea in 1977–2020.

temperature of the seawater are located at a 500-metre distance from the discharge location. The hourly average temperature of the cooling water led into the sea may be, at maximum, 34 °C. If the hourly average temperature of the cooling water led into the sea exceeds a value of 32 °C for a minimum of 24 hours, how this impacts the condition of the sea area must be investigated.

Since the power plant's power uprating, the average thermal load into the sea has been approximately 57,000 terajoules (TJ) a year (Figure 4-4). The limit value for the thermal load specified in the environmental permit is 60,000 TJ a year. The average amount of heat led into the sea during a 24-hour period is therefore around 156 TJ per day of operation.

4.3 SERVICE WATER

In addition to cooling water, the power plant needs raw water for the operation of the power plant process as well as for domestic and fire water purposes. The raw water is abstracted from the Lappomträsket lake (Figure 9-30), which is located approximately five kilometres north of the power plant. If the power plant's operation is extended, the supply of service water will remain unchanged. Preliminary investigations into the possibility of procuring water from the municipal water supply plant as an alternative to the current supply have been carried out. Even in this case, the current form of procuring service water would be retained alongside the new water connection. In the future, other means of procuring water will also be investigated as the technology continues to advance. Table 4-2 presents the environmental aspects of the power plant's extended operation in terms of service water requirements and supply.

4.3.1 Current supply of service water

The raw water pumped from Lappomträsket lake is used to produce the service water needed by the power plant. Raw water is used as the power plant's process, fire, cleaning and rinsing water as well as its domestic water. Lappomträsket lake is regulated with the aim of reserving a sufficient volume of water for Loviisa power plant's raw water needs.

Table 4-2. The environmental aspects of the power plant's extended operation in terms of service water requirements and supply.

Environmental aspect	Current operation of the power plant	Extending operation
Service water requirements and supply		
Volume	Process water 100,000–200,000 m³/year Domestic water 25,000–75,000 m³/year	No major changes.
Intake of service water	Lappomträsket lake. The water level of Lappomträsket lake is regulated in accordance with the water permit's permit conditions.	Lappomträsket lake. The procurement of service water from the water mains system of the town of Loviisa has been investigated as an alternative. The regulation stipulations regarding Lappomträsket lake defined in the water permit will not change.

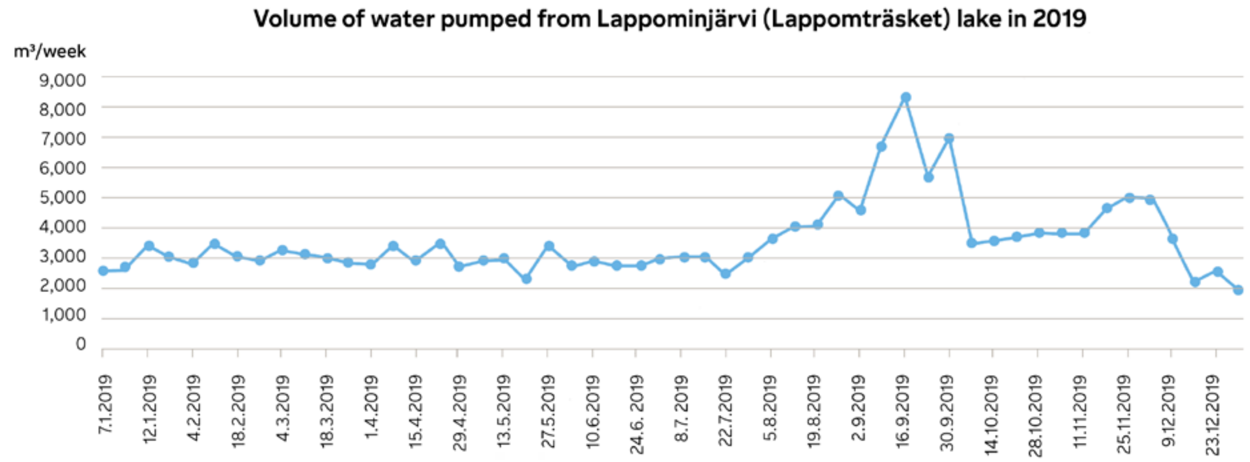

Figure 4-5. Volume of raw water taken by the power plant from Lappomträsket lake in 2019.

The power plant has a service water abstraction permit in accordance with the Water Act (264/1961), granted by the Water Rights Court by its decision on 27 December 1976, for the abstraction of raw water from Lappomträsket lake. The said permit applies to leading water from the Lappomträsket lake and the regulation of the water level. According to the permit conditions, water may be taken from the lake at a rate of 180 m³/h on a short-term basis and at a maximum rate of 150 m³/h over every three months. The upper and lower limits for the regulation are +3.25 m and +2.3 m respectively, and if the water level falls below the lower limit, no water at all may be abstracted from the lake. In addition to these permit conditions, the permit defines monitoring obligations, and other things.

An average of 20–30 m³/h of water is pumped for the power plant's service purposes. The annual intake of water from Lappomträsket lake has been approximately 200,000 m³. Figure 4-5 shows the weekly water intake variation in 2019. The figure illustrates how the water intake increases during the power plant's annual outages (August–September), as the consumption of process water and domestic water increases markedly compared to a situation of steady power operation. The greater water consumption during annual outages is the result of the filling and emptying of processes as well as the greater number of workers in the power plant area and the increased consumption of domestic water resulting from their stay.

The water taken from the lake is treated at the power plant area's raw water treatment plant before it is led to the water reservoirs and the process. The water treatment is based on chemicalisation, clarification and sand filtration. The treated water is kept in two domestic water tanks, the volumes of which are 140 m³ and 160 m³, as well as in two underground water pools, both with a volume of 1,500 m³. The salt-free process water needed by the power plant is produced with an ion exchange technique from the power plant's service water at the water demineralising plant. The salt-free water produced at the water demineralising plant is stored in a total of four 1,000 m³ tanks. Both power plant units have two tanks. Figure 4-6 shows how the raw water entering the raw water treatment plant is divided into the process water led to the water demineralising plant for treatment and the domestic water.

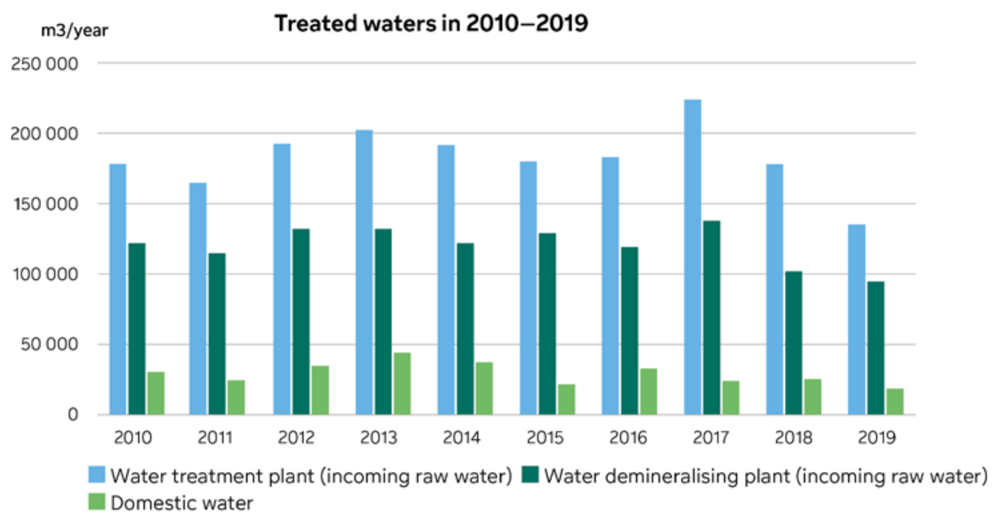

Figure 4-6. The volume of waters treated at the water supply plant, water demineralising plant and the wastewater treatment plant in 2010–2019.

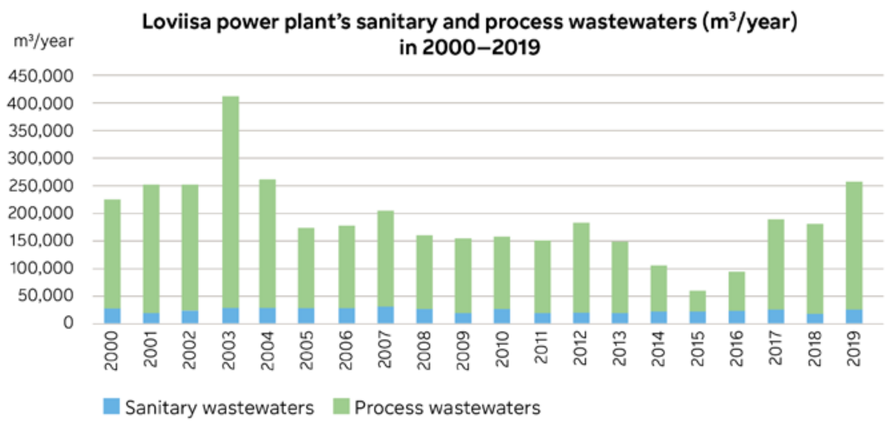

Figure 4-7. Volumes of Loviisa power plant's sanitary and process wastewaters (m^3/year) in 2000–2019.

4.3.2 Changes to service water procurement

In the future, the power plant's service water will still be taken from Lappomträsket lake, either entirely, as today, or partially, in which case part of the intake of water from Lappomträsket lake will be substituted by the procurement of other service water. The possibility of cooperation with the town of Loviisa (Loviisan Vesiliikelaitos) has been preliminarily explored as an alternative to the power plant's own procurement of service water and water treatment. This would mean the procurement of domestic water and possibly also process water from the water supply network of the town of Loviisa. Should the service water be procured from the town of Loviisa, the power plant's current raw water supply system and water treatment plant would nevertheless, for reliability purposes, remain in use for the power plant's process and domestic water, and Lappomträsket would continue to be regulated. The feasibility of the alternative is being reviewed in cooperation with the town of Loviisa.

4.4 WASTEWATER

The power plant generates various wastewaters, including sanitary wastewater, process water and washing waters. The wastewaters are treated appropriately in the power plant area; the discharge locations of the treated wastewaters are shown in Figure 1-5.

Currently, the sanitary wastewaters are treated in the power plant area's wastewater treatment plant. If the operation is extended, continuing the use of the wastewater treatment plant in the power plant area for the treatment of the sanitary wastewaters is one alternative. Another alternative to the current method for treating sanitary wastewaters is being considered as part of the possible change in the procurement of service water. In this alternative, the sanitary wastewaters would be led to the Vårdö wastewater treatment plant of the town of Loviisa (Loviisan Vesiliikelaitos). Table 4-3 presents the environmental aspects of the power plant's extended operation in terms of wastewaters.

4.4.1 Sanitary wastewaters

If the operation is extended, the sanitary wastewaters are treated in the same way as today or at the Vårdö wastewater treatment plant of the town of Loviisa.

Currently, sanitary wastewaters are treated in the wastewater treatment plant located within the power plant area; an average of approximately 24,000 m^3 of sanitary wastewater a year has been led to this plant in 2000–2019 (Figure 4-7). The total volume of wastewater includes, in addition to the power plant area's sanitary wastewaters, the supernatants of Loviisan Smoltti Oy's fish farm (roughly 240 m^3/year) and the supernatants of the raw water treatment plant. The aluminium hydroxide deposits in the raw water treatment plant's supernatants are put into use as the wastewater treatment plant's precipitant. The treatment plant has also treated the wastewaters of the Svartholma fortress, which are led to the treatment plant at an average rate of 0.5 m^3/day. The sanitary wastewater treated at the power plant's wastewater treatment plant has been led to the Hudöfjärden discharge location.

The wastewaters led into the sea from the power plant's wastewater treatment plant are treated so that the wastewater's total phosphorus concentration, calculated as an average is, in line with the permit conditions, a maximum of 0.7 mg/l, and the wastewater's biological oxygen demand (BOD_{7ATU}) is a maximum of 15 mg O_2/l. The purifying efficiency must be at least 90% for both variables. The average total nitrogen load of the sanitary wastewater has been approximately 840 kg per year, and the total phosphorus load approximately 9 kg per year. In 2000-2019, the biological oxygen demand (BHK7 value) of the sanitary wastewater averaged 171 kg per year, the chemical oxygen demand (COD value) averaged 413 kg per year, and the solids load averaged 496 kg per year. If the operation is extended, the load caused by the sanitary wastewaters will remain similar to its current load.

An alternative to the current method for treating sanitary wastewaters is being considered as part of the possible change in the procurement of service water. In this alternative, the sanitary wastewaters would be led to the Vårdö wastewater treatment plant of the town of Loviisa (Loviisan Vesiliikelaitos). The discharge point of Vårdö's wastewater treatment plant is in Loviisanlahti bay, some 4 km from the power plant's discharge point. In this case, the wastewater volumes generated at the power plant would remain unchanged. The load resulting from Loviisa power plant's sanitary wastewaters would be accounted for in the permit conditions of the Vårdö wastewater treatment plant. At the power plant, the need to treat wastewater will continue for as long as permanent operations of any kind are engaged in within the power plant area.

Table 4-3. The environmental aspects of the power plant's extended operation in terms of wastewaters.

Environmental aspect	Current operation of the power plant	Extending operation
Sanitary wastewaters		
Volume	20,000–30,000 m^3/year On average 60 m^3/day (max. 120 m^3/day)	No major changes.
Discharge location	The Hudöfjärden discharge point.	The Hudöfjärden discharge point or the discharge point of Loviisan Vesi's Vårdö wastewater treatment plant in Loviisanlahti bay (roughly 4 km from the power plant's discharge point).
Loads	Average total nitrogen 840 kg/year Average total phosphorus 9 kg/year In accordance with the power plant's current permit conditions: - maximum annual average of total phosphorus concentration 0.7 mg/l - maximum biological oxygen demand 15 mg O2/l - minimum purifying efficiency 90%.	No major changes. Will remain unchanged or be accounted for in the permit conditions of the Vårdö wastewater treatment plant.
Sludge	The sludge generated in the wastewater treatment is led to the peat basins. The compost generated in this process will be used in the landscaping carried out in the power plant area.	Will remain unchanged or be transferred for treatment at the Vårdö wastewater treatment plant.
Process wastewater		
Volume	An average of 160,000 m^3/year.	No major changes.
Discharge location	Led into the cooling water channel, and via the channel and the discharge location to the Hästholmsfjärden side.	Will remain unchanged.
Loads	Average total nitrogen 800 kg/year Average total phosphorus 9 kg/year	No major changes.
Other waters led into the sea		
	Including rinsing waters, oily waters, the L/ILW repository's seepage waters, rainwaters and water in the ground, appropriately treated.	No major changes.

4.4.2 Process wastewater

If the operation is extended, the volumes and treatment methods of process wastewaters would remain the same as in current operations.

Various process wastewaters in the power plant's operation are generated from the regeneration water of the demineralising plant and condensate purification facilities, the turbine hall's seepage water, the water from the steam generators' blowdown water treatment plant, and the emptying waters of the neutralisation tanks. In addition, radioactive water, led into the active water treatment systems, is generated in the primary system's processes and the sewer system of the radiation controlled area. The wastewaters of the laundry and the laboratory in the radiation controlled area are led either into the cooling waters via the control tanks or to the treatment systems, depending on the waters' activity. All seepages, water on the floors, sampling discharges and other wastewaters are collected in the neutralisation tanks at the chemical station, in which the waters are neutralised with sodium hydroxide or nitric acid (pH 6–9) before being discharged into the sea.

Nearly all process wastewaters generated at the power plant are ultimately led into sea within the cooling water. The annual volumes of Loviisa power plant's process wastewaters (m^3/year) in 2000–2019 are shown in Figure 4-7. During the period in question, the average volume of process wastewaters was approximately 160,000 m^3 a year. The average total nitrogen load of the process wastewater has been approximately 800 kg per year, and the total phosphorus load approximately 9 kg per year. The controlled discharge of the evaporation concentrate from which caesium has been separated is carried out at three to four-year intervals. It is visible in the nutrient load of the process wastewaters (see Chapter 4.12.2).

4.4.3 Other waters led into the sea

If operation is extended, other waters in addition to sanitary and process wastewaters will be generated. These include:

- the seawater used for the flushing of the travelling basket filters of the seawater pump stations, which is led into Hästholmsfjärden within the cooling water;
- the rinsing water of the water supply plant's sand filters;
- oily wastewaters, which are led into oil separation, from where the treated water is led into the power plant's cooling water channel, and further on into Hästholms-fjärden;
- the L/ILW repository's seepage waters (approximately 20,000–40,000 m³/year), which are pumped into the sea at Hudöfjärden (see Chapter 5.2);
- rainwater and meltwater (i.e. stormwaters), as well as water in the ground.

Figure 4-8. VVER-440 fuel bundle.

4.5 PROCUREMENT OF NUCLEAR FUEL

The fuel used by Loviisa power plant is made from uranium ore, packaged into fuel bundles (Figure 4-8). The power plant's annual fuel requirement totals approximately 24 tonnes of uranium dioxide (UO_2), and the power plant's reactors contain a total of approximately 89 tonnes of uranium dioxide. If the operation is extended, the fuel requirement will remain unchanged.

The reactors of both of Loviisa power plant's power plant units contain a total of 313 fuel bundles. Currently, around a quarter of the fuel is removed from the reactor every year during the refuelling outage, and the removed bundles are replaced with fresh fuel bundles. The places of the fuel bundles remaining in the reactor are also switched for the achievement of optimal power density. Unused fresh fuel is only mildly radioactive. The fuel becomes highly radioactive in the reactor, where it emits a high level of radiation.

Fortum will procure the fuel of Loviisa power plant as complete bundles from the Russian TVEL Fuel Company ("TVEL") until the current operating licence expires. If Loviisa power plant's service life is extended, the fuel procurement will be reviewed in accordance with Fortum's general procurement procedures. In addition to actual use, the planning concerning the fuel bundles accounts for the stress to which they are subject during handling and transport, including the handling phases related to long-term storage and final disposal.

The nuclear fuel intended for Loviisa is delivered to Finland via rail or by sea, and to the power plant by road. An average of two transports of fresh fuel is carried out every year. The fresh fuel stored in the dry storage at Loviisa power plant usually meets the fuel requirements for one or two years. Table 4-4 presents the environmental aspects of the power plant's extended operation in terms of the procurement of nuclear fuel.

4.6 SPENT NUCLEAR FUEL

Nuclear fuel becomes highly radioactive in the reactor during operation, which is why its handling and storage require special measures. In the power plant's current operations, an average of 168 fuel bundles is moved from the reactor buildings to the interim storages for spent fuel every year. The power plant will accumulate some 7,700 bundles of spent nuclear fuel during its current service life.

The extension of operation would not change the quantity of the spent nuclear fuel generated annually, but the total quantity of spent nuclear fuel would increase during the additional years of operation. The development of the fuel aims to improve fuel economy. While fuel economy is already highly optimised, the potential for increasing the efficiency of fuel use even further is being studied.

If the operation is extended (by about 20 years), the power plant will accumulate some 3,700 additional fuel bundles, in which case the total accumulation would be roughly 11,400 bundles. When accounting for any changes in the method of fuel loading and fuel planning, as well as the potential increase in the number of dummy elements, the maximum amount of spent fuel would be 12,800 bundles.

The increase in the total amount of spent nuclear fuel would increase the need for interim storage capacity in the power plant area. Because of this, the existing interim storage for spent nuclear fuel either needs to be expanded or the existing storage capacity must be increased by some other means. Table 4-5 presents the environmental aspects of the power plant's extended operation in terms of the spent nuclear fuel.

After removal from the reactor, spent fuel bundles at Loviisa power plant are cooled for a few years in the reactor building's refuelling pool, during which time most of the radioactive fission products will decay and the heat production will decrease. Once the fuel bundles have cooled sufficiently it is moved, within a radiation shield, to a water pool in a separate interim storage for spent fuel in the power plant area (Figure 4-9). Water acts as a radiation shield and cools the spent nuclear fuel. The interim storage has been designed to ensure that the cooling of the spent fuel is sufficient, and that criticality is impossible. The cooling of the spent fuel is continued in the interim storage until its activity and heat production are sufficiently low for it to be moved to the final disposal facility for spent fuel in Olkiluoto. The spent nuclear fuel of Loviisa power plant's power plant units must be kept in interim storage for a minimum of 20 years prior to final disposal.

The condition of the spent fuel is monitored regularly during the interim storage by conducting the long-term storage condition monitoring programme with respect to the bundles selected for monitoring, for example. The aim is to ensure that the condition of the spent fuel also remains sufficient during the long-term storage in terms of the fuel handling required by the final disposal. The chemical environment of the storage pools is also relevant for maintaining the fuel's integrity. The chemical state of the storage pools is monitored in accordance with the technical specifications of Loviisa's power plant units. The activity of the water in the pools is likewise monitored.

The extension of the power plant's service life requires an increase to the storage capacity for spent fuel. In addition to the fuel accumulation, or the power plant's service life, the need for storage capacity depends on the time at which the final disposal commences. If the fuel's final disposal is not initiated prior to 2050, storage places will be needed for a maximum of 12,800 bundles in 2050. The storage capacity can be increased by storing the spent nuclear fuel more densely in the pools of a current interim storage or by building more storage pools, for example. Denser storage means replacing the original "open" fuel racks with denser racks. The additional pools would be built as an extension to the existing pools in interim storage for spent fuel 2 and a maximum of two new pools would be built. During the construction of the additional pools, the final fuel pool must be empty to ensure the buildings can be connected. This is why the possible decision to expand must be made in

Table 4-4. The environmental aspects of the power plant's extended operation in terms of the procurement of nuclear fuel.

Environmental aspect	Current operation of the power plant	Extending operation
Procurement of nuclear fuel	The annual need for nuclear fuel is approximately 24 tonnes of uranium dioxide.	No change.

Table 4-5. The environmental aspects of the power plant's extended operation in terms of spent nuclear fuel.

Environmental aspect	Current operation of the power plant	Extending operation
Spent nuclear fuel		
Fuel accumulation	The annual accumulation is approximately 168 fuel bundles. Total accumulation by the end of the current operating licences is approximately 7,700 fuel bundles.	Would not increase the annual accumulation, but the total amount would increase as the service life is extended. The number of fuel bundles that would accumulate during the extended operation (approximately 20 years) would be around 3,700, meaning that the total accumulation would be approximately 11,400, but no more than approximately 12,800 fuel bundles.
Interim storage	There are two existing interim storages for spent fuel.	Either the expansion of one of the two existing interim storages with two new water pools or the denser placement of fuel bundles in the water pools of the existing storages.

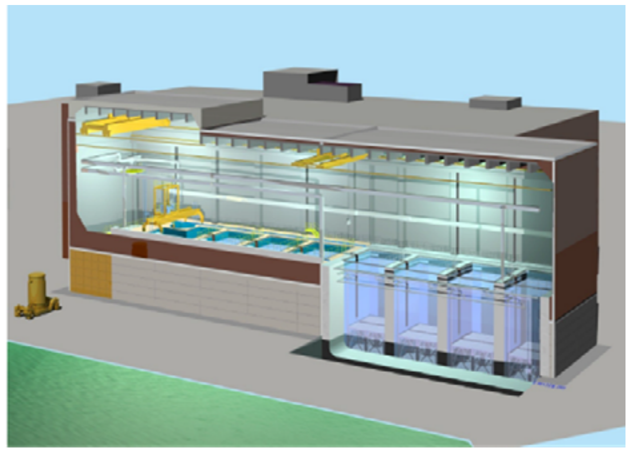

Figure 4-9. Loviisa power plant's storage 2 for spent fuel.

Table 4-6. The environmental aspects of the power plant's extended operation in terms of operational waste.

Environmental aspect	Current operation of the power plant	Extending operation
Operational waste		
Low-level waste	The current accumulation rate is 20–30 m^3/year. The volume to be generated by the end of the current operating licences is approximately 2,700 m^3.	The annual accumulation would be the same, but the total amount would increase as the service life is extended. An extension of roughly 20 years would generate approximately 600 m^3 of low-level waste, i.e. approximately 3,300 m^3 in total. The use of concrete vessels as part of the final disposal of maintenance waste is under investigation.
Intermediate-level waste	The current accumulation rate is 15–30 m^3/year, and when solidified and packed, 60–120 m^3/year. The volume to be generated by the end of the current operating licences is approximately 4,900 m^3.	The annual accumulation would be the same, but the total amount would increase as the service life is extended. An extension of roughly 20 years would generate approximately 2,400 m^3 of intermediate-level packed waste, i.e. approximately 7,300 m^3 in total.
L/ILW repository's capacity	Currently houses three equipped spaces in the bedrock for low-level maintenance waste and one for intermediate-level solidified waste.	The capacity is also sufficient for the final disposal of the low- and intermediate-level waste generated during the extended operation.

good time before the storage capacity of interim storage 2 for spent fuel is full. The other fuel pools may contain fuel during construction. Corresponding work was carried out during the first expansion of interim storage 2 for spent fuel, which was completed in 2000. The selection of the way in which the interim storage capacity will be increased will be made later, based on the time at which fuel transports begin, for example, and the power plant's service life.

The heat production of spent nuclear fuel reduces during interim storage. This compensates for the increase of the interim storage's cooling requirement as the total amount of the fuel in interim storage grows. The cooling capacity of the interim storage can be increased by increasing the flow of the cooling water to the heat exchangers or by increasing the size of the heat exchangers. During the decommissioning phase, the storage for spent nuclear fuel will be made independent, and the cooling system related to this phase is described in more detail in Chapter 5.4.

The extension of the service life will not have an impact on the handling of the fuel after its removal from the reactor. The safety of the fuel storage is maintained in the same manner as during the power plant's operation, by ensuring the fuel's sufficient cooling, subcriticality and radiation shielding, and by securing the fuel's integrity.

The transport, encapsulation and final disposal of the spent fuel is described in Chapter 5.7.

4.7 OPERATIONAL WASTE

In addition to spent nuclear fuel, the nuclear power plant's operations generate low and intermediate-level operational waste. Low-level waste means nuclear waste whose activity is sufficiently low to allow handling without special radiation protection arrangements, whereas the activity of intermediate-level waste is so high that its handling requires efficient radiation protection arrangements. In addition to low and intermediate-level waste, waste that can, due to its low level of radioactivity, be cleared from the regulatory control required by nuclear energy legislation pursuant to section 27 c of the Nuclear Energy Act, and handled further in the same manner as conventional industrial waste, is also generated in the nuclear power plant's radiation controlled area. Detailed safety requirements pertaining to clearance from regulatory control are presented in STUK's YVL Guide D.4.

In its current operation, the power plant generates approximately 20–30 m^3 of low-level waste a year and approximately 15–30 m^3 of intermediate-level waste a year (approximately 60–120 m^3 a year when solidified and packed). Extending the operation of the power plant will not have a material effect on the accumulation rate of the radioactive waste generated annually. An extension of roughly 20 years generates approximately 600 m^3 of low-level waste and approximately 2,400 m^3 of intermediate-level waste when the waste is packed.

If the operation of the power plant is extended, the waste management methods will remain primarily the same as those currently used. The final disposal facility's capacity for low and intermediate-level waste is also sufficient for the final disposal of the low and intermediate-level waste generated during the extended operation. The most important potential change to occur during the extended operation that is being investigated is the use of concrete vessels as part of the final disposal concept of maintenance waste barrels to ensure occupational and radiation safety during the final disposal facility's long operating phase. Table 4-6 presents the environmental aspects of the power plant's extended operation in terms of operational waste.

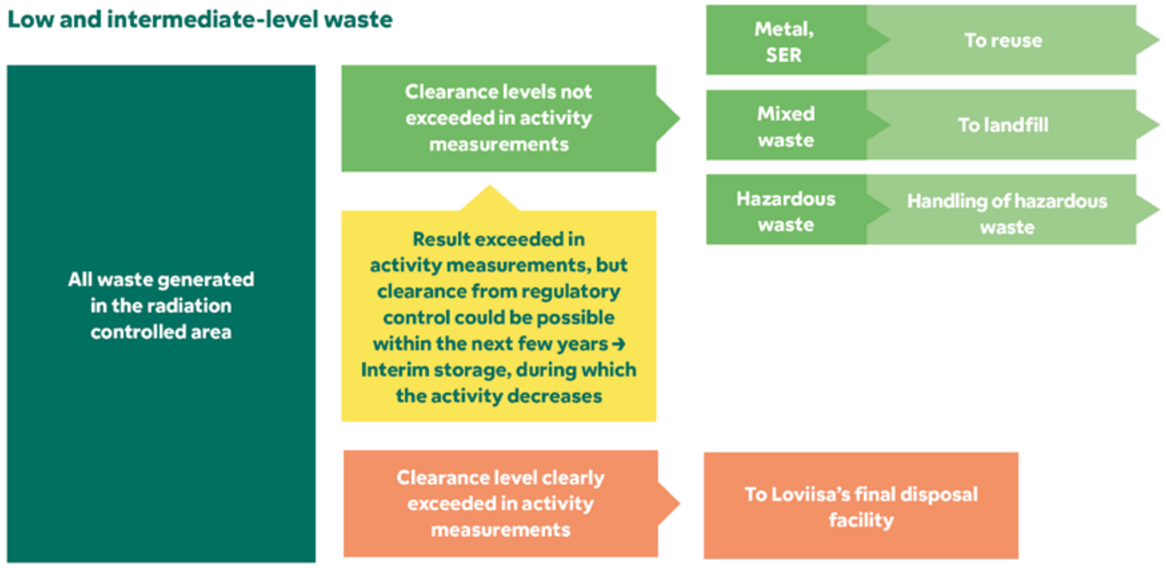

Figure 4-10. Breakdown of maintenance waste into waste to be cleared from regulatory control and waste to be deposited for final disposal.

4.7.1 Waste management principles

The basis of nuclear waste management is to permanently isolate the waste from human habitation. According to the Nuclear Energy Act (990/1987), nuclear waste must be handled, stored and permanently disposed of in Finland. The Nuclear Energy Decree (161/1988) further defines the nuclear waste to be permanently disposed of in Finnish ground or bedrock. More specific requirements are set for the final disposal of nuclear waste are set in STUK's Regulation on the Safety of Disposal of Nuclear Waste (Y/4/2018) and in STUK's YVL Guides (nuclear safety guides).

The safety of the final disposal of nuclear waste in the bedrock is based on release barriers designed according to the waste's radioactivity. The release barriers allow for the isolation of the nuclear waste from organic nature and human habitation. The bedrock itself is one of the release barriers. Other technical release barriers may include the waste matrix (solidification product, i.e. concrete which contains waste) that binds the radioactive substances, the waste container, the buffer surrounding the waste container, the backfilling of the final disposal halls and the closing structures of the disposal facility.

The final disposal of nuclear waste is planned and implemented so that it does not require continuous supervision of the final disposal location to ensure long-term safety after the halls have been closed. Long-term safety refers to the safety following the closure of the L/ILW repository, in which the primary objective is to limit the radiation exposure caused by the waste to people living in the vicinity of the repository and other living beings. According to international and Finnish surveys, the necessary nuclear waste management measures can be implemented in a controlled and safe manner.

4.7.2 Quantity and quality

4.7.2.1 Low-level waste

The majority of the radioactive waste generated in the power plant's radiation controlled area is low-level waste. This applies to both the power plant's current operations and any potential extension of operation. This waste consists primarily of maintenance waste (including insulation materials, old work clothing, machine and equipment parts, used tools and packaging materials).

The low-level maintenance waste generated in the radiation controlled area is pre-sorted in the location where it is generated. It is then sorted in separate waste handling halls and, with the exception of scrap metal fit to be cleared from regulatory control, is packed in conventional 200-litre steel barrels. The barrels' level of radioactivity is analysed with a gamma spectrometer. The activity of scrap metal fit to be cleared from regulatory control is verified with several consecutive manual measurements and the radiation measuring devices of vehicles. Based on the activity content, the maintenance waste is either deposited for final disposal in the final disposal halls built for it in the L/ILW repository or cleared from regulatory control pursuant to the Nuclear Energy Act when its activity is below the clearance limits set by STUK (Figure 4-10). The waste can also be placed in interim storage in the power plant area's storage locations before final disposal or clearance from regulatory control.

Only about a quarter of the barrels of maintenance waste filled in the radiation-controlled area during a year ends up in final disposal, and the remainder can be cleared from

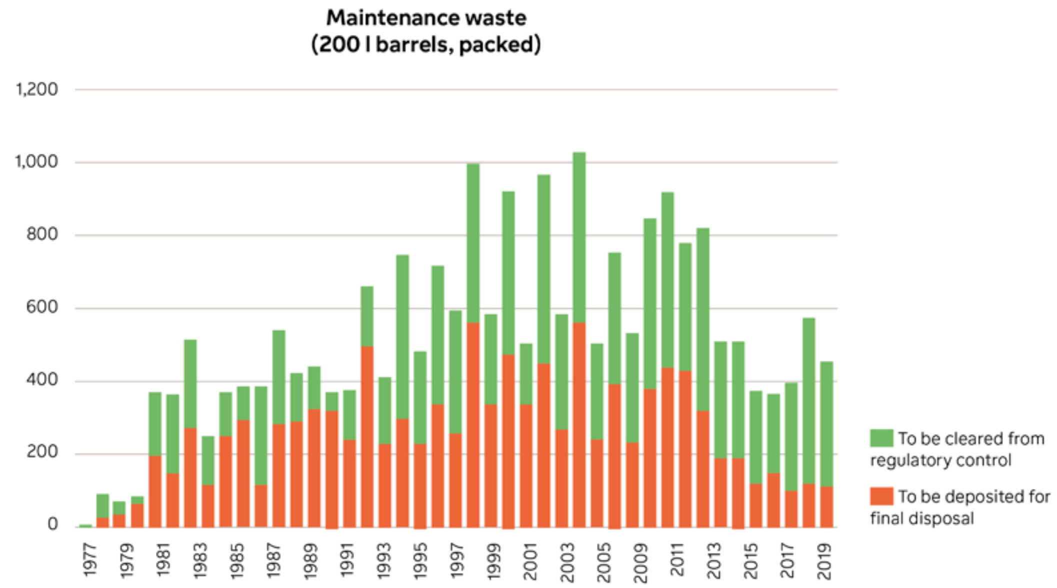

Figure 4-11. The number of waste barrels generated at Loviisa power plant divided by the barrels cleared from regulatory control and deposited for final disposal in 1977–2019.

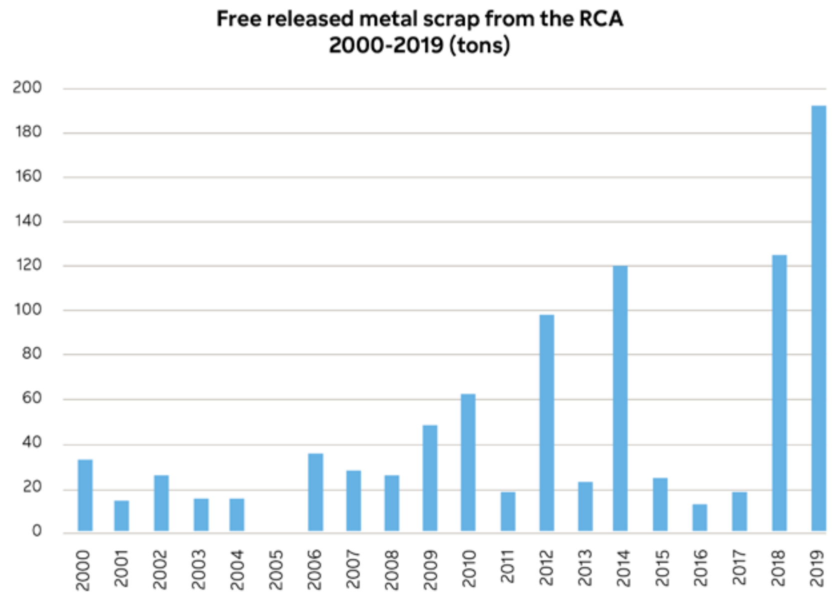

Figure 4-12. Amount of scrap metal cleared from regulatory control in 2000–2019.

regulatory control (Figure 4-11). In recent years, a little more than a hundred barrels have ended up in final disposal. The amount of scrap metal cleared from regulatory control in recent years is shown in Figure 4-12. The annual volume of the scrap metal cleared varies greatly based on the maintenance work and equipment replacements carried out.

The accumulation rate of low-level waste to be deposited in final disposal is approximately 20–30 m³/year, and the volume that will be generated by the end of the current operating licences is roughly 2,700 m³. If the operation is extended, the annual accumulation of low-level waste would be the same as it currently is, but the total volume would grow as the service life extends. An extended operation of roughly 20 years would generate approximately 600 m³ of low-level waste, in which case its total volume would be approximately 3,300 m³. The total activity of low-level waste is of a magnitude less than 1 terabecquerel (TBq).

Waste to be cleared from regulatory control is handled as conventional waste and sent for processing outside the power plant (Chapter 4.8).

4.7.2.2 Intermediate-level waste

The intermediate-level waste generated at the power plant is primarily liquid radioactive waste generated in the radioactive process and sewer networks during the power plant's operation. Liquid waste includes the ion-exchange resins used to clean the process systems, the evaporation concentrate of sewage waters, and various types of sludge and precipitate generated in the cleaning of containers, for example. The current accumulation rate of intermediate-level waste is 15–30 m³ a year, and when solidified and packed, their volume is 60–120 m³ a year. The total volume of intermediate-level waste that will be generated by the end of the current operating licences is approximately 4,900 m³. If the operation is extended, the annual accumulation of intermediate-level waste would be the same as it currently is, but the total volume would grow as the service life extends. An extended operation of roughly 20 years would generate approximately 2,400 m³ of intermediate-level packed waste, i.e. approximately 7,300 m³ in total. The total activity of intermediate-level waste is of a magnitude of 10–100 TBq.

Liquid radioactive waste is initially placed in interim storage in the liquid waste storage, which houses eight 300 m³ storage tanks. The treatment of the power plant's process and sewage water generates a liquid evaporation concentrate. The radioactive caesium in the evaporation concentrate is separated with the selective CsTreat® ion-exchange mass. The activity concentration of the purified evaporation concentrate after the separation is sufficiently low to allow its discharge into the sea; the caesium separation filters are transferred to the solidification plant, where they are packed in a concrete final disposal container intended for the filters. Liquid waste to be solidified – such as ion-exchange resins and the bottom set beds of the evaporation concentrate tanks – will be transferred via piping from the liquid waste storage to the solidification plant. At the solidification plant, liquid radioactive waste is mixed, in the final disposal container made from reinforced concrete, with cement, blast furnace slag and additives into a firm solidification product. The end product of this process is a solid waste container, in which the radioactive substances are bound in a solid waste matrix, which slows down the release of the radioactive substances. Solid waste containers are also easier and safer to handle, store, transport and deposit for final disposal than liquid non-solidified waste. A simplified diagram depicting the handling of liquid waste is shown in Figure 4-13.

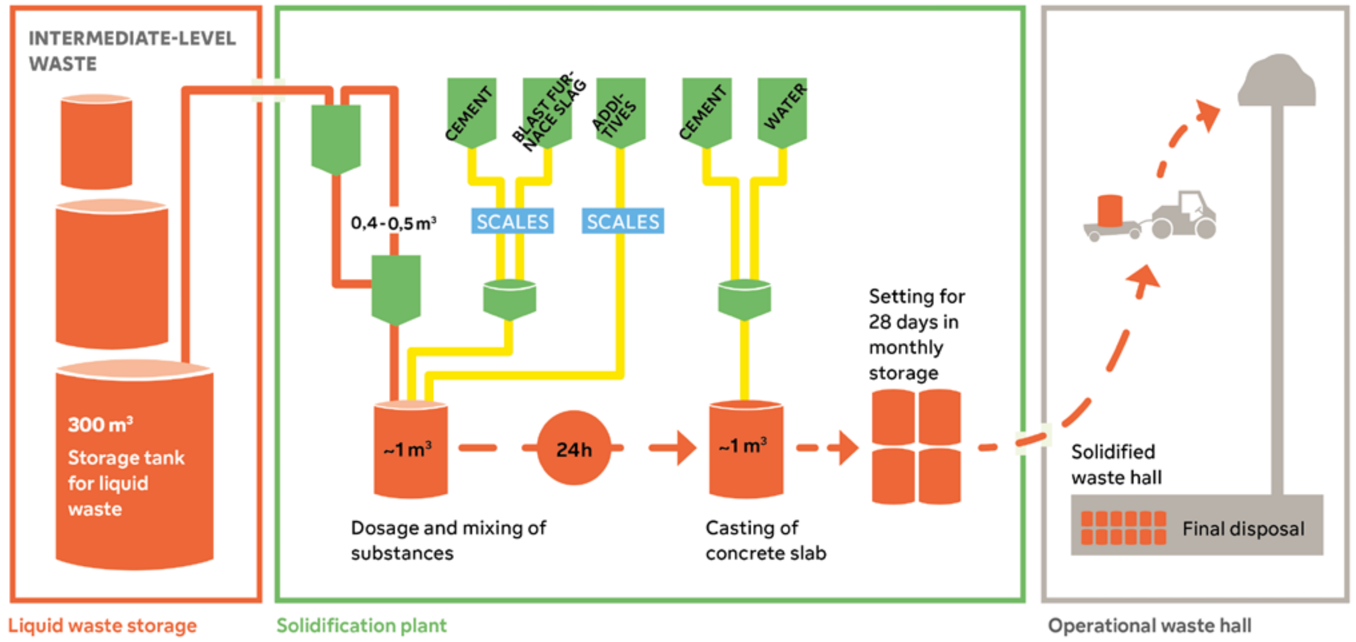

Figure 4-13. Handling of liquid waste.

4.7.2.3 Other radioactive waste

In addition to the liquid waste and maintenance waste described above, small quantities of other radioactive waste are generated in the radiation controlled area, including various filters and intermediate-level dry waste. This waste is handled according to the methods designed for each type of waste concerned, and it is deposited for final disposal in the L/ILW repository.

Very small quantities of waste containing uranium have also been generated during the operation of the power plant (such as certain measuring instruments used in reactor control), which have not been deposited in the L/ILW repository for final disposal so far. A permit for the final disposal of this waste in the L/ILW repository can also be applied for in connection to the licensing process of the final disposal facility.

4.7.3 Final disposal

The final disposal facility for the low and intermediate-level waste of Loviisa power plant (the L/ILW repository, see Chapter 1.3.4.7) currently contains three equipped spaces in the bedrock for maintenance waste and one for solidified waste. The L/ILW repository's capacity is also sufficient for the final disposal of the low and intermediate-level waste generated during the extended operation.

Figure 4-14. Barrels of maintenance waste stacked in a final disposal hall.

Figure 4-15. The transfer of the first solidified waste container into the concrete basin in the solidified waste hall in December 2019.

The L/ILW repository was issued with an operating licence in 1998, when the final disposal of dry maintenance waste packed in steel barrels began (Figure 4-14). At the end of 2019, the facility contained approximately 10,000 barrels, or about 2,000 m^3 of maintenance waste. The final disposal of solidified liquid waste began in late 2019 (Figure 4-15).

If the operation of the power plant is extended, the waste management methods will remain primarily the same as those currently used.

The low and intermediate-level waste containers from the power plant to be deposited for final disposal are transferred from the power plant's facilities to the L/ILW repository in batches. The transfer to the L/ILW repository is carried out with tractor-pulled transport platforms. The maintenance waste is taken to the maintenance waste halls reserved for it in the L/ILW repository. In two of the maintenance waste halls, the maintenance waste barrels are stacked with the help of forklifts. The stacks are supported with plywood boards. The third maintenance waste hall allows for the use of individual barrel racks that can be lifted with a gantry crane. The solidified waste containers are deposited in the concrete basin for solidified waste built into the bedrock; the basin's walls are 60 cm thick. The waste containers are lowered into the basin with the help of a bridge crane, and the space between the waste containers is filled with a cement-based casting.

The most significant change in waste management measures related to the extension of operation is the change made to the final disposal concept for maintenance waste packed in barrels. The investigations initiated in respect of this review various alternative solutions, such as the use of concrete containers as part of the waste barrels' final disposal concept. Originally, the final disposal concept of the maintenance waste had been planned for an operating phase clearly shorter than currently planned. The conceptual change will serve to ensure contamination control and the sufficient stability of the stacks of maintenance waste barrels in terms of occupational safety during a longer operating phase than previously. The conceptual change will not have a material impact on the long-term safety of final disposal.

During a long service life, the radioactivity of the maintenance waste in the final disposal halls will also decrease as a result of radioactive decay, which means that a long service life can also allow for a significant portion of the maintenance waste to be cleared from regulatory control and handled as conventional waste.

The L/ILW repository's emissions are monitored by measuring the activity of the exhaust air and any possible water that has seeped onto the floors of the waste halls. If any significant activity is observed in such waters, they can be purified separately. However, it is rare for water to seep onto the floors of the waste halls, and there has been no need for its purification during the L/ILW repository's operating history. Instructions for the L/ILW repository's maintenance, ageing management and monitoring are given in the power plant's instructions. These include regular inspection rounds, as well as a number of measurements involving rock mechanics, groundwater chemistry and hydrology.

The L/ILW repository is intended to be closed after all low and intermediate-level waste generated in the Loviisa power plant area (including decommissioning waste) has been deposited there. The closure is described in more detail in Chapter 5.5. Long-term safety cases in accordance with STUK's requirements have been prepared for the L/ILW repository during all stages of its lifecycle, most recently in 2018. The cases are used to demonstrate that the long-term safety impacts are at an acceptable level after the final disposal facility is closed.

Table 4-7. The environmental aspects of the power plant's extended operation in terms of conventional waste.

Environmental aspect	Current operation of the power plant	Extending operation
	Conventional waste	
Conventional waste	400–1,000 t/year, of which a maximum of 15% is deposited in a landfill, and the rest is reused.	No major changes.
Hazardous waste	20–100 t/year	No major changes.

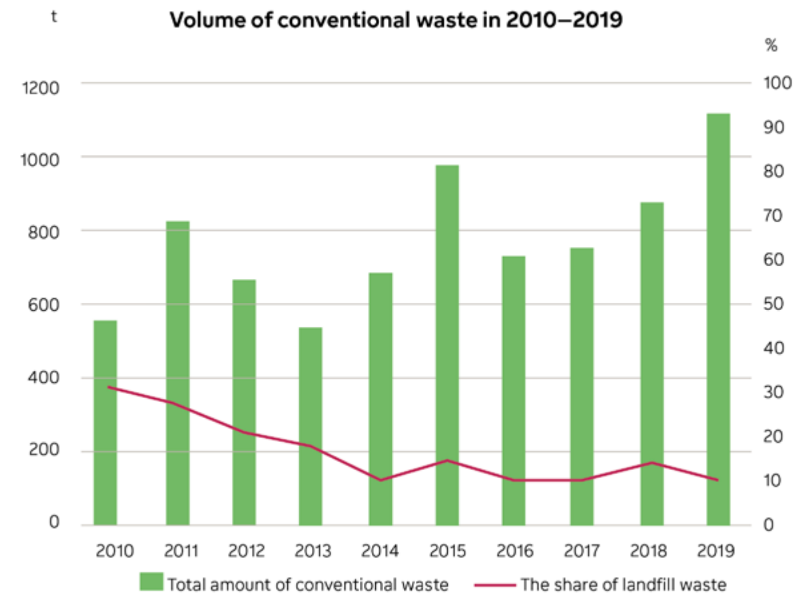

Figure 4-16. Total volume of Loviisa power plant's conventional waste and share of landfill waste in 2010–2019.

4.8 CONVENTIONAL WASTE

A nuclear power plant, like other industrial plants, generates conventional waste (for example, paper, plastic and food waste, as well as scrap metal) and hazardous waste (such as fluorescent tubes and waste oils), which is not radioactive. An extension to the power plant's operation would not especially change the annual volume of conventional waste generated. As today, waste volumes could vary from one year to the next, depending on the construction, maintenance or repair work carried out in the power plant area, for example. Table 4-7 presents the environmental aspects of the power plant's extended operation in terms of conventional waste.

Most of the conventional waste is reused as materials or energy, and only a small portion of the waste generated annually ends up in a landfill (Figure 4-16). The annual waste quantities vary, depending on the scope of work carried out in the annual outage. Waste is managed as required by the power plant's environmental permit. Conventional waste is handled in the same manner as corresponding waste elsewhere in the industrial sector.

Table 4-8. The environmental aspects of the power plant's extended operation in terms of chemicals.

Environmental aspect	Current operation of the power plant	Extending operation
	Chemicals	
Use and storage	The industrial handling and storage of chemicals at Loviisa power plant is extensive. Loviisa power plant is a facility that is subject to a safety assessment as defined in the decree on the industrial handling and storage of hazardous chemicals (855/2012). The obligation is based on hydrazine (use approximately 2 t/year).	The annual storage and usage volumes of the chemicals would remain unchanged. It is possible for some chemicals to be replaced by others (for example, hydrazine with a less harmful substance/substances).

Table 4-9. The current annual usage and storage volumes of Loviisa power plant's key chemicals.

Chemical	Average amount used per year	Storage volume, maximum
Ammonia	0.2 t	0.5 t
Ammonia water, 24.5%	6.5 t	16 t
Boric acid	4 t	135 t
Hydrazine, 35%	2 t	5 t
Light fuel oil	260 t	595 t
Sodium hydroxide, 50%	55 t	50 t
Sodium hypochlorite, 10–15%	1 t	1.6 t
Polyaluminium chloride, 30–40%	9 t	15 t
Sulphuric acid, 98%	25 t	28 t
Nitric acid, 60%	5 t	19 t
Hydrogen	2.5 t	0.25 t

4.9 CHEMICALS

Loviisa power plant uses various chemicals in the production of process water and the regulation of water chemistry, for example. The usage and storage volumes of the chemicals will remain at their current levels even if the operation is extended.

Fortum monitors research concerning the water chemistry of nuclear power plants and industry operational experiences. As knowledge and operational experiences increase, it is possible that the chemicals used in the process systems during the extended operation will be replaced by less harmful ones, or that the water chemistry in terms of the corrosion conditions will be improved. Table 4-8 presents the environmental aspects of the power plant's extended operation in terms of chemicals.

The industrial handling and storage of chemicals at Loviisa power plant is extensive. Loviisa power plant is an institution subject to a safety assessment as defined in the decree on the industrial handling and storage of hazardous chemicals (855/2012). An institution subject to a safety assessment is obligated to prepare a safety assessment and submit it to the Finnish Safety and Chemicals Agency (Tukes). Among other things, the safety assessment reviews any major accident hazards caused by hazardous chemicals and the preparedness for them. The obligation is based on the quantities and properties of the chemicals. The obligation to prepare the safety assessment at Loviisa power plant is based on the use of hydrazine, which is classified as a toxic chemical hazardous to the environment.

Chemicals are used in the production of process water and to regulate the water chemistry of the plant's various systems. In addition, chemicals are used to clean the equipment and pipelines, process the exhaust gases of the primary system and produce ice for the reactor building's ice condensers.

The process chemicals used most are ammonia water, hydrazine, boric acid, sodium hydroxide, nitric acid and sulphuric acid. The annual usage and storage volumes of the key chemicals currently in use are shown in Table 4-9.

Ammonia water is used at the power plant to regulate the pH of water in the primary and secondary systems. In the primary system, ammonia water is also used to create reducing conditions. If the operation is extended, the usage volumes of ammonia water would remain unchanged, but it is possible for ammonia water to be partially replaced by another alkalising chemical such as ethanolamine.

Among other things, hydrazine is used as an oxygen removal chemical for process water to prevent corrosion. The use of hydrazine at the power plant takes place through closed systems. For now, hydrazine cannot be replaced by other chemicals, but Fortum is supporting a study that aims to find a safer and less harmful chemical that might replace hydrazine. Such replacements would be less harmful inorganic and organic compounds.

Boric acid is used for reactor power (reactivity) control. Sodium hydroxide and nitric acid are used to regulate the pH of both process waters and wastewaters. The unloading of sodium hydroxide and nitric acid, which are deliveresd in tank trucks, takes place at the unloading point for chemicals, where it is unloaded directly into the TB station's 14.35 m^3 storage tanks equipped with overfill protectors. The tanks are located within containment pools.

Sulphuric acid and sodium hydroxide are used for the regeneration of ion exchangers and to regulate the pH of wastewaters. Sulphuric acid is delivered to the power plant by tank trucks, and is stored in 15 m^3 tanks of the water demineralising plant. Sulphuric acid is unloaded at the unloading point for chemicals directly into storage tanks with overfill protectors. The tanks are located within containment pool.

Table 4-10. The environmental aspects of the power plant's extended operation in terms of noise, vibration, traffic and conventional emissions into air.

Environmental aspect	Current operation of the power plant	Extending operation
	Chemicals	
Noise and vibration	The power plant's most significant sources of noise consist of the transformers, ventilation equipment, ejectors and traffic. The testing of safety valves during annual outages.	No major changes, but temporary noise and vibration may be caused by potential modification and construction work.
Traffic	The average daily traffic to the power plant is approximately 500 vehicles, of which approximately 40 are heavy-duty vehicles. Annual outages increase traffic volumes temporarily to a maximum of about 1,000 vehicles per day, of which a maximum of 100 are heavy-duty vehicles.	No major changes, but potential construction work may occasionally increase traffic volumes, particularly of heavy-duty vehicles.

Polyaluminium chloride and sodium hypochlorite are used in purifying raw water into domestic water and further on to process water, for example. If the operation is extended, the usage volumes of the water plant chemicals would remain unchanged.

The power plant's processes also rely on flammable liquids and gases. Hydrogen is used in the cooling of the rotors of the turbines' generators, whereas ammonia is used as a cooling agent and a regulator of process water pH.

Light fuel oil is used in the power plant's diesel generators and engines. Light fuel oil is primarily stored in 120–130 m^3 tanks.

In addition, the power plant uses a number of other chemicals in line with its chemicals permit.

Solid chemicals are stored in their original containers in a separate chemical storage. Liquid chemicals are stored primarily in the process facilities, in barrels or containers, or in storage tanks. Any liquid chemical spills are collected in containment basins and tanks. The unloading points for chemicals are also furnished with containment tanks.

4.10 CONSTRUCTION WORK AS WELL AS NOISE, VIBRATION AND TRAFFIC

The potential new additional buildings to be constructed in the power plant area during the extension of the power plant's operation include a cafeteria building in the vicinity of the office building, an inspection or reception warehouse, a wastewater treatment plant, a storage hall for waste, and a welding hall. These buildings would be located in areas already built or would replace old buildings, meaning that there would be no need for new areas to be built on the island of Hästholmen.

If the operation is extended, the noise, vibration and traffic would be similar to their current levels. Only potential modification and construction work could result in temporary noise and vibration; they could also occasionally increase the volume of traffic. Table 4-10 presents the environmental aspects of the power plant's extended operation in terms of noise, vibration and traffic.

4.10.1 Noise

In the current operation, as would be the case in extended operation, the power plant's most significant sources of noise include the transformers and ventilation equipment which, according to observations made during the measurements, emit a steady subdued drone or hum. In addition, the power plant's ejectors generate a cyclic sound. The testing of the main steam system's safety valves carried out once a year before the annual outage is an exception to this rule.

The noise in the power plant's surroundings has been surveyed with environmental noise measurements, in which the environmental noise at the measuring points has been at most on a par with the nighttime (40 dB) and daytime (45 dB) limit values.

4.10.2 Vibration

The operation of the power plant units causes no vibration that can be detected by human senses outside the power plant area. The only source of vibration in the power plant's immediate surroundings is the power plant's traffic. In the current situation, the vibration caused by traffic in the environment has not been measured, but it is estimated to be minimal, based on the traffic and soil data. Temporary vibration may be caused by potential modification and construction work during the extended operation.

4.10.3 Traffic

The power plant's traffic during current operation consists primarily of commuting and maintenance traffic, as well as transports of fresh nuclear fuel, various pieces of equipment, chemicals, fuel oil, gases and waste management. This would also apply to the power plant's extended operation. The chemicals and fuel oil related to the power plant operations are transported to the power plant by road, in the same manner as other goods transports. In the power plant area, transports follow a guided transport route.

Table 4-11. The environmental aspects of the power plant's extended operation in terms of conventional emissions into the air.

Environmental aspect	Current operation of the power plant	Extending operation
Conventional emissions into the air	Diesel generators and engines: some nitrogen oxide, carbon dioxide, sulphur dioxide and particulate emissions attributable to periodic testing.	The diesel generators' and engines' emissions into the air will remain at the current level.

Most of the commuter traffic is by passenger cars, but buses are also used. The power plant has around 500 permanent employees and approximately 100 subcontractors working in the area on a permanent basis. In addition, annual outages and projects employ around 700–1,300 contractor employees every year, depending on the scope of any given project or outage. The average daily traffic to the power plant is approximately 500 vehicles, of which approximately 40 are heavy-duty vehicles. Annual outages increase traffic volumes temporarily to a maximum of about 1,000 vehicles per day, of which a maximum of 100 are heavy-duty vehicles.

4.11 CONVENTIONAL EMISSIONS INTO THE AIR

In exceptional situations, the power supply of Loviisa power plant is secured by diesel generators and engines.

The diesel generators and engines in the power plant area generate emissions into the air, i.e. in practice, carbon dioxide, nitrogen oxide, sulphur oxide and particulate emissions. The use of the generators and engines is limited to test runs and is therefore extremely minor. The emissions of the emergency diesel generators and the diesel-powered emergency power plant are calculated according to the consumption of light fuel oil and reported annually to the environmental protection authorities. The average emissions of the emergency diesel generators and the diesel-powered emergency power plant are low. In 2014–2020, the average annual carbon dioxide emissions amounted to approximately 724 tonnes, while the equivalent figures for nitrogen oxides, sulphur oxides and particulate emissions were approximately 19.4 tonnes, 0.46 tonnes and 0.023 tonnes, respectively.

Table 4-12. The environmental aspects of the power plant's extended operation in terms of the emissions of radioactive substances. The numerical values of the power plant's current emissions are based on the actual emissions in 2009–2019.

Environmental aspect	Current operation of the power plant	Extending operation
Radioactive emissions into the air	Noble gases (Kr-87eq.): range: 4.7-8 TBq/year average: 5.8 TBq/year *The emission limit is 14,000 TBq/year*	No major changes.
	Iodines (I-131eq.): range: 0.0000002–0.00005 TBq/year average: 0.00001 TBq/year *The emission limit is 0.22 TBq/year*	No major changes.
	Aerosols*) range: 0.00003-0.0008 TBq/year average: 0.00014 TBq/year	No major changes.
	Tritium (H-3)*) range: 0.1-0.4 TBq/year average: 0.2 TBq/year	No major changes.
	Carbon-14 (C-14)*) range: 0.3-0.5 TBq/year average: 0.4 TBq/year	No major changes.
Radioactive discharges into the sea	Tritium (H-3) range: 13-21 TBq/year average: 16.0 TBq/year *The emission limit is 150 TBq/year*	No major changes.
	Other fission and activation products range: 0.0001-0.002 TBq/year average: 0.0006 TBq/year *The emission limit is 0.89 TBq/year*	No major changes.

**) No separate emission or discharge limit has been defined for the emission or discharge type.*

Table 4-13. Emissions into the air in 2009-2019.

Emission of discharge type	Maksimum [GBq]	Maximum's share of the emission limit [%]	Minimum [GBq]	Average [GBq/a]
Noble gases	8.0E+03 (2009)	0.06	4.7E+03 (2018)	5.8E+03
Iodine	4.8E-02 (2010)	0.02	2.3E-04 (2012)	1.0E-02
Aerosols	8.4E-01 (2013)	-	2.6E-02 (2019)	1.4E-01
Tritium	4.4E+02 (2009)	-	1.3E+02 (2014)	2.0E+02
Carbon-14	4.6E+02 (2013)	-	3.2E+02 (2010 ja 2011)	3.7E+02

In addition to the aforementioned, there are small diesel generators in the power plant area for a severe reactor accident, and small diesel generators in the auxiliary emergency feedwater system and in the fire water pumping station. These consume very little fuel compared to the emergency diesel generators and the diesel-powered emergency power plant.

The power plant's transports and passenger traffic cause exhaust emissions into the air. Any modification and construction work to be carried out in the area may cause local dust. Table 4-11 presents the environmental aspects of the power plant's extended operation in terms of conventional emissions into the air.

4.12 EMISSIONS OF RADIOACTIVE SUBSTANCES AND THEIR LIMITATION

A nuclear power plant generates radioactive substances during its operation. Small quantities of radioactive substances are released into the air and sea in a controlled manner in compliance with the criteria set in legislation, and the licences and regulations concerning the operations. The quantity of the radioactive substances to be released into the environment is effectively limited by delaying and filtering the emissions. The radioactive emissions generated in the normal operation of Loviisa power plant would remain at their current level during the extended operation. Table 4-12 presents the environmental aspects of the power plant's extended operation in terms of the emissions of radioactive substances.

The power plant's emissions of radioactive substances into the air and sea are constantly monitored. Loviisa power plant's radioactive discharges into the sea and emissions into the air have amounted to a fraction of the limits set for them. The impact of the emissions on the people in the vicinity and the surrounding environment is minimal (see Chapter 9.15.5).

4.12.1 Emissions into air

The power plant's radioactive emissions into the air during operation largely consist of noble gases, aerosols, halogens and gaseous activation products. Most of the radionuclides released into the environment are short-lived and are only detected occasionally in the immediate vicinity of the power plant during environmental radiation monitoring.

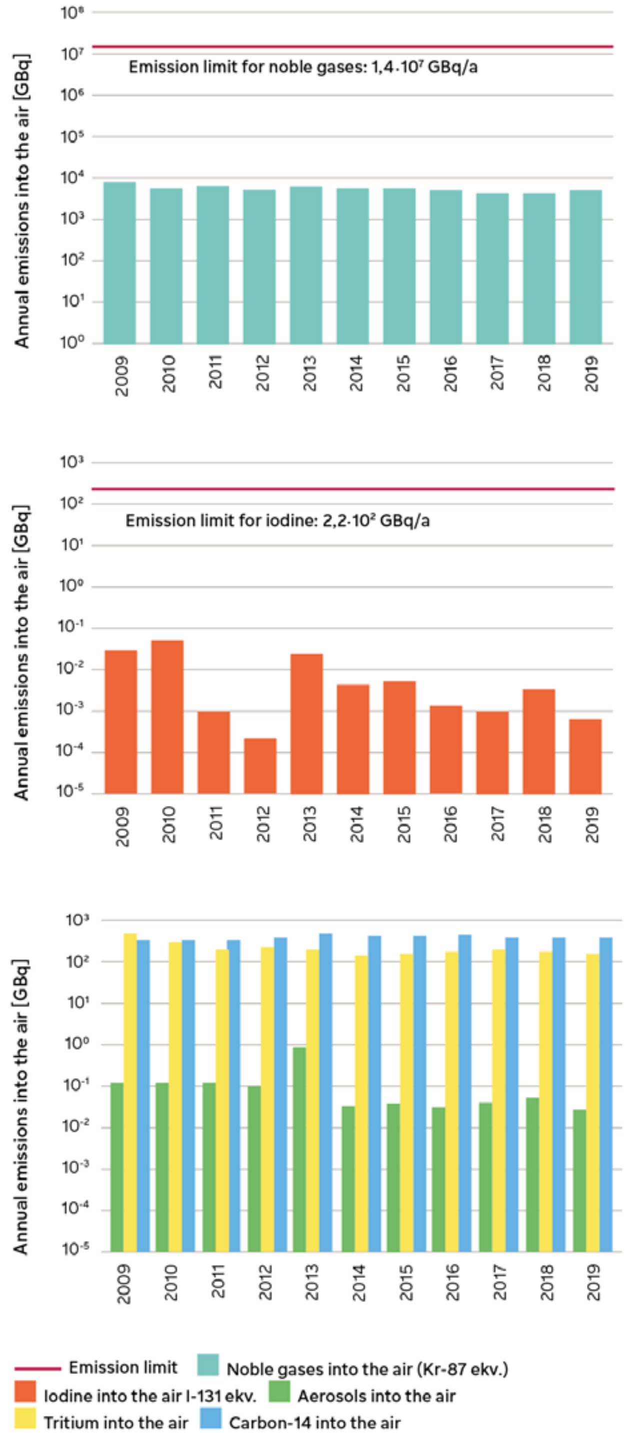

Figure 4-17. Loviisa power plant's radioactive emissions into the air in 2009–2019, and the emission limits for noble gases and iodine.

In the processing of the radioactive gases generated in the power plant, the gases are collected, filtered and delayed to reduce radioactivity and limit emissions. Gases containing small amounts of radioactive substances are released into the air through the vent stack in a controlled manner and to a height of more than 100 metres, where the gases are mixed and diluted into the atmosphere.

Loviisa power plant's radioactive emissions into the air in 2009-2019 and the emission limits are presented in Figure 4-17. The emission limits have been set for emissions of

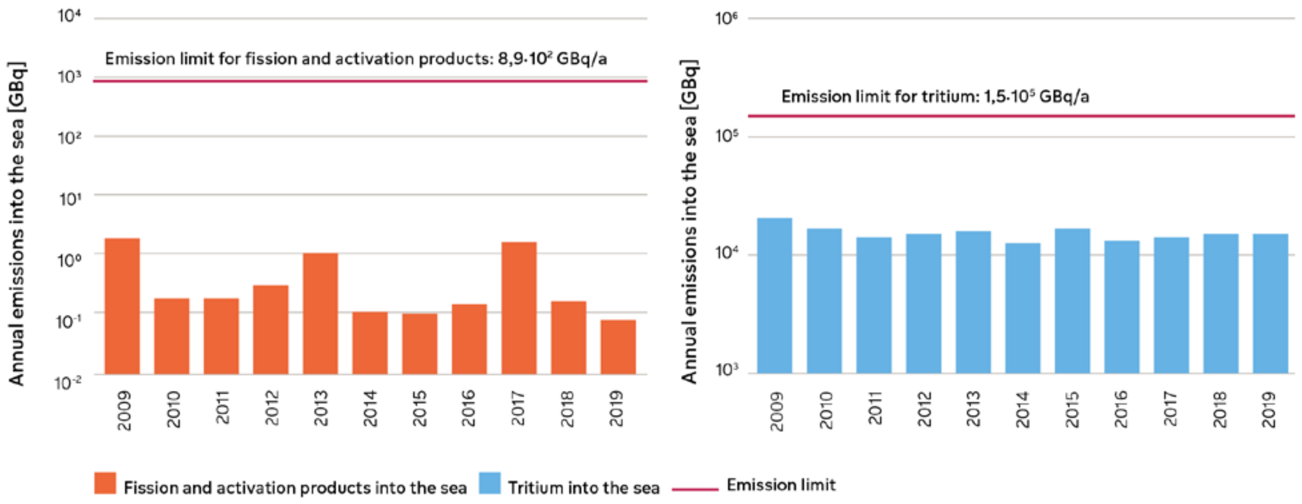

Figure 4-18. Loviisa power plant's radioactive discharges into the sea in 2009–2019 and the emission limits for tritium as well as for fission and activation products.

Table 4-14. Discharges into the sea 2009-2019

Emission or discharge type	Maximum [GBq]	Maximum's share of the emission limit [%]	Minimum [GBq]	Average [GBq/a]
Tritium	2.1E+04 (2009)	13.8	1.3E+04 (2018)	1.6E+04
Fission and activation products into the sea	1.9E+00 (2009)	0.22	1.0E-01 (2012)	0.6E+00

noble gases and iodine, the quantities of which can be influenced through delay and filtering measures. The quantities of the other types of emissions are proportional to the power plant's energy production, which is why their quantities cannot be influenced to any significant extent. At their highest, the emissions of radioactive noble gases into the air from the power plant in 2009-2019 were approximately 0.06% of the emission limit (in 2009), and iodine emissions were approximately 0.02% of the emission limit (in 2010). The power plant's radioactive emissions into the air have remained significantly below the emission limits set for them.

4.12.2 Discharges into water systems

The power plant's radioactive discharges into the sea during power operation consist primarily of process water discharges, sewage water from the radiation controlled area, waste-water from the washing of the protective clothing used in the radiation controlled area, and the discharges of the purified evaporation concentrate. Before their controlled discharge into the sea, the waters are treated and delayed to reduce radioactivity and limit emissions. The activity is measured, and discharging is only allowed when the activity remains below the limits set by the authorities. The water that contains small quantities of radioactivity to be released into the sea in a controlled manner from the power plant is mixed with the cooling water flow in the cooling water discharge channel and diluted considerably.

Loviisa power plant's radioactive discharges into the sea in 2009-2019 and the emission limits are presented in Figure 4-18. At their highest, the power plant's emissions of tritium (H-3) into the sea in 2009-2019 were approximately 14% of the emission limit, and the emissions of other fission and activation products were approximately 0.2% of the emission limit (in 2009). Thus, the power plant's radioactive discharges into the sea have been significantly below the limits set for them.

Improvement measures that aim to reduce the radiation doses to which residents in the surrounding area are exposed have been carried out at Loviisa power plant. One of the most significant of these measures is the adoption of the caesium-separation method for the treatment of liquid waste. The method allows a significant portion (typically, more than 99%) of the caesium in the low-level surface waters of the liquid waste storage's evaporation concentrate tanks to be removed before discharge. The waters from which caesium has been separated are usually discharged at approximately three to four-year intervals, and even then, the emissions remain significantly below the emission limits. In Figure 4-18, the discharges of fission and activation products in 2009, 2013 and 2017, which are slightly higher than in other years, are a result of the planned discharge of the evaporation concentrate from which caesium has been separated.

4.12.3 Best available technique

Improvement measures that aim to reduce the radiation doses to which residents in the surrounding area are exposed have been carried out at Loviisa power plant. Loviisa power plant monitors the development of technology, and in accordance with the principle of continuous improvement, measures that aim to reduce emission quantities would also be carried out during the power plant's extended operation. Technological advances are also monitored at Loviisa power plant to ensure the implementation of the BAT (best available technique) principle. In connection with limiting emissions, the premise of the BAT principle is to make use of technically and economically feasible best available techniques which can be implemented at a reasonable cost. However, the pursuit of the BAT principle must also account for the broader perspective of the ALARA (as low as reasonably achievable) principle, which aims to optimise radiation protection. According to the ALARA principle, any review of different technologies must, in addition to the radiation exposure of residents in the surrounding area, account for the radiation exposure of the power plant's employees, and any project's feasibility will depend on the overall picture formed on their basis.

During 2010–2019, the calculated annual radiation dose caused by the radioactive emissions of Loviisa power plant to residents in the surrounding area was 0.00014...0.00029 mSv. The average annual radiation dose of a person who resides in Finland, calculated according to STUK's 2018 data, is approximately 5.9 mSv. Therefore, approximately 0.002...0.005% of the annual radiation dose of a resident in the surrounding area of Loviisa power plant in 2010–2019 was caused by the power plant's operations. This demonstrates that Loviisa power plant's emissions of radioactive substances are already at a very low level. This also means that any further reduction of the emission quantities will require continuously greater measures, while the benefits to be gained from them will not necessarily be very significant. Furthermore, depending on the approach or technique, even a small reduction in the radiation dose of residents in the surrounding area may increase the radiation doses of the power plant's employees. If this occurs, the situation must be viewed from the perspective of the ALARA principle.

Numerous projects that aim to limit emissions and reduce te radiation doses of employees have been carried out during the operating history of Loviisa power plant in accordance with the BAT principle. Examples of these include replacing the silver discs in the safety valves of the primary treatment system for the primary system's discharge waters with silver-free rupture discs (silver which, when activated, turns radioactive, no longer ends up in the primary system) and replacing the antimony-containing seals of the primary coolant pumps with antimony-free seals (reduces the amount of activating antimony and thereby the personnel's radiation doses and radioactive emission attributable to it). Loviisa power plant is planning or presently conducting the following projects in accordance with the BAT principle, with the aim of limiting emissions and discharges:

- an investigation that aims to map the emission reduction improvements of the treatment system for active gases;
- an investigation of leading the analysers' discharge waters behind the sewer line's drain tap to reduce the arsenic-76 isotope emissions into the air;
- a renewal of the fume cupboards in the primary system's sampling;
- removing the source of silver in the sealing water lines of the primary coolant pumps.

4.13 SUMMARY OF THE ENVIRONMENTAL ASPECTS OF EXTENDING OPERATION

Table 4-15 shows a summary of the environmental aspects of the extension of the power plant's operation.

Table 4-15. Summary of the environmental aspects of extending the operation.

Environmental aspect	Current operation of the power plant	Extending operation
Cooling water		
Consumption and thermal load of cooling water	Consumption, on average, 1,300 million m^3 (max. 1,800 million m^3)	No change.
	Average thermal load, 57,000 TJ (max. 60,000 TJ)	No change.
Service water requirements and supply		
Volume	Process water 100,000–200,000 m^3/year Domestic water 25,000–75,000 m^3/year	No major changes.
Intake of service water	Lappomträsket lake. The water level of Lappomträsket lake is regulated in accordance with the water permit's permit conditions.	Lappomträsket lake. The procurement of service water from the water mains system of the town of Loviisa has been investigated as an alternative. The regulation stipulations regarding Lappomträsket lake defined in the water permit will not change.
Sanitary wastewaters		
Volume	20,000 - 30,000 m^3/year An average of 60 m^3/day (max. 120 m^3/day)	No major changes.
Discharge location	The Hudöfjärden discharge point.	The Hudöfjärden discharge point or the discharge point of Loviisan Vesi's Vårdö wastewater treatment plant in Loviisanlahti bay (roughly 4 km from the power plant's discharge point).
Loads	Average total nitrogen 840 kg/year Average total phosphorus 9 kg/year In accordance with the power plant's current permit conditions: - maximum annual average of total phosphorus concentration 0.7 mg/l - maximum biological oxygen demand 15 mg O_2/l - minimum purifying efficiency 90%.	No major changes. Will remain unchanged or be accounted for in the permit conditions of the Vårdö wastewater treatment plant.
Sludge	The sludge generated in the wastewater treatment is led to the peat basins. The compost generated in this process will be used in the landscaping carried out in the power plant area.	Will remain unchanged or be transferred for treatment at the Vårdö wastewater treatment plant.
Process wastewater		
Volume	An average of 160,000 m^3/year.	No major changes.
Discharge location	Led into the cooling water channel, and via the channel and the discharge location to the Hästholmsfjärden side.	Will remain unchanged.
Loads	Average total nitrogen 800 kg/year Average total phosphorus 9 kg/year	No major changes.
Other waters led into the sea		
	Including rinsing waters, oily waters, the L/ILW repository's seepage waters, rainwaters and water in the ground, appropriately treated.	No major changes.

Environmental aspect	Current operation of the power plant	Extending operation
Nuclear fuel		
Procurement of nuclear fuel	The annual need for nuclear fuel is approximately 24 tonnes of uranium dioxide.	No change.
Spent nuclear fuel		
Fuel accumulation	The annual accumulation is approximately 168 fuel bundles. Total accumulation by the end of the current operating licences is approximately 7,700 fuel bundles.	Would not increase the annual accumulation, but the total amount would increase as the service life is extended. The number of fuel bundles that would accumulate during the extended operation (20 years) would be around 3,700, meaning that the total accumulation would be approximately 11,400, but no more than approximately 12,800 fuel bundles.
Interim storage	There are two existing storages for spent fuel.	Either the expansion of one of the two storages with two new water pools or the denser placement of fuel bundles in the water pools of the existing storages.
Operational waste		
Low-level waste	The current accumulation rate is 20–30 m^3/year. The volume to be generated by the end of the current operating licences is approximately 2,700 m^3.	The annual accumulation would be the same, but the total amount would increase as the service life is extended. An extension of roughly 20 years would generate approximately 600 m^3 of low-level waste, i.e. approximately 3,300 m^3 in total. The use of concrete vessels as part of the final disposal of maintenance waste is under investigation.
Intermediate-level waste	The current accumulation rate is 15–30 m^3/year, and when solidified and packed, 60–120 m^3/year. The volume to be generated by the end of the current operating licences is approximately 4,900 m^3.	The annual accumulation would be the same, but the total amount would increase as the service life is extended. An extension of roughly 20 years would generate approximately 2,400 m^3 of intermediate-level packed waste, i.e. approximately 7,300 m^3 in total.
L/ILW repository's capacity	Currently houses three equipped spaces in the bedrock for low-level maintenance waste and one for intermediate-level solidified waste.	The capacity is also sufficient for the final disposal of the low- and intermediate-level waste generated during the extended operation.
Chemicals		
Conventional waste	400–1,000 t/year, of which a maximum of 15% is deposited in a landfill, and the rest is reused.	No major changes.
Hazardous waste	20–100 t/year	No major changes.
Chemicals		
Use and storage	The industrial handling and storage of chemicals at Loviisa power plant is extensive. Loviisa power plant is a facility that is subject to a safety assessment as defined in the decree on the industrial handling and storage of hazardous chemicals (855/2012). The obligation is based on hydrazine (use approximately 2 t/year).	The annual storage and usage volumes of the chemicals would remain unchanged. It is possible for some chemicals to be replaced by others (for example, hydrazine with a less harmful substance/substances).

Environmental aspect	Current operation of the power plant	Extending operation
Noise, vibration and traffic		
Noise and vibration	The power plant's most significant sources of noise consist of the transformers, ventilation equipment, ejectors and traffic. The testing of safety valves during annual outages.	No major changes, but temporary noise and vibration may be caused by potential modification and construction work.
Traffic	The average daily traffic to the power plant is approximately 500 vehicles, of which approximately 40 are heavy-duty vehicles. Annual outages increase traffic volumes temporarily to a maximum of about 1,000 vehicles per day, of which a maximum of 100 are heavy-duty vehicles.	No major changes, but potential construction work may occasionally increase traffic volumes, particularly of heavy-duty vehicles.
Conventional emissions into the air		
Emissions into air	Diesel generators and engines: some nitrogen oxide, carbon dioxide, sulphur dioxide and particulate emissions.	The diesel generators' and engines' emissions into the air will remain at the current level.
Radioactive emissions		
Emissions into air	Noble gases (Kr-87eq.): range: 4.7-8 TBq/year average: 5.8 TBq/year *The emission limit is 14,000 TBq/year*	No major changes.
	Iodines (I-131eq.): range: 0.0000002–0.00005 TBq/year average: 0.00001 TBq/year *The emission limit is 0.22 TBq/year*	No major changes.
	Aerosols*) range: 0.00003-0.0008 TBq/year average: 0.00014 TBq/year	No major changes.
	Tritium (H-3)*) range: 0.1-0.4 TBq/year average: 0.2 TBq/year	No major changes.
	Carbon-14 (C-14)*) range: 0.3-0.5 TBq/year average: 0.4 TBq/year	No major changes.
Discharges into the sea	Tritium (H-3) range: 13-21 TBq/year average: 16.0 TBq/year *The emission limit is 150 TBq/year*	No major changes.
	Other fission and activation products range: 0.0001-0.002 TBq/year average: 0.0006 TBq/year *The emission limit is 0.89 TBq/year*	No major changes.

**) No separate emission or discharge limit has been defined for the emission or discharge type.*

5. VE0: Decommissioning

Option VE0 is the decommissioning of Loviisa nuclear power plant following the expiration of the current licence period. Among other things, the decommissioning is subject to a decommissioning licence pursuant to the Nuclear Energy Act. A new operating licence must be sought for the period following the end of electricity production in terms of the plant parts to be made independent (see Chapter 12). A plan for the decommissioning of Loviisa power plant has been drawn up and was updated most recently in 2018. The current decommissioning plan, drawn up according to the brownfield principle (see Chapter 5.6), applies to a decommissioning that would be carried out after the current licence period (2027/2030), covering the dismantling of radioactive plant parts, the treatment of waste and the final disposal of radioactive waste. The dismantling schedules, waste volumes, transport volumes and other quantities apply primarily to the radioactive plant parts alone and their dismantling. Measures outside the scope of the current decommissioning plan – i.e. the dismantling of plant parts which are not radioactive, or the "greenfield principle" (see Chapter 5.6) and the power plant area's further use – are discussed separately in Chapters 5.3.3 and 5.8.6.

If the power plant's operation is extended, the decommissioning plan will be updated to concern a decommissioning to be carried out later (according to Option VE1, in the 2050s). In this case, the decommissioning would be carried out primarily as described in this chapter with regard to Option VE0. Chapter 5.9 describes the key differences between Options VE0 and VE1 in terms of the implementation of decommissioning.

5.1 DECOMMISSIONING PHASES AND SCHEDULE

The decommissioning of a nuclear power plant is a regulatory activity subject to the provisions of the Nuclear Energy Act and Decree, as well as the regulations and guidelines of STUK issued by virtue of them. In Fortum's plans, decommissioning covers the dismantling of the radioactive systems, structures and components, and the final disposal of the resulting decommissioning waste. The licensing process of the decommissioning is prepared for well in advance of the commencement of the actual decommissioning work. Among other things, the decommissioning requires a decommissioning licence pursuant to the Nuclear Energy Act. In addition, it requires the application for licences for the L/ILW repository and plant parts to be made independent, the decommissioning and closure of which will take place at a later date, once the storage of the spent fuel comes to an end. The licensing process is explained in more detail in Chapter 12.

An updated version of the decommissioning plan drawn up during the period of operation is submitted to the authorities at least every six years, in accordance with the Nuclear Energy Act. The decommissioning plan for Loviisa power plant was last updated in 2018. The current decommissioning strategy is the immediate dismantling of the power plant and the final disposal of the dismantling waste. The decommissioning plan details all of the phases related to the decommissioning and the current plans concerning the phases. The plans are updated and specified gradually in accordance with the experience gained from the operation of the power plant, the comments received from and requirements set by the authorities, and the monitoring of international projects. The final decommissioning plan is submitted to the authorities for approval in good time before applying for the decommissioning licence.

The decommissioning of Loviisa power plant includes the following phases:

- preparation phase and the expansion of the L/ILW repository
- the first dismantling phase
- the operation of the plant parts to be made independent and the L/ILW repository occurring between the dismantling phases
- the second dismantling phase, which will end with the closure of the L/ILW repository.

The power plant units are decommissioned after the electricity production phase of Loviisa power plant. This decommissioning begins with a **preparation phase** that lasts for a few years. Before the electricity production ends, the L/ILW repository will be expanded for the final disposal of the decommissioning waste. The electricity production will end first in the power plant unit Loviisa 1 and approximately three years later in power plant unit Loviisa 2.

Dismantling phase 1 will be carried out after the preparation phase. It entails the dismantling of the reactor building's activated and contaminated parts. According to the current

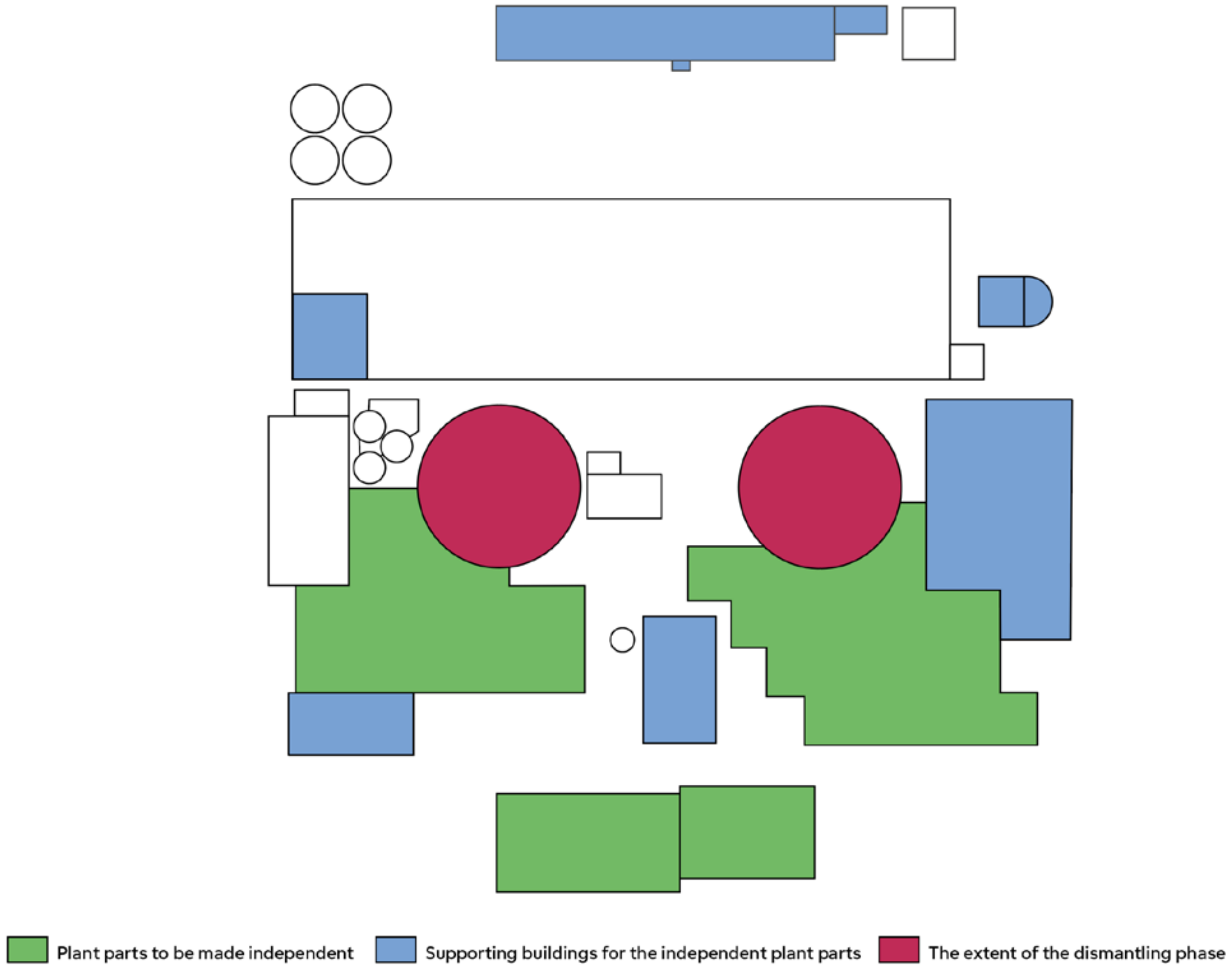

Figure 5-1. The activated and contaminated parts of the reactor buildings, marked in red, will be dismantled during dismantling phase 1, while the plant parts marked in green will be made independent. Their operation during independent operation will be supported by the buildings marked in blue.

plan, the preparation phases and the first dismantling phases will be conducted gradually in such a way that Loviisa 1's dismantling phase and Loviisa 2's preparation phase are carried out simultaneously. During and after preparation and dismantling phase 1, spent nuclear fuel will be stored in the interim storage for spent fuel. No later than before the shutdown of the Loviisa 2 power plant unit, the **plant parts** needed for the interim storage of spent fuel, the storage and solidification of liquid waste, and the final disposal of waste **will be made independent** so that they can operate safely without the power plant systems to be dismantled during dismantling phase 1. The plant parts to be made independent from the power plant are the interim storage for spent nuclear fuel, the liquid waste storage and the solidification plant as well as the necessary parts in the power plant's auxiliary buildings. Making a plant part independent refers to the separation of certain functions, such as cooling or ventilation, from the systems of the power plant units to ensure the said plant parts to be made independent can function without the power plant units. The L/ILW repository also functions as an independent facility. The plant parts to be made independent, and the plant parts and reactor buildings supporting them, the radioactive parts of which will be dismantled during dismantling phase 1, are shown in Figure 5-1.

The spent nuclear fuel is stored in the interim storage for spent fuel until the spent fuel's transport for final disposal is concluded. **Dismantling phase 2**, during which the plant parts that have been made independent are decommissioned, can be carried out once all the spent nuclear fuel has been transported for final disposal. Once the radioactive waste of dismantling phase 2 has been deposited for final disposal, the L/ILW repository will be closed permanently. For its part, the closure aims to ensure the long-term safety of the waste's final disposal.

The final detailed dismantling plans are drawn up well in advance of the beginning of the dismantling work.

Figure 5-2 depicts a tentative schedule for the dismantling phases in accordance with VE0.

During decommissioning, the personnel in the power plant area consists of Fortum's own staff and external contractors. The estimated maximum number of personnel is approximately 400 people. The need for workforce during

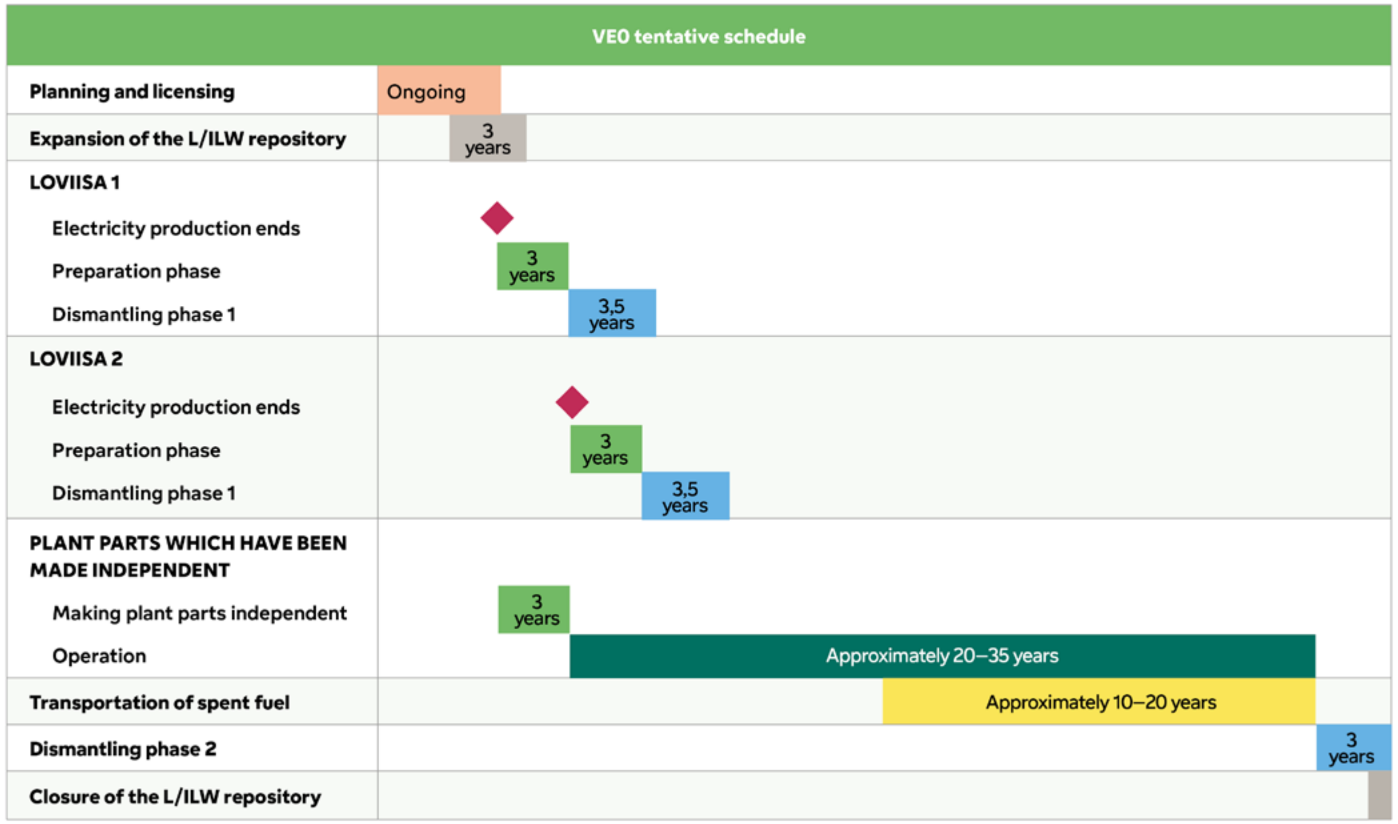

Figure 5-2. depicts a tentative schedule for the dismantling phases in accordance with VE0.

the dismantling of Loviisa's two units will equal roughly 5 million working hours, or some 3,000 person-years, divided evenly among the power plant's own personnel and contractors.

5.2 EXPANSION OF THE L/ILW REPOSITORY AND OTHER CONSTRUCTION

5.2.1 Expansion of the L/ILW repository

The L/ILW repository intended for low- and intermediate-level waste is already largely built, and houses maintenance waste and solidified waste from the period of operation. For the purposes of decommissioning waste, the L/ILW repository will be expanded with new waste halls. According to the current plan, the new waste halls required for the decommissioning waste will be built in the L/ILW repository as illustrated in Figure 5-3.

The intention is to deposit the activated waste of both power plant units (excluding the reactor pressure vessels and their internals) and part of the contaminated waste, in applicable packages, in dismantling waste hall 1 (PJT-1). The hall will also house unpacked medium-sized contaminated equipment. In the hall-like space of dismantling waste hall 1, the waste will be deposited in a concrete basin around 94 m in length, 16 m in width and 10 m deep. According to the current plans, the quarrying volume of dismantling waste hall 1 would be approximately 31,000 m^3.

Dismantling waste hall 2 (PTJ-2) will house the contaminated blocks of concrete detached from the power plant's structures in unpacked form and other contaminated waste in final disposal packages. According to the current plans, the concrete basin in the hall would be as wide and deep as the trough planned for dismantling waste hall 1, but 60 m long. The quarrying volume planned for dismantling waste hall 2 is approximately 17,000 m^3.

The pressure vessel silos will be located next to the large component hall. The silos will house the reactor pressure vessels, internals included, meaning that the pressure vessels will also serve as the final disposal packages. According to the current plans, the quarrying volume of a single silo would be around 600 m^3, and the silos would extend to a depth of 127 m below sea level. The largest components of the primary systems will be deposited in the large component hall above the silos, each in one piece. The combined volume of the large component hall and the pressure vessel silos would be approximately 9,000 m^3. The quarrying volume of the vehicle access tunnel leading to the hall and the component loading hall would be approximately 14,000 m^3 according to the current plan.

The combined volume of the expansions of the actual waste halls according to the L/ILW repository's expansion plan would therefore be 57,000 m^3, and the expansion

Figure 5-3. An illustration of the final disposal facility of Loviisa power plant for low and intermediate-level waste. In addition to the existing halls, the illustration shows the planned final disposal halls for decommissioning waste in green. In the illustration, PJT-1 and PJT-2 refer to halls 1 and 2 for dismantling waste.

volume combined with the other spaces to be quarried would be 71,000 m^3. Studies of the bedrock's suitability are still underway in the planned locations of the waste halls, which means the plan's details may still change.

The final disposal capacity of the L/ILW repository's current expansion plan has also been deemed adequate for all the waste if the power plant's service life is extended in accordance with VE1. The main reasons for this are the success achieved in reducing the accumulation rate of the operational waste generated during operation and the fact that an extension of service life would not increase the volume of the decommissioning waste to any significant degree.

According to the current plans, the construction work related to the L/ILW repository's expansion is set to begin no later than two years before the start of the preparation phase of Loviisa 1's decommissioning and has been estimated to last roughly three years. This will allow decommissioning waste to be deposited in the L/ILW repository when the dismantling phase begins. The expansion entails the quarrying of approximately 71,000 m^3 of rock (rapakivi granite), the volume of which as quarry material is approximately 100,000 m^3. After the expansion, the L/ILW repository's total volume will be around 188,000 m^3.

5.2.2 Other construction work related to decommissioning

During the preparation phase, a ramp leading from the power plant area's yard level to both reactor buildings will be built for the transport of the large components in the reactor buildings. The ramp will allow the reactor pressure vessels, internals, steam generators and other large components to be transported out of the reactor buildings. Holes will be punched through the walls of the containment buildings and reactor buildings as part of the construction of the transport routes.

A new seawater pumping station, smaller than the current one, will be built for the interim storage for spent nuclear fuel to be made independent. The new station's capacity will be more suitable for the decreasing need for cooling water. The construction of additional space in which spent nuclear fuel could be transferred to the transfer casks has also been considered during the planning for the handling of spent nuclear fuel. The necessity of this expansion will nevertheless be assessed in more detail at a later date.

In other respects, the aim is to make use of existing buildings during the decommissioning. All necessary waste treatment and storage capacity is to be located within the buildings in the power plant area which have been in use during the power plant's operation. These buildings will only be subject to necessary modification such as the dismantling of interior walls. Interim halls can be built in the power plant area for the dismantling work if necessary.

5.3 PREPARATION FOR DECOMMISSIONING AND DISMANTLING WORK

5.3.1 Preparation phase

The preparation phase of the decommissioning will begin after the production operation at each power plant unit has ended and will last until the beginning of the actual dismantling work. The end of the power plant units' electricity production and the beginning of the preparation phase has been staggered across three years so that the preparation phase will first be carried out in unit Loviisa 1 while unit Loviisa 2 is still producing electricity. When unit 2 is finally shud down as well and its preparation phase begins, unit 1 will shift from its preparation phase to dismantling phase 1 (see Figure 5-2). The duration of the preparation phase will be approximately three years in both power plant units, and the preparation phase will be similar for both units. However, in accordance with the plans made for the current service life, the purchases made and waste handling spaces built during Loviisa 1's preparation phase can be utilised during the preparation phase of Loviisa 2. This is likely to slightly shorten the preparation phase of Loviisa 2.

In Option VE1, both power plant units may possibly be shut down at the same time. If the preparation phases of the power plant units are not staggered, the schedule will not contain the aforementioned difference.

The most important tasks to be carried out during the preparation phase include:

- the opening of the reactor, as well as the transfer of the reactor's internals and spent fuel into the refuelling pools for cooling, and subsequently to the interim storage for spent fuel;
- the emptying and rinsing of the process systems and the thawing and emptying of the ice condenser;
- the treatment of active wastewaters by utilising evaporation and ion-exchange systems;
- the decontamination of the primary system when the radiation levels during decommissioning require it;
- the maintenance and preparation of the processes needed for the decommissioning;
- space modifications and the clearing of areas;
- the construction of waste treatment facilities primarily in spaces freed from other use;
- preparing the transport arrangements for the large components:
- equipment purchases.

All spent nuclear fuel will be transferred to the interim storages for spent nuclear fuel during the 18-month cooling period following the reactor's shutdown. The transfer of spent fuel from the reactor hall to the interim storages for spent fuel must be performed more frequently than during normal operation, because the fuel transfer casks cannot be packed full due to the fuel's shorter cooling period. After the transfer of the spent fuel, the reactor's dummy elements and control rod absorbers will also be transferred into the pools of the interim storage for spent fuel to await further treatment.

Following this, the fuel pool in the reactor building will be emptied, the fuel racks will be dismantled, and the pool will be decontaminated so that it can be put to use in subsequent decommissioning work phases for the interim storage and treatment of decommissioning waste.

The waste flows to be treated during the decommissioning will be much more voluminous and diverse than during the power plant's normal operation. To enable the efficient and smooth treatment of the waste flows, appropriate waste measuring, packaging and decontamination points will be built into the power plant's facilities.

All process systems to be dismantled will be emptied and rinsed of process waters. In connection with the systems' emptying, the primary system may also be chemically decontaminated, i.e. purified from radioactive impurities. This will allow the radiation doses resulting from work in the vicinity of the primary system to be reduced. The final decision on the performance of the decontamination will be made once the activity levels of the decommissioning phase are known. In its narrowest sense, the scope of the decontamination may cover the primary piping alone, and at its broadest, the entire primary system, including auxiliary systems. One possible method that can be used for the decontamination is the HP/CORD UV method, in which the decontamination chemicals are oxalic acid and permanganic acid, and part of the resulting decontamination waste can be decayed with the help of UV light.

The process waters will initially be pumped into storage tanks, and their pH value is adjusted so that the ion-exchangers function as efficiently as possible. Following the removal of the radionuclides, the waters will again be pumped into the storage tanks, and laboratory samples will be taken from them. If necessary, the process waters can also be delayed before their discharge into the sea. The volume of the process waters can also be reduced prior to purification with the help of evaporators.

If the primary system is decontaminated, this will also generate liquid waste which contains chemicals. The wastewater resulting from decontamination is treated in the same manner as all other radioactive waters, and the portion of the purified water falling below the emission limits is discharged into the sea.

The treatment processes of the waters generate liquid radioactive waste; the used ion-exchangers and evaporation concentrates resulting from the evaporation. This waste is solidified at the power plant's solidification plant into concrete waste containers using a method based on cementation. The same method has also been used to treat any liquid waste generated during operation so far. The solidification renders the liquid waste into a form fit for final disposal. The treatment and solidification of liquid waste is a time-consuming process. The wastewater generated during the power plant units' preparation phases will continue to be treated after the preparation phases. All solidified waste will be deposited for final disposal in the L/ILW repository's final disposal hall for solidified waste, which is already in use.

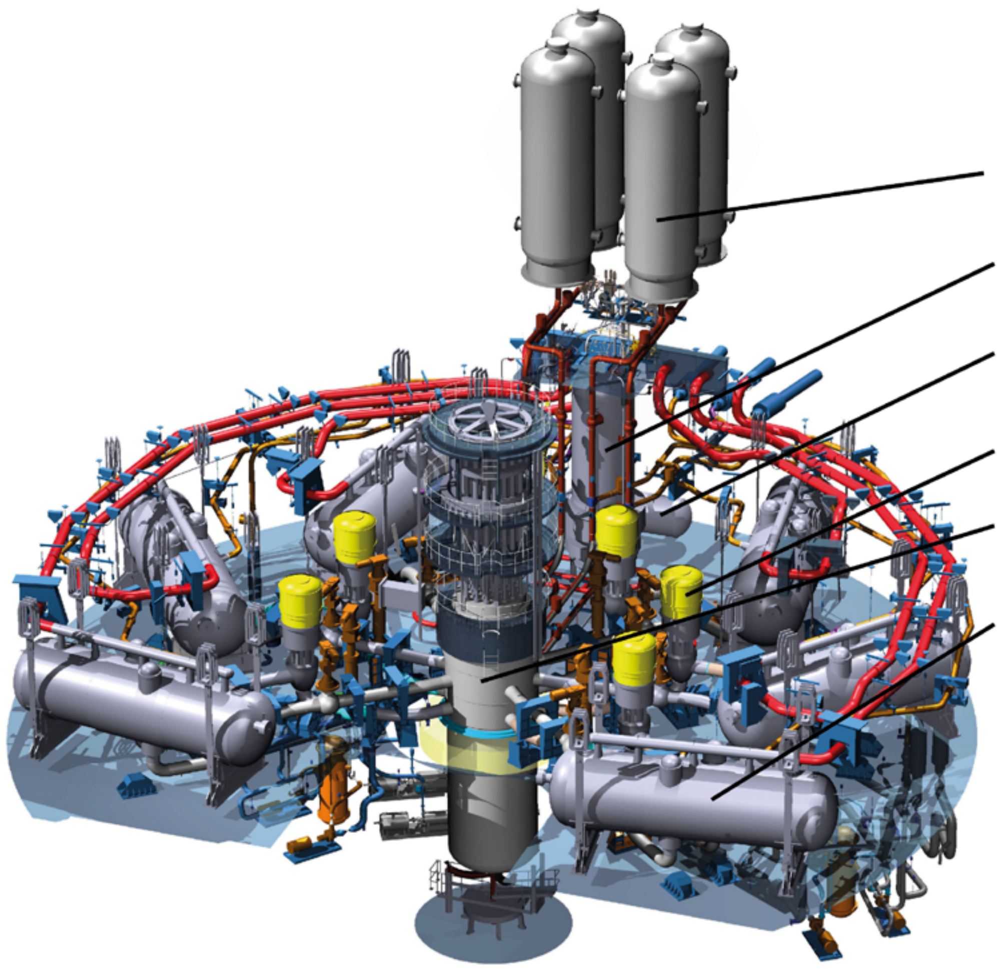

Figure 5-4. An illustration of the primary system of Loviisa power plant unit. The illustration indicates the large components which, according to current plans, are to be deposited for final disposal in one piece.

5.3.2 Dismantling of radioactive parts

5.3.2.1 Measures

The dismantling strategy selected for Loviisa power plant is immediate dismantling, which means the dismantling measures will commence immediately after the preparation phase. The scope of the first dismantling phase will cover the activated and contaminated systems, equipment and structures of both power plant units' reactor buildings. According to the current plans, the duration of the first dismantling phase will be approximately 3.5 years per power plant unit.

The structures and systems to be dismantled can be divided into two categories based on their activity type: activated and contaminated. The activated material has been exposed to strong neutron radiation in the reactor or its surroundings, and has become radioactive as a result. Activated components or structures at Loviisa power plant include the reactor pressure vessel, the internals of reactors, dummy elements, the absorbator elements of control rods and the control rods' connection rods, the reactor's thermal insulation layers and the reactor's biological shield. In addition, the floor structures of the steam generator space contain concrete with a very low activation level.

Contaminated material is material polluted by radioactive dirt that cannot be detected by sensory means, i.e. contamination. Contamination occurs when material from the primary system's inner surfaces comes loose and activates as it is carried to the reactor in the coolant. Unlike activated materials, contaminated materials are not in themselves radioactive; rather, the radiation they emit is wholly caused by contamination. Because of this, some contaminated materials may be cleared from regulatory control either as is or after decontamination.

Contaminated components or structures, on the other hand, consist of large components (steam generators, pressurisers, hydro accumulators and bubblers, i.e. pressuriser relief tanks), the systems and process equipment connected with the reactor, and concrete structures which have been contaminated due to exposure to active water. Figure 5-4 shows the primary system's large components, of which the reactor pressure vessel, internals included, has been activated, and the rest contaminated.

Both activated and contaminated structures can be dismantled with methods and equipment already in use. However, activated structures are primarily more active than contaminated structures, due to which special attention must be paid to radiation protection measures, and remote-controlled dismantling tools should be preferred insofar as it is possible. According to the current plans, large radioactive components will be deposited for final disposal in one piece so that large-scale and difficult cutting-up work can be avoided.

Radioactive parts will be dismantled at the same time as the dismantling waste is treated. The dismantling measures will begin with the detachment of the **reactor pressure vessel's** lid, the removal of the reactor's internals from the reactor pressure vessel, and the detachment of the reactor pressure vessel. The removal of the internals corresponds to measures carried out during normal annual outages, due to which there is plenty of previous experience of it. The dismantling of the pressure vessel is begun with the removal of the thermal insulation layers and the dismantling of the bottom parts of the biological shield. The pressure vessel's pipe branches to the primary system are then cut by sawing or milling. To reduce radiation levels and maintain integrity, steel plates are welded onto the pipe stubs. The dose rates at the work location are sufficiently low to allow the safe performance of cutting and welding measures. The loose pressure vessel is placed within a radiation shield, after which the entirety is moved and lifted onto a transport platform and transported for final disposal.

The **dummy elements** protect the pressure vessel from the neutron radiation emitted by the fuel. The dummy elements will be transferred to the interim storage for spent fuel during the preparation phase. Following the pressure vessel's final disposal, the dummy elements will be transported from the interim storage for spent fuel to the reactor hall's decontamination pool, from where they will be lifted into a transport package and transported into the reactor pressure vessel deposited for final disposal. The **control rod absorbers** are removed according to the same principles as the dummy elements, but they are deposited for final disposal within their own purpose-built packages.

Both reactor halls house a **dry silo**, which functions as storage for the components removed from the reactor. Some of the components stored in the dry silos are highly active. In terms of their structure, the dry silos are roughly 6 m deep concrete structures with steel storage pipes inside. The pipes contain stored radioactive waste, and the mouths of the pipes are covered with steel stoppers. According to the current plans, the dry silos will be sawed loose of the surrounding structures in one piece with the help of a diamond wire saw and transferred into concrete radiation shields. Prior to transport to the L/ILW repository, the radiation shields will be reinforced with a lead cover.

The **biological shield** surrounding the reactor pressure vessel and the **concrete** surrounding the shield have been activated by neutron radiation. Concrete which cannot be cleared from regulatory control must be dismantled and deposited for final disposal. An investigation based on drilled concrete samples and activation calculation has been conducted on the dismantling depth required by this concrete. The concrete will be dismantled with a remote-controlled diamond-grinding wheel and a chipping robot, which can be operated from a service platform to be built on top of the reactor cavity. Before the dismantling begins, the reactor cavity will be filled with water so that the contaminated concrete dust cannot escape into the air of the surrounding space. The extent to which the floor of the steam generator space has been activated has also been investigated on the basis of concrete samples bored from the steam generator space.

The dismantling of the **primary system's large contaminated components** will begin by cutting all the pipe branches and their related electric couplings. The cut connections will be closed with flange joints or by welding steel plates onto them so that the contamination contained by the components cannot spread and so that the components can be deposited for final disposal in one piece. The haulage tracks that will be built for the components will be used to move the components out of the reactor building with the help of a crane. Due to their size, the primary system's large components cannot be transported to the final disposal halls along the power plant units' normal internal routes. A ramp will therefore be built, and transport openings will be made in the walls of the reactor buildings.

Other contaminated process systems will be dismantled according to their activity level so that the most active systems are dismantled first. The dismantling is begun from the primary piping, which will be cut by sawing or milling. The treatment system of the primary water will be dismantled next using the same methods, after which the work will move on to the dismantling of the other systems in the steam generator space. The methods by which systems with a lower activity level can be dismantled include plasma cutting, sawing, milling and hydraulic cutters. The systems external to the steam generator space are dismantled last, using the same methods.

5.3.2.2 Treatment and final disposal of radioactive waste

The material to be dismantled from the power plant area's buildings is divided into waste categories based on activity level, material, type of activity (activated/contaminated) and size. Decommissioning waste can be divided roughly into activated dismantling waste, contaminated dismantling waste, maintenance waste and liquid waste, solidified for final disposal. Any waste that cannot be cleared from regulatory control is treated as radioactive waste. Depending on its properties, it is treated in accordance with the process designed for its own waste category, packed in waste packages if necessary and transported to the L/ILW repository's final disposal halls for decommissioning waste. One alternative is also to decontaminate pieces which can be cleared from regulatory control after decontamination or pieces whose decontamination would decrease the dismantling staff's radiation doses to a significant degree.

The power plant's activated equipment and structures contain the vast majority of the activity in the decommissioning waste. Of the activated plant parts, the reactor pressure vessels will be treated and deposited for final disposal, according to the current strategy, in one piece.

Table 5-1. The estimate concerns the amount of activity during the L/ILW repository's estimated closure in 2068.

Type of waste	Activity in 2068 [TBq]
Activated dismantling waste	approximately 22,000
Contaminated dismantling waste	1
Maintenance waste	0.3
Waste to be solidified	10
Total	approximately 22,000

They will also function as final disposal packages. The reactor pressure vessels will be transported in a special vehicle under a radiation shield to the pressure vessel silos built for them in the L/ILW repository. The pressure vessels' internals and dummy elements will be placed in interim storage for the duration of the pressure vessels' transfer and then transported in purpose-built transfer casks into the pressure vessels in the L/ILW repository's pressure vessel silos. Other activated equipment and activated concrete structures will be dismantled and packed into applicable concrete or wooden crates so that they can be transported to the L/ILW repository's dismantling waste hall 1.

Contaminated process systems and equipment will be treated appropriately and deposited for final disposal in the L/ILW repository. After interim storage, the pressure vessel's lid will be transported to the L/ILW repository under a radiation shield and attached to the pressure vessel once all the components to be deposited for final disposal in the pressure vessel have been placed inside it. The primary system's large components will be deposited for final disposal in one piece in the large component hall above the pressure vessel silos. Other contaminated plant parts will be dismantled and cut when necessary for packaging. They will be deposited for final disposal in concrete or wooden crates, or in one piece in the L/ILW repository's dismantling waste halls 1 and 2. In addition to systems and equipment, the concrete structures of a nuclear power plant may become contaminated as a result of leaks in the process systems or pool lining, or due to the dismantling measures carried out during the decommissioning phase. The contaminated concrete structures will be dismantled and deposited for final disposal in the L/ILW repository either as concrete blocks, in which case they will be shielded for the duration of transport to prevent the contamination from spreading, or packed in concrete or wooden crates.

The maintenance waste generated during the decommissioning phase (which includes protective equipment, tools, etc.) will be packed in barrels, and any barrels exceeding the limit values for clearance from regulatory control will be transported to the L/ILW repository's maintenance waste hall 3 for final disposal.

The treatment of liquid waste generated during the preparation phase will be continued during dismantling phase 1 in the manner described in Chapter 5.3.1. Sawing sludge from the dismantling of contaminated concrete structures will also be generated during the dismantling work, and it will be solidified and deposited in final disposal in the same manner.

No later than during the decommissioning phase, very small quantities of waste containing uranium (such as some measuring instruments used in reactor control), which have not yet been deposited in the L/ILW repository for final disposal, need to be deposited for final disposal.

All in all, the volume of the waste generated during the preparation phase and dismantling phases is expected to amount to roughly 25,000 m³. The activity of the waste to be deposited in the L/ILW repository for final disposal will for the most part be in activated dismantling waste, and only a fraction of the total activity will derive from contaminated dismantling waste, maintenance waste and solidified waste. The activity in the decommissioning waste is expected to be distributed among the different types of waste in accordance with Table 5-1. The assessment concerns the amount of activity approximately three years after the L/ILW repository's estimated closure in 2068. At that time, it is estimated that the total activity of the decommissioning waste will be around 22,000 TBq. Depending on the spent nuclear fuel's transport schedule, the L/ILW repository's closure may be possible even before 2065.

The calculation of the activity estimate only accounts for nuclides with a half-life of more than 5 years, because only these nuclides have the most relevance for long-term safety. In addition to decommissioning waste, operational waste generated during the power plant's operation has already been deposited and will continue to be deposited in the L/ILW repository. The activity of the operational waste is again a fraction of the activity of the decommissioning waste, and it is included in the rounding of the final value.

If 20 years is added to the power plant's service life in line with VE1, the volume of the nuclear waste generated during operation and the activity of some types of decommissioning waste will increase. The amount by which the total activity increases can be influenced by the accumulation rate of the waste type, the neutron flux it experiences, and the half-life of the nuclides it contains. In the case of a new operating licence, if it is assumed that the repository's closure is delayed by 20 years, the activity of the decommissioning waste when the repository closes, around 2088, will be in the region of 33,000 TBq. Of the radioactive nuclides contained by the decommissioning waste, the most relevant for the radiation safety of the dismantling work during the decommissioning is cobalt-60 and the most relevant for long-term safety are carbon-14 and nickel-59.

In addition to radioactive waste, the L/ILW repository can also house conventional dismantling waste or dismantling waste with very low-level activity, such as crushed concrete. The maximum volume of waste with a very low level of activity is 50,000 m³, and it will be used as much as possible as the L/ILW repository's filling material, along with quarried rock. The use of concrete as a filling material will increase the pH of the water in the repository, thereby slowing down corrosion and contributing to the long-term safety of the final disposal halls. Some of the dismantled concrete can also be cleared from regulatory control, in which case it will be handled as conventional waste (see Chapter 5.3.3).

Following the decommissioning's dismantling work, the buildings will be subject to surface contamination and activity mapping. The necessary additional dismantling measures or decontaminations will be carried out on the basis of the measurements, and when the clearance levels are not exceeded, the buildings can be cleared from regulatory control. Following such a clearance, the buildings will be repurposed or dismantled, which will result in conventional waste.

During the decommissioning's waste treatment processes, the waste will be placed in interim storage within the power plant for the purpose of activity measurements and packaging.

5.3.3 Conventional dismantling measures

5.3.3.1 Measures

The planning concerning the decommissioning of Loviisa power plant has so far focused primarily on the dismantling and treatment of radioactive parts. The decommissioning will nevertheless also entail conventional dismantling measures that generate conventional non-radioactive dismantling waste. The plans concerning conventional dismantling will be specified as the project progresses. The plans can make use of the experiences gained during the dismantling of Fortum Power and Heat Oy's Inkoo power plant, and the decommissioning projects of Sweden's nuclear power plants, for example.

The objective of the planning of dismantling work is to carry out the dismantling as efficiently and economically as possible, and in compliance with occupational safety and environmental requirements. The planning should pay particular attention to locating load-bearing structures, their dismantling sequence and support during the work, and fall protection so that the risks can be managed and any premature collapse can be avoided, for example. The plan concerning the dismantling work also accounts for the necessary measures aiming to prevent environmental nuisance such as noise and the spread of dust. The transfer and transport of dismantling waste and the recycling of waste material also require advance planning. A demolition survey will be conducted prior to the plant's dismantling, including a survey and studies of harmful substances, as well as a review of dismantled materials.

In its maximum extent, the conventional dismantling will cover all structures and equipment remaining after all the active parts have been dismantled and deposited in final disposal during the decommissioning proper. Structures within the scope of conventional dismantling will be identified on the basis of activity determinations carried out during the decommissioning. Structures that can be cleared from regulatory control can be dismantled by conventional means. Once the structures have been cleared from regulatory control, the dismantling of the non-active side will no longer be an activity subject to the Nuclear Energy Act and STUK's supervision.

The dismantling of non-active parts can be carried out flexibly later so that it does not inconvenience the actual decommissioning. Nevertheless, the dismantling of machinery and equipment, in particular, should be carried out simultaneously with the actual decommissioning so that the expertise and shared infrastructure of that phase can be utilised. The dismantling accounts for the equipment's possible reuse. The aim is to carry out the dismantling measures of any equipment intended to be reused so that the equipment remains intact and undamaged, and therefore fit for reuse. Some of the components could be sold to other plants as spare parts, for example.

The conventional dismantling can be carried out with methods already in use (the dismantling can be equated with the dismantling of any other power plant). The dismantling of active parts relies on more detailed techniques suitable for the work in question, such as diamond wire sawing and chipping robots. Conventional dismantling can be carried out with the help of the most common methods, given that radiation protection and supervision is no longer necessary. Conventional methods include oxygen cutting for parts consisting of metal or hydraulic chipping with excavators for concrete structures. Concrete structures can also be dismantled with various pieces of auxiliary equipment attached to cranes or excavators.

The dismantling of structures can be planned so that the dismantling and crushing of concrete can be carried out at the same time. This would also make crushed concrete suitable for reuse available at an earlier juncture. The prerequisites for starting the reuse of crushed concrete are the sufficient quantity of the crushed concrete and the completion of the EP-Tox-Test results.

Potentially harmful substances in construction materials should be considered in the demolition of buildings. The buildings were constructed when the use of asbestos and other substances now deemed harmful was common in construction projects. The demolition must be carried out in compliance with valid legislation (Act on Certain Requirements Concerning Asbestos Removal Work 684/2015), and the relevant guidelines and regulations. Before the demolition of buildings, any construction materials potentially containing asbestos or other harmful substances must be identified. The asbestos and harmful substances inspection will be carried out in connection with the demolition survey as required by law and regulations. The means by which the survey of harmful substances can be performed include sampling, visual observations, and the systematic review of any equipment and structures in which harmful substances are known to potentially occur. The most suitable dismantling methods are selected on the basis of the survey of harmful substances. It is likewise advisable to prepare for a situation in which materials containing harmful substances are found even in surprising locations in connection with the dismantling and demolition measures.

Based on asbestos surveys carried out thus far at Loviisa power plant, asbestos is most often present in the following:

- asbestos fabric (pipe insulation, cable bends, the feed-throughs of cables and pipes, as well as in pipes, tanks and heat exchangers insulated with spacers);
- building boards used in wall and ceiling structures;
- in sheet gaskets used in various systems as flanged seals;
- in the spiral wound gaskets of main shut-off valves;
- vinyl tiles;
- adhesives, mortar and fillers.

At least some of the structures containing asbestos will be replaced by asbestos-free alternatives during operation, prior to the start of the decommissioning, when systems are opened, for example The plan is to replace the sheer gaskets used in the systems with an asbestos-free material.

The reuse of materials containing asbestos is prohibited. The dismantling of materials containing asbestos or other harmful substances must be carried out before other dismantling work begins. In addition to asbestos, the construction materials may contain PAH and PCB compounds, heavy metals and oils, for example. Based on experience gained during the dismantling of Inkoo power plant, the condensators, in particular, must be inspected for PCB compounds. The valid Waste Act and the guidelines issued by local waste treatment authorities should be complied with when handling waste containing asbestos or other harmful substances.

5.3.3.2 Treatment and final disposal of conventional waste

Before demolition, a demolition survey is conducted at the site to determine the type and quantity of the materials the demolition of the buildings produces. A suitable way of handling the materials and any further use of them will be determined in connection with the demolition survey. The inspections to be carried out before the demolition of the buildings will determine the suitability of the dismantled material for reuse, recycling and recovery, making it possible to separate recoverable materials from other materials. Any possibilities of reusing the moveable property in the buildings are also investigated.

The further use of non-harmful dismantled material generated in the dismantling work is subject to the following hierarchy:

1. reducing the amount of waste generated;
2. reuse;
3. recycling;
4. other use (use as energy, or as backfill in the case of non-hazardous waste);
5. final treatment.

In the dismantling operation, the greater the amount of the dismantled material that can be reused, the smaller the amount of waste generated will be. The dismantling plan therefore includes an investigation of any plant parts suitable for potential reuse. For example, selling equipment as spare parts constitutes reuse.

The potential for reusing concrete and brick waste will be ensured by samples taken from and EP-Tox-Test conducted on the intact structures. The quality of the crushed concrete will also be tested subsequently. The prerequisites for concrete's suitability for reuse are specified in the Government Decree on the Recovery of Certain Wastes in Earth Construction (843/2017). The dismantling plans for structures or equipment identified as reusable accounts for the most suitable dismantling methods for eventual reuse (such as keeping equipment intact). Based on prior dismantling experiences, it can be assumed that some 90% of the material remaining after the removal of active parts will be reusable. The aim is to utilise as much of the reusable material as possible for the use of the power plant area to avoid unnecessary transports. Current estimates put the amount of the clean concrete in the buildings to be cleared from regulatory control at 355,000 tonnes. If the buildings cleared from regulatory control are dismantled, the principal option is to use the crushed concrete at the dismantling site in connection with the potential replacement of material, or when filling or closing the L/ILW repository. Other options for the reuse of the dismantled concrete include road, street and field structures.

Other conventional waste to be cleared from regulatory control and categorised as waste, such as metal, plastic, glass, plasterboard and wood waste, as well as waste electrical and electronic equipment (WEEE) to be classified as hazardous waste, are directed when possible to a waste management provider licensed to accept such waste. Should all buildings in the power plant area, following their clearance from regulatory control, be dismantled in accordance with the greenfield principle, current estimates put the amount of metal to be accumulated from the power plant area at 52,000 tonnes, of which approximately 41,000 tonnes – consisting of copper, steel and stainless steel – would be recyclable. If the materials are not suitable for recycling, they are reused for energy.

If the dismantled material is not suitable for recovery, its suitability for landfill disposal is determined. The suitability for landfill disposal is verified in accordance with valid requirements set by the authorities. The prerequisites of suitability for landfill disposal are specified in the Government Decree on Landfills (331/2013).

5.4 PLANT PARTS TO BE MADE INDEPENDENT

5.4.1 Making plant parts independent, and their operation

A phase of independent operation will occur between Loviisa power plant's first and second dismantling phases. During this phase, the interim storages for spent nuclear fuel, the liquid waste storage and solidification plant, the L/ILW repository and some parts of the auxiliary buildings will still be in use (Figure 5-5). These buildings and all the functions, systems and structures materially bound to their operation and

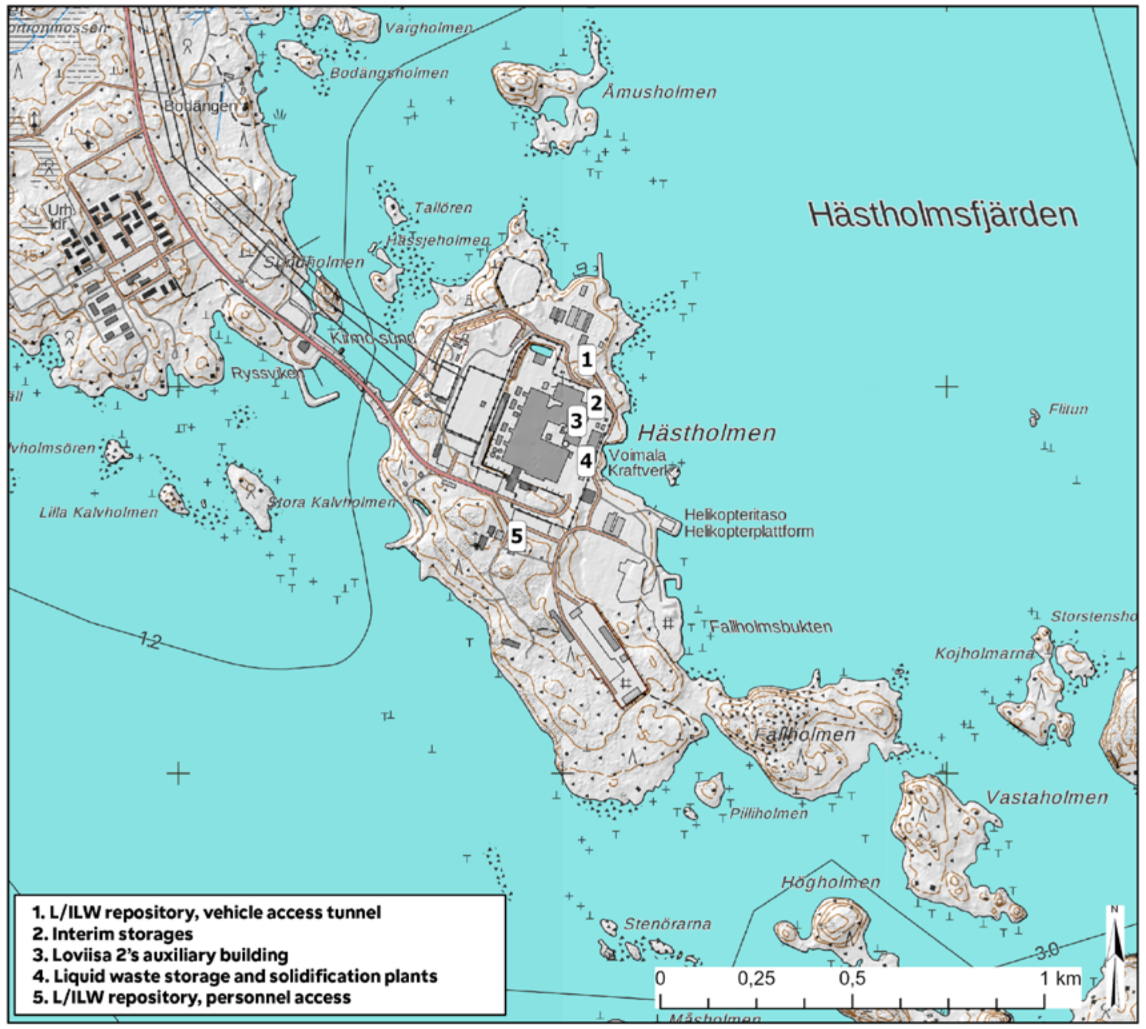

Figure 5-5. Plant parts to be made independent at Loviisa power plant.

safety will be retained in such a way that they can operate without disruption or breaks. Such related functions include:

- the electric, automation and signalling systems;
- the diesel backups of power supply;
- the special sewage system of the radiation controlled area and the sewage water treatment system;
- the domestic water supply;
- the water demineralising plant as well as the storage and supply of desalinated water;
- the storage building for strong chemicals;
- the storage and supply of boron;
- ventilation and heating as well as the cooling of systems;
- fire safety systems and the fire water pumping station;
- radioactive gaseous waste treatment systems and radiation protection;
- waste management;
- the laboratory and sampling systems.

During the independent operation of Loviisa power plant, the power plant's spent nuclear fuel will be placed in interim storage and cooled until it has been delivered in full for final disposal to Posiva's final disposal halls.

Small amounts of maintenance waste will be generated during the spent fuel's interim storage. This maintenance waste will be packed in barrels and measured, and any barrels exceeding the clearance levels will be transported to the L/ILW repository's maintenance waste halls for final disposal. In addition, liquid radioactive waste generated during the power plant's operating history and yet to be treated will be stored, solidified and deposited for final disposal in the L/ILW repository during the relevant phase. The treatment of both solid and liquid waste during the phase of independent operation will be carried out in the same manner as described in Chapter 5.3.2.2.

A majority of the modifications to be made concern Loviisa 2's auxiliary building and the interim storages for spent fuel located there. The liquid waste storage, solidification plant and the L/ILW repository are technically already fairly independent of the rest of the power plant, which means their need of modification is minor.

The systems to be used during the phase of independent operation must function in the same manner as during the power plant units' energy production. This requires modifications and updates to some of the systems to be retained. The causes of the modification needs include the condition and dimensioning of the systems. The final extent of the necessary modification work will become clear closer to the independent operation phase. According to preliminary plans, the modification work to be performed for the plant parts to be made independent will be carried out during the preparation phase of the Loviisa 1 power plant unit. The commencement of the modification work can be brought forward if this is deemed necessary as the plans become clearer. The modification work will be completed before energy production at the Loviisa 2 unit comes to an end. The modification work will be carried out without compromising the safety of the power plant or any part of it.

The power plant's need for electricity, cooling water and many other resources will be reduced to a fraction of the original once the phase of independent operation begins. The power plant's various systems have been dimensioned to meet the need for these resources during the power plant units' energy production. The capacity of some of the systems and components to be retained is therefore oversized for the intended future use. The maintenance of such systems may prove uneconomic, due to which they will be replaced by new ones if necessary, so that the plant will better meet the system requirements of the independent operation phase.

The systems retained for the independent operation phase must remain functional and safe for operation for several decades after the power plant units' energy production has ended. The condition of the systems must therefore be assessed prior to the preparatory work of the independent operation phase. Although the systems will be replaced by new ones, these will be equivalent to the old systems to the extent deemed necessary. The decision may also be influenced by the sufficiency and availability of spare parts.

The power plant's spent nuclear fuel will be placed in interim storage in the storage pools of interim storage 1 and 2 for spent fuel until final disposal. The most important function of the interim storage for spent fuel is to cool the water in the storage pools, which is warmed by the spent nuclear fuel. The water used in the storage pools contains boron, and with the boron in the fuel racks, this water prevents the fuel's criticality. The water in the fuel pools will be cooled with the pools' own cooling systems, the heat exchangers of which will transfer the heat released by the fuel through the heat component cooling system into the sea. The component cooling system will also be connected to the cooling tower, from where the heat can be transferred into the air instead of the sea. The nuclear safety of the interim storages for spent nuclear fuel is discussed in Chapter 7.5.4.

The most significant modification in terms of the interim storages for spent fuel concerns the heat sink of the cooling of their pool waters. During the independent operation phase, the current seawater system used for cooling will be oversized due to the considerably lower need for heat transfer, which is why it will be renewed. According to the current plans, a new seawater pumping station with markedly lower cooling efficiency will be built for the power plant (see Chapter 5.2.2). According to the current plans, the volume of seawater extracted by the new seawater pumping station would be around 1,600,000 m^3 a year.

When cooled fuel is shipped from the interim storages for spent fuel to final disposal, the fuel will be dried and packed into transfer casks. The equipment needed for drying and packing the fuel and loading the transfer casks will be procured. Spaces in which the fuel can be prepared for transport safely will also be arranged.

The liquid radioactive waste generated at the power plant is stored in the liquid waste storage. During the independent operation phase, the liquid waste storage and the solidification plant will be charged with handling all liquid radioactive waste so that once the phase ends, the liquid waste storage will be entirely empty. The liquid waste storage and solidification plants are connected to some of the systems in the auxiliary building of unit Loviisa 1. For the independent operation phase, the buildings will be connected to the equivalent systems of Loviisa 2, while the connections to unit Loviisa 1 will be dismantled.

The only modifications to be made to the systems of the L/ILW repository for the independent operation concern control room functions and fire safety.

The plans concerning the independent operation phase and its preparation work will be specified at a later date.

5.4.2 Dismantling of the plant parts to be made independent

The dismantling phase of the plant parts to be made independent and the other buildings and related functions required for their operation is called the second dismantling phase. The scope of the decommissioning's second dismantling phase covers contaminated systems, equipment and structures in the auxiliary buildings, interim storage for spent fuel, the liquid waste storage and the solidification plant. The quantity of the contamination and the required extent of the dismantling will be determined before the dismantling work begins. The scope of the dismantling during decommissioning covers any material that cannot be cleared from regulatory control.

Prior to the beginning of the second dismantling phase, the spent nuclear fuel in the interim storages for spent fuel will be delivered for final disposal (see Chapter 5.5). The interim storage for spent fuel will then be discontinued and can be dismantled. The pools of the interim storage for spent fuel will be emptied, and their pool waters will be delivered to the liquid waste storage and further for treatment in the appropriate manner. The combined volume of water in the storage and reloading pools of the interim storages for spent fuel will be more than 4,700 m^3. Following the treatment, all water established as purified will be discharged into the sea. The liquid waste storage and the solidification plant will remain in operation until all the power plant's liquid radioactive waste has been treated. All remaining liquid radioactive waste will be cast in concrete in the solidification plant and deposited in the L/ILW repository for final disposal.

After this, the work of the second dismantling phase will proceed to the dismantling of the auxiliary building's systems. The systems related to the interim storage of spent fuel and the treatment of liquid waste are among the systems to be dismantled later. All radioactive waste generated during the second dismantling phase will be deposited in the power plant's own L/ILW repository.

5.5 CLOSURE OF THE FINAL DISPOSAL HALLS AND THE L/ILW REPOSITORY

The L/ILW repository of Loviisa power plant will remain in operation until all low and intermediate-level waste generated during the decommissioning has been deposited for final disposal in the L/ILW repository. After this, the L/ILW repository will be closed. The extra space in the waste basins in the solidified waste hall and dismantling waste hall 1 will be filled with crushed rock, after which concrete slabs will be cast on top of them. The large component hall, dismantling waste hall 1, the ventilation and personnel shafts, loading area, control room and the maintenance space will be filled with crushed rock or with the crushed concrete generated during the dismantling of the power plant's concrete structures.

In addition to the fillings consisting of crushed rock or concrete, the plan is to construct one and five-metre-thick reinforced steel caps for the mouths of the waste halls, in shafts, the shafts' mouths at ground level and at the perimeters of the fragmented rock zones. Following the fillings and cappings, the repository will be closed permanently by filling the entire length of the vehicle access tunnel with the crushed rock generated during the quarrying of the waste halls' expansion and casting a massive reinforced steel seal at the repository's entrance. All in all, the volume of crushed or blasted rock or concrete needed to fill in the halls, shafts and vehicle access tunnel will be approximately 110,000 m^3.

The final disposal of nuclear waste has been completed when STUK deems that the nuclear waste has been disposed of in a manner approved by STUK. Correspondingly, a nuclear facility is considered to have been decommissioned when STUK deems the quantity of radioactive substances in the buildings and soil of the power plant area to meet the legal requirements. After this, an authority (the Ministry of Economic Affairs and Employment) will prescribe Fortum's management obligation to have ended, and the ownership of and responsibilities for the nuclear waste will be transferred to the State. After closure, the area will be subject to post-closure control by the authorities. The purpose of the closure is to contribute to the long-term safety of the final disposal (Chapter 7).

5.6 FURTHER USE OF THE AREA

Two different basic scenarios for the power plant area's further use can currently be identified. These are the area's further use as an industrial area (the brownfield principle) and the area's restoration to its natural state (the greenfield principle). The current decommissioning plan of Loviisa power plant has been drawn up according to the brownfield principle. Regardless of the concept of further use, the area does not allow for deep excavations, given that the final disposal halls of the active waste are located underneath it.

The area's further use as an industrial area

According to what is referred to as the brownfield principle, the buildings cleared from regulatory control are left standing for the purposes of possible future use. The buildings' potential for reuse will be investigated when the dismantling plans for the buildings have been drawn up. Among other options, the buildings could be used as industrial or storage buildings, following the necessary renovations.

Should the brownfield scenario be implemented, the buildings in the power plant area could be reused in the area's next purpose of use as applicable. This would conserve the natural resources consumed by the construction of entirely new buildings. This alternative is also on the highest level in the waste management hierarchy, given that the aim is to avoid the generation of waste.

Restoring the area to a near natural state

According to what is referred to as the greenfield principle, all buildings and structures in the power plant area are dismantled, and as a result, the power plant area is restored to a condition close to its natural state that was prevalent in the area prior to the power plant's construction.

If all the buildings in the power plant area are dismantled, the area will be subject to thorough landscaping. The recoverable crushed concrete resulting from the crushing of the concrete structures of the buildings to be dismantled will be used to fill in any depressions left in the locations where the buildings used to stand. The crushed concrete can also be put to use in the base fill work of the area's yard and roads, thereby reducing the amount of waste generated and the amount of any artificial fill brought to the area.

The greenfield principle allows the repurposing of the area for recreational use, for example.

5.7 SPENT NUCLEAR FUEL

Spent nuclear fuel is placed in interim storage in the interim storage for spent fuel within the power plant area. During the interim storage, the activity and heat production of the spent fuel will decrease to a significant degree. In due course, the spent nuclear fuel will be transferred from the power plant area to Posiva Oy's encapsulation plant and final disposal facility at Olkiluoto in Eurajoki. The final disposal of the spent nuclear fuel of Loviisa power plant is discussed in more detail in Posiva's 2008 EIA procedure and the materials of its 2012 construction permit application (Posiva Oy 2008 and Posiva Oy 2012), among other documents. Liability for the spent nuclear fuel will transfer to Posiva Oy when the spent nuclear fuel packed in a transfer cask departs from the power plant's interim storage for Posiva's encapsulation and final disposal facility.

5.7.1 Packing and handling of fuel

The fuel will be packed under water in a storage pool for nuclear fuel into a transfer cask designed for this purpose. After the fuel has been packed, the transfer cask will be lifted from the storage pool, decontaminated from any radioactive contamination and dried, contents included, with special drying equipment. After this, the cask will be filled with helium. The packaged, dried and helium-filled transfer cask will then be lifted onto a transport platform and moved with a towing vehicle. For the duration of the transport, the cask will be set in a horizontal position, and its ends will be fitted with collision protection. The cask and transport platform will be covered with a weather guard for the duration of the transport.

The adequate cooling of the fuel and its subcriticality will be ensured at all stages. The fuel's integrity will likewise be secured. At no point during packaging or transport will fuel be transported in this fashion without radiation shielding. The handling and transport plans to be prepared for the final disposal of spent fuel will be specified closer to the time of the decommissioning.

5.7.2 Transport

Following the measures carried out in the power plant area, the spent nuclear fuel can be transported from the power plant for final disposal either by road or by sea. Posiva Oy is responsible for the transport of such waste. There are a number of possible routes for road transport from Loviisa to Olkiluoto. The transport will be supervised, meaning it will be accompanied by the necessary escort personnel such as the police and STUK's supervisor.

Due to feeder traffic, the route of the maritime transport option will be composed of a combination of transport modes (road-sea-road). The maritime transport can be carried out with a vessel similar to M/S Sigrid, for example. She is owned by SKB, which is responsible for Sweden's nuclear fuel and nuclear waste management. M/S Sigrid is a vessel which is in operation and has been built for the purpose of nuclear waste transports. It is capable of transporting a deadweight of 1,600 tonnes. The maritime transport option includes the option to use the Port of Valko in the town of Loviisa, located approximately 25 km by road from the interim storage for spent nuclear fuel. The option of building a shipping lane and a loading dock to the island of Hästholmen has been reserved in the proposal concerning the partial disposition plan and the town planning proposal. The use of the Port of Rauma and Olkiluto Port has also been reviewed.

Depending on when the final disposal of the spent fuel begins and on the power plant's service life, the fuel may already be transported for final disposal during the power plant's operation. According to current estimates, there would be 6–8 road transports of spent nuclear fuel a year (one cask at a time) or 2 transports by sea a year (3–4 casks at a time). The number of fuel transports will depend on the total volume of the fuel, the size of the transport cask and the number of casks transported at any one time, among other things. The fuel must be held in interim storage for a minimum of 20 years before its final disposal so that the residual heat capacity falls to a sufficient level. According to current estimates, the transport of fuel for final disposal will begin in the 2040s and last for approximately 10–20 years. The transport of spent nuclear fuel is strictly regulated by national and international regulations and agreements, and fuel transports in Finland are subject to a permit to be applied for from STUK.

5.7.3 Encapsulation and final disposal

The fuel will be delivered to the reception facility of Posiva's encapsulation plant in a transfer cask. The transfer cask will be docked tightly in the encapsulation plant's fuel processing chamber, in which the fuel will be moved from the cask to a final disposal capsule. The fuel will be packed in a gastight, corrosion-resistant cast iron capsule which protects the fuel bundles from the mechanical stress occurring deep within the bedrock. The operations of the encapsulation plant will include the reception of the transfer casks, fuel encapsulation, welding covers onto the capsules and the inspection of the welding seams. The final disposal capsules will be moved to the final disposal hall by lift via the vehicle access tunnel.

The final disposal facility or spent nuclear fuel will be located at a depth of approximately 430 m from ground level. The underground final disposal facility will consist of three parts: the final disposal tunnels (in which the capsules containing the spent nuclear fuel will be deposited); the central tunnels (which will connect the final disposal tunnels and shafts); and technical auxiliary rooms. In the final disposal hall, the capsules will be deposited in a vertical final disposal hole drilled into the floor of the final disposal tunnel. The space left between the capsule and the rock will be filled with blocks of bentonite, which are capable of binding great volumes of water and swelling up to ten times their original volume. The swollen bentonite will fill the space surrounding the copper capsule tightly and prevent water from getting into the vicinity of the copper capsule. On the other hand, it will also prevent radioactive substances from entering the rock in the event of a leaking capsule. The bentonite buffer surrounding the capsule will also protect the capsule from mechanical stress, i.e. the rock's possible movement. Once the final disposal holes have been filled with final disposal capsules and protected with bentonite, the tunnel will be filled, and its mouth will be closed with a plug structure designed for the purpose.

5.8 ENVIRONMENTAL ASPECTS OF DECOMMISSIONING

5.8.1 Cooling water

When the electricity production ends, the need for cooling water will be considerably reduced. Fuel will be stored in both reactor buildings for another two years or so after the electricity production has ended. The need for cooling water at a single power plant unit will then be roughly equivalent to the need for cooling water during an annual outage, which is a fraction of the need for cooling water during operation. Once the spent nuclear fuel has been moved to the interim storage for spent fuel, the need for cooling water in the reactor buildings will end or become negligible compared to the need for cooling water during electricity production.

The most important systems in need of cooling water during the independent operation phase are the cooling systems of the pool waters in interim storages 1 and 2 for spent fuel. The current cooling systems of both interim storages for spent fuel transfer a maximum of 46.5 TJ of thermal energy a year into the sea. The thermal energy is primarily discharged into the sea. The air cooling towers are used in the event of a disruption at the seawater pumping station. A partial revision of the cooling chain of the interim storages for spent fuel is nevertheless being planned and may have some impact on the final amount of the thermal energy. In addition to the cooling of the interim storages for spent fuel, the plant parts made independent will employ individual heat exchangers. The ultimate heat sink of these heat exchangers will be seawater. However, the combined thermal power of these heat exchangers will be markedly lower than the thermal power of the heat exchangers in the interim storages for spent fuel. This means that the need for cooling water during the phase of independent operation will be a fraction of what it is during energy production.

The environmental aspects of the decommissioning in terms of cooling water are shown in Table 5-2.

Table 5-2. The environmental aspects of decommissioning in terms of cooling water.

Environmental aspect	Expansion of the L/ILW repository	Decommissioning of the power plant (preparation phase and dismantling phase 1)	The operation and decommissioning of the plant parts to be made independent as well as the closure of the L/ILW repository
Cooling water	The expansion of the L/ILW repository does not require cooling water. (At this point, the power plant produces electricity as usual; the need for and use of cooling water as during current operation: an average of 1,300 million m³/year and 57,000 TJ/year).	The need for cooling water (roughly 1.6 million m³/year) and the thermal discharge (at maximum 46.5 TJ a year) will be a fraction of what they are during the power plant's current operation.	

5.8.2 Service water

During the dismantling phases of the decommissioning and during independent operation, the water connections of the supply of service water will basically be the same as during the power plant's operation.

The power plant will be in operation during the expansion of the L/ILW repository, and the amount of service water consumed by the power plant's domestic, process and fire waters will be equal to the amount consumed during operation. In addition, the repository's quarrying will require approximately 15,000–150,000 m³ of service water a year, depending on the construction phase.

During decommissioning, the average need for service water will remain the same, or it will decrease as the operations come to an end. The power plant's need for process waters will decrease, but some decommissioning measures – such as the decontaminations and concrete sawing – will require service water on a non-recurring basis.

Given that there will be less staff in the power plant area, the consumption of domestic water is expected to be less than during operation. If the consumption of domestic water is set in proportion to the number of personnel, its consumption during the dismantling phases of decommissioning will be 13,000–57,000 m³ a year. During independent operation, the need for domestic water will be even smaller.

Table 5-3 presents the environmental aspects of decommissioning in terms of service water requirements and supply.

Table 5-3. The environmental aspects of decommissioning in terms of service water requirements and supply.

Environmental aspect	Expansion of the L/ILW repository	Decommissioning of the power plant (preparation phase and dismantling phase 1)	The operation and decommissioning of the plant parts to be made independent as well as the closure of the L/ILW repository
Service water requirement and supply	The quarrying work will require approximately 15,000–150,000 m³ of water/year. (At this point, the power plant will continue to produce electricity; the need for service water is equal to current operation: Process water 100,000–200,000 m³/year Domestic water 25,000–75,000 m³/year).	Domestic water 13,000–57,000 m³/year Process water varyingly, but less than during operation, on average.	Domestic water less than during decommissioning. Process water markedly less than during operation.

5.8.3 Wastewater

The sanitary wastewater and process wastewater generated during decommissioning and independent operation will be treated and discharged into the sea in a manner equivalent to that during the power plant's operation. The emission limits for waters to be discharged into the sea are confirmed by the authorities. The environmental aspects of the decommissioning in terms of wastewaters are shown in Table 5-4.

Sanitary wastewaters

As a result of additional staff, a slightly greater volume of sanitary wastewater may be generated temporarily in connection with the expansion of the L/ILW repository. No more than a few dozen of the contractor's employees will be working on the expansion in the power plant area.

Table 5-4. The environmental aspects of decommissioning in terms of wastewaters.

Environmental aspect	Expansion of the L/ILW repository	The power plant's decommissioning (preparation phase and dismantling phase 1)	The operation and decommissioning of the plant parts to be made independent as well as the closure of the L/ILW repository
Sanitary wastewaters	The impact of contractors' personnel will be minor.	The volume will be the same as or less than during operation.	The volume will be smaller than during the power plant's operation.
Construction and process wastewaters	Construction wastewater varyingly: 15,000–150,000 m³/year for a period of three years; estimated total emissions: oils and greases < 2,000 kg phosphorus < 35 kg nitrogen < 2,600 kg solids < 63 t The volume of the L/ILW repository's seepage water will increase temporarily.	The average volume of conventional process wastewater will be lower than during operation. Any unnecessary chemicals remaining in the tanks will be processed as harmful substances. Wastewater from the decontamination of individual pieces that falls below emission limits Emptying of process systems: less than 12,000 m³ of water that falls below emission limits	The volume of conventional process wastewater will be markedly lower than during the power plant's operation. Emptying of process systems: less than 3,000 m³ of water that falls below emission limits.

While the number of personnel in the power plant area will vary during the decommissioning and independent operation, it will remain lower than during operation, due to which the volume of sanitary wastewater is likely to remain at the same or a lower level than when the power plant is in operation (24,000 m³ a year). The sanitary wastewater will be fed to the wastewater treatment plant for treatment.

L/ILW repository's construction wastewater and seepage water

During the expansion of the L/ILW repository, water will be needed for the quarrying, among other things. This will result in construction wastewater. Based on the water consumption of the L/ILW repository's previous construction projects, it can be estimated that the volume of construction wastewater generated in a year will range from 15,000 to 150,000 m³. The construction wastewaters will have a nitrogen content attributable to explosives, as well as a phosphorus and nitrogen content resulting from rock quarrying. They will also contain oils and greases, as well as solids. The construction wastewaters will not contain activity. The total emissions shown in Table 5-4 have been estimated on the basis of the emissions of the repository's first construction phase in 1993–1996, but the emissions will probably be lower than this, depending on the treatment method.

The construction wastewater generated in the L/ILW repository during the construction work will be pumped into setting tanks. In the setting tanks, the solids in the water will settle at the bottom, and any oil will be removed from the surface by skimming. From the setting tanks, the waters will be discharged into the sea in a controlled manner. The quality of the waters pumped out will be monitored, especially with regard to nitrogen. When necessary, the wastewater will be treated so that it falls below the emission limits valid at the time. In addition, seepage water from the bedrock will be generated during the expansion work. This seepage water will be treated appropriately prior to its discharge into the sea. When the L/ILW repository is under expansion, the volume of seepage waters will increase temporarily due to the rock engineering.

Process wastewater

During decommissioning and independent operation, conventional process wastewaters will be generated at the raw water treatment plant, water demineralising plant and the condensate purification plant, among others. As the need for these functions decreases, so will the volume of their related process wastewaters. The volume of the process wastewaters and the emission loads carried to water systems along with them are therefore likely to be considerably lower than during operation. Alternatively, they will exceed the initial level only temporarily during decommissioning.

The wastewaters generated in the decontamination of individual pieces during decommissioning will be treated in batches by evaporation, which will result in water with a small nitrogen content being discharged into the sea. During the preparation phase, the emptying of the reactor building's process waters and the wastewaters of the primary system's decontamination will result in a maximum of 7,000–12,000 m³ of purified water which can be discharged into the sea. The volume of the water will depend on the

Table 5-5. The environmental aspects of decommissioning in terms of spent nuclear fuel.

Environmental aspect	Expansion of the L/ILW repository	Decommissioning of the power plant (preparation phase and dismantling phase 1)	The operation and decommissioning of the plant parts to be made independent as well as the closure of the L/ILW repository
Spent nuclear fuel	At this point, the power plant still produces electricity, stored as during current use in the interim storages for spent fuel.	Stored in the interim storages for spent fuel which have been made independent of the power plant.	The use of the interim storages for spent fuel will end once the spent nuclear fuel has been transported for final disposal. The estimated number of road transports for final disposal is 6–8 per year; alternatively, approximately 2 maritime transports per year.

Table 5-6. The quantities of decommissioning waste types per waste hall.

Decommissioning waste Hall	Mass unpacked [t]	Volume in final disposal [m³]
Activated waste		
Pressure vessel silos	870	430
Dismantling waste hall 1	1,490	2,870
Activated, total	**2,360**	**3,300**
Contaminated waste		
Large component hall	2,900	2,500
Dismantling waste hall 1	4,000	7,500
Dismantling waste hall 2	10,500	9,000
Contaminated, total	**17,400**	**19,000**
Maintenance waste etc. Maintenance waste hall 3	**630**	**700**
Solidified waste Solidified waste hall	**350–680**	**1,160–2,260**
Total	**20,740–21,070**	**24,160–25,260**

extent of the decontamination. Once independent operation comes to an end, the treatment of the process waters in the interim storage for spent fuel will result in a maximum of 3,000 m³ of water falling below the emission limits. This water will be discharged into the sea. Radioactive discharges into the water systems are discussed in Chapter 4.12.2.

5.8.4 Spent nuclear fuel

The handling of spent nuclear fuel during decommissioning, as well as its transport and final disposal, are described in Chapter 5.7. Table 5-5 presents the environmental aspects of the decommissioning in terms of the spent nuclear fuel.

5.8.5 Decommissioning waste and operational waste

Operational waste means the low and intermediate-level waste generated during the nuclear power plant's operation. Once the power plant's electricity production has ended, operational waste will still be generated from the operation of the plant parts to be made independent until the beginning of the second dismantling phase. Decommissioning waste means waste which contains activity generated during the preparation phase of the decommissioning and during dismantling phases 1 and 2.

The decommissioning waste accumulated during the preparation phase and dismantling phases 1 and 2 is detailed and broken down by final disposal hall in Table 5-6. In addition to the exterior volume of the final disposal packages or the waste to be deposited in an unpacked form, the table shows the mass of each type of waste in its unpacked form. Decommissioning waste can be categorised according to waste type as follows:

- Activated waste – i.e. equipment and structures exposed to neutron radiation which have themselves become radioactive – will constitute the largest part of the radioactivity of decommissioning waste. When packed, the volume of activated waste will be 3,300 m³.

Table 5-7. The environmental aspects of decommissioning in terms of decommissioning/operational waste.

Environmental aspect	Expansion of the L/ILW repository	Decommissioning of the power plant (preparation phase and dismantling phase 1)	The operation and decommissioning of the plant parts to be made independent as well as the closure of the L/ILW repository
Operational waste	At this point, the power plant will continue to produce electricity; operational waste will be generated in the same manner as in current operation. The expansion of the L/ILW repository will not generate radioactive waste.	Operational waste will not be generated.	• Solidified liquid waste: 260 m³ • Maintenance waste: 20 m³
Decommissioning waste		• Activated waste: 3,300 m³ • Contamined waste: 19,000 m³ • Maintenance waste: 700 m³ • Solidified liquid waste: 2,260 m³ • Concrete with a ver low level of activity: less than 50,000 m³	

- Contaminated waste – i.e. components and structures which have been in contact with radioactive liquids and to which radioactive substances have then stuck, or which have absorbed radioactive substances – will constitute the largest part of the decommissioning waste's volume. The combined volume of packed and unpacked contaminated waste to be deposited in final disposal will be approximately 19,000 m³.
- Maintenance waste resembles the maintenance waste generated during the power plant's operation and includes protective equipment, tools, etc. The volume of maintenance waste generated during the preparation of decommissioning and the dismantling phases will be roughly 700 m³.
- Liquid waste will be generated from the wastewaters of processes, for example, and during decommissioning work phases which use water, such as during the cutting of concrete. The number of waste packages solidified during the decommissioning's preparation phase and the first dismantling phase will be around 520–1,160, depending on the extent of the decontamination and the resulting volume of wastewater, among other things. The corresponding exterior volume of the waste packages will be approximately 900–2,000 m³. Once independent operation comes to an end, all the process waters of the interim storage for spent fuel will be emptied and treated, which will result in approximately 150 solidified waste containers. The volume of these 150 waste containers is 260 m³.

The quantity and radioactivity of operational waste generated by the operation of plants parts that have been made independent will be significantly smaller than that of decommissioning waste. The pool waters will be purified during the independent operation of the interim storage for spent fuel, and the ion-exchangers generated in the purification have been estimated to result in a maximum of 150 solidified waste packages (260 m³), depending on the duration of the independent operation and the waste's accumulation rate. These packages will be deposited for final disposal in the solidified waste hall along with other solidified waste. The operation of the plant parts made independent will generate very little maintenance waste, roughly only 10–20 m³ throughout the period of independent operation. Maintenance waste will be deposited for final disposal in maintenance waste hall 3.

In addition, the plan is to use concrete dismantled from the power plant's buildings as a filling material in the closure of the final disposal halls, given that concrete will provide conditions favourable to long-term safety in the final disposal halls. The concrete that can be used for the filling will include both contaminated concrete with a very low level of activity and concrete free from radioactivity. The maximum volume of concrete with a very low level of activity will be 50,000 m³.

All the decommissioning waste and the operational waste generated after the end of the power plant's electricity production is shown in Table 5-7.

5.8.6 Reusable material and conventional waste

The expansion of the L/ILW repository will generate reusable quarry material. The estimated volume of the rapakivi granite to be quarried is 71,000 m³, which is equivalent to 100,000 m³ as quarry material. The quarry material will be transported by truck from the repository onto the surface and placed in interim storage, insofar as possible, in the power plant area or its immediate vicinity. The quarry material can subsequently be used as a filling material at the time of the L/ILW repository's closure and potentially in the final landscaping of the power plant area. Alternatively, the quarry material can also be used in the earthworks of other operators in the surrounding area. According to the current schedule, the L/ILW repository will be closed once the plant parts to be made independent have been dismantled, meaning that the majority of the quarry material would remain in interim storage for about 40 years.

Table 5-8 presents the environmental aspects of the decommissioning in terms of conventional waste.

Environmental aspect	Expansion of the L/ILW repository	Decommissioning of the power plant (preparation phase and dismantling phase 1)	The operation and decommissioning of the plant parts to be made independent as well as the closure of the L/ILW repository
Reusable material	The volume of rapakivi granite to be quarried is 71,000 m³ which equates to 100,000 m³ of quarry material. The L/ILW repository's expanded total volume will be around 188,000 m³.	Recyclable metal (steel, stainless steel and copper) 21,000–37,000 t. Concrete resulting from the dismantling of buildings 178,000–320,000 t.	Recyclable metal (steel, stainless steel and copper) 4,000–21,000 t. Concrete resulting from the dismantling of buildings 36,000–178,000 t.
Maintenance waste cleared from regulatory control	At this point, the power plant will continue to produce electricity; conventional waste will be generated in the same manner as in the current operation. The expansion of the L/ILW repository will not generate maintenance waste, and the volume of conventional waste will be very low.	2,400 m³	The amount of waste generated in the operation of the plant parts to be made independent which will be cleared from regulatory control will be specified later.
Hazardous waste generated during decommissioning		11,000–40,000 t	2,000–22,000 t
Other conventional waste		Approximately 100–200 t/year	The amount of conventional waste will be very low.

Once the buildings have been cleared from regulatory control, they may be completely dismantled. In this case, conventional materials that may be fit for reuse include concrete and recyclable metals. The buildings to be dismantled have been estimated to contain a total of 355,000 tonnes of concrete and 41,000 tonnes of recyclable metals. According to current plans, there is not yet full certainty about the buildings which will be dismantled in connection with the actual decommissioning, and which buildings are to be dismantled in connection with the dismantling of the plant parts to be made independent. Some of the buildings may also be left to be dismantled after the dismantling of the independent plant parts. It can nevertheless be estimated that the buildings to be dismantled in connection with the decommissioning will account for 50–90% of the amount of concrete and recyclable metal.

Based on experiences from the Inkoo dismantling project, hazardous waste pursuant to section 6 of the Waste Act (646/2011) will account for approximately 5–10% of the total volume of dismantling waste. In the decommissioning of Loviisa power plant, this equates to 11,000–40,000 tonnes of waste and 2,000–22,000 tonnes in the dismantling of the plant parts to be made independent, depending on which buildings will be dismantled during each phase. The quantity of the hazardous waste will be specified later.

Conventional maintenance waste, most of which can be cleared from regulatory control, will also be generated. The portion of waste to be cleared from regulatory control every year at Loviisa power plant has increased in recent years. Currently, some 80% of the waste generated at the power plant is cleared from regulatory control. Estimates put the volume of maintenance waste generated during decommissioning and to be deposited for final disposal at 600 m³. This allows an estimate that the volume of waste generated and cleared from regulatory control would be around 2,400 m³. The activity distribution of the waste generated during decommissioning may differ from that of the maintenance waste generated during operation, due to which the aforementioned estimate is indicative.

The waste volume estimates of the plant parts to be made independent will be specified later. It is nevertheless likely that the plant parts to be made independent will generate much less maintenance waste than during normal operation. The amount of other conventional waste generated is estimated to be less than during operation, roughly 100–200 tonnes a year.

Table 5-8 presents the environmental aspects of the decommissioning in terms of conventional waste.

5.8.7 Chemicals

The greatest temporary need for the use of chemicals during the decommissioning will occur in connection with the possible decontamination of the primary system. The extent of and need for decontamination will be determined prior to the closure of the power plant units once the systems' activity levels during decommissioning are known. The primary

Table 5-9. The environmental aspects of decommissioning in terms of chemicals.

Environmental aspect	Expansion of the L/ILW repository	Decommissioning of the power plant (preparation phase and dismantling phase 1)	The operation and decommissioning of the plant parts to be made independent as well as the closure of the L/ILW repository
Chemicals	Explosives will be used in the quarrying of the L/ILW repository. At this point, the power plant will produce electricity normally. Chemicals will be used as during the current operation.	Chemicals will be used in decontamination work, the solidification of liquid waste, the neutralisation of waste solutions and in pH control, among other processes. Used in the decontamination of the primary system: Oxalic acid (11 tonnes) Permanganic acid (40 m^3) Hydrogen peroxide (2 tonnes) The chemicals will be treated appropriately.	At the liquid waste storage, chemicals will be used for solidification and the control of pH values, maintaining the boron content of the water in the interim storages for spent fuel and in the water demineralising plant/treatment of radioactive gaseous waste. The chemicals will be treated appropriately.

system's decontamination will be carried out during the preparation phase of the decommissioning, possibly with the HP/CORD UV method, in which the decontamination chemicals used are oxalic acid and permanganic acid. Part of the decontamination solution can be broken down into water and carbon dioxide by means of UV degradation. The degradation process also relies on hydrogen peroxide. Ion-exchanger resins and evaporation will also be used in the treatment of the decontamination solutions and waters generated. The used ion-exchange resins and the evaporation concentrates resulting from the evaporation are solidified into concrete containers and deposited for final disposal.

The maximum amounts of the required chemicals can be estimated on the basis of the large-scale decontamination of Loviisa 2's primary system carried out in 1994 during operation. The amount of permanganic acid ($HMnO_4$) used at the time was 20 m^3, while the amount of oxalic acid ($C_2H_2O_4$) used was 5,300 kg. Hydrogen peroxide (H_2O_2) use amounted to 1,000 kg. The decontamination to be carried out during decommissioning will not require as much hydrogen peroxide as the decontamination carried out during operation, because during operation, it is used, in addition to UV degradation, to form a protective layer in the piping to prevent recontamination. The protective layer will not be necessary during the decommissioning, given that the risk of contamination is no longer relevant. The aforementioned figures concern a single power plant unit, meaning that the figures will be doubled for the decommissioning. The decommissioning's other decontamination work will rely on the same chemicals as during the power plant's operation. The chemicals to be used are oxalic acid ($(COOH)_2$), sodium hydroxide (NaOH) and potassium permanganate ($KMnO_4$). The dismantling work to be carried out in the power plant units and the decontaminations of small individual pieces to be carried out in the site will rely on various solvents and oils, for example.

In decommissioning, the systems related to the primary system will be emptied and rinsed during the decommissioning's preparation phase. After this, the primary system's water chemistry will no longer need to be maintained.

The processes of the plant parts to be made independent require boric acid (H_3BO_3), nitric acid (HNO_3), sulphuric acid (H_2SO_4) and sodium hydroxide. The boric acid will be used to maintain the level of boron content in the fuel pools of the interim storage for spent fuel required for maintaining a sufficient subcriticality margin. The nitric acid will be used to adjust the pH value of the evaporation concentrate in the liquid waste storage. Meanwhile, sodium hydroxide and sulphuric acid will be required at the water demineralising plant. Sodium hydroxide is also used in the treatment of radioactive gaseous waste and in the solidification plant's solidification processes.

Unnecessary chemical tanks are emptied, and their content is treated appropriately as hazardous waste.

Explosives will be used in the quarrying work of the L/ILW repository's expansion.

The environmental aspects of the decommissioning in terms of chemicals are shown in Table 5-9.

5.8.8 Noise, vibration, traffic and conventional emissions into the air

Temporary noise from underground blasting work, the transport of quarry material to the surface and the ventilation system in use during quarrying will be generated during the L/ILW repository's three-year expansion phase. If some of the quarry material needs to be crushed for further use, the crushing will be carried out, insofar as possible, in the vicinity of the area where the quarry material was generated.

The noise during the dismantling phase of the decommissioning systems can be equated with the noise caused by construction work. This noise is momentary, and the systems' dismantling work will take place largely within buildings. Most occasional noise will be generated by the dismantling of buildings cleared from regulatory control, if they are dismantled according to the greenfield principle, and the crushing of the concrete resulting from the dismantling. The independent operation of the interim storages for spent fuel will generate very little noise, mostly deriving from ventilation and other equipment.

Vibration will be generated by the underground blasting work of the L/ILW repository's expansion, the transport of the quarry material to the interim storage area and the stacking itself, the most large-scale dismantling work and by the heavy-duty vehicles primarily in the power plant area. The vibration effects of the L/ILW repository's construction work will be minimised with the help of quarrying plans.

The traffic generated by the decommissioning will be mainly generated in the power plant area or in its vicinity and relate to the quarry material's transport to interim storage, the transport of the decommissioning waste to the L/ILW repository and finally, from the transport of the L/ILW repository's filling or quarry material. The transports of the rock quarried during the L/ILW repository's expansion to the interim storage area will require some 5,000–11,000 transports, depending on the vehicles. Estimates put the number of transports needed throughout the dismantling work of the decommissioning for the transport of the waste to be deposited in the L/ILW repository for final disposal at approximately 4,000, and the number of heavy and oversized transports at less than 80. During the L/ILW repository's closure phase, the number of transports needed to transport filling or quarry material to the L/ILW repository equates roughly to the number of transports needed in connection with the L/ILW repository's quarrying.

Other traffic in the power plant area will be generated by the transport of waste to be removed, the goods delivered to the power plant area and personnel traffic. Depending on the phase of the decommissioning work, estimates put the maximum number of heavy-duty transports a day at 100. The number of heavy-duty transports during independent operation will be lower than during the plant's operation and will amount to some 40 vehicles a day at most. During the construction work of the L/ILW repository's expansion, the personnel traffic will increase by a maximum of a few dozen cars a day. At its busiest, personnel traffic during the dismantling phases of the decommissioning is estimated to amount to a maximum of 800 cars a day, and during independent operation, to a maximum of 250 cars a day. The rock engineering and dismantling equipment to be delivered to the power plant area are likely to require occasional heavy and oversized transports. The estimated number of road transports of spent nuclear fuel for final disposal is 6–8 per year; alternatively, approximately 2 maritime transports per year. Even at their greatest, the traffic volumes are estimated to be in the region of the traffic during the annual outages of current operation.

Conventional emissions into the air consist of tailpipe emissions, the construction dust generated by the dismantling work, the dust raised by traffic, the stone dust generated by underground blasting, the transport of quarry material and its stacking, as well as of the nitrogen oxide and sulphur oxide emissions resulting from the underground blasting. The dust resulting from the driving and stacking of the quarry material, in particular, can be reduced by hosing down the loads of quarry material and the stacking area in dry weather. In addition, during the decommissioning and independent operation the power plant area will have diesel used only when necessary. Their periodic testing will generate some nitrogen oxide and sulphur oxide emissions as well as particulate emissions.

Table 5-10 details the noise, vibration, traffic and conventional emissions into the air generated during the L/ILW repository's expansion, the power plant's decommissioning and independent operation.

5.8.9 Emissions of radioactive substances and their limitation

After the spent nuclear fuel has been transferred from the reactor building to the interim storage for spent fuel, the power plant unit cannot be the source of any significant radioactive emissions into the environment. During decommissioning, limited radioactive emissions into the air or water systems may result from the dismantling of the power plant's radioactive structures and systems and their treatment, as well as from the treatment of the remaining radioactive process solutions. Activity emissions will primarily be influenced by the selected dismantling and treatment methods (such as decontamination and filtering) as well as by the time of the emissions compared to the end of the power plant's operation (delaying). Decommissioning plans ensure that the spread of radioactive substances can be reliably prevented during decommissioning. The dismantling follows procedures similar to those in use during the power plant's annual outages, when contaminated systems are opened and serviced.

The emissions generated during Loviisa power plant's decommissioning phase cannot be estimated at this stage of planning, given that not all the dismantling and treatment methods to be used have been specified and selected yet. The targets and emission limits for radioactive emissions during the decommissioning phase will be defined as the decommissioning plans progress. In addition to the emissions generated, the emission limits will be influenced by the flow of cooling waters, for example. A detailed assessment of the need for cooling water during the decommissioning phase has not been possible at this stage of planning, because the cooling technologies influencing it – including heat exchangers, heat pumps or cooling towers – have yet to be determined and selected. In any case, the need for cooling water during the decommissioning phase will be much smaller than for a power plant in production. A reduction in the flow of cooling water has a significant impact on the dilution of wastewater discharges. It therefore also influences emission limits, due to which the emission limits of an operational power plant cannot be applied to a decommissioning. The emission limits within the framework of which the decommissioning must be carried out are confirmed by STUK. The Nuclear Energy Decree sets the limit for the annual dose to which a member of the public is exposed in connection with the decommissioning of a nuclear power plant or other nuclear facility with a nuclear

Table 5-10. The environmental aspects of the decommissioning in terms of noise, vibration, traffic and conventional emissions into the air.

Environmental aspect	Expansion of the L/ILW repository	Decommissioning of the power plant (preparation phase and dismantling phase 1)	The operation and decommissioning of the plant parts to be made independent as well as the closure of the L/ILW repository
Noise	At this point, the power plant will continue to produce electricity; noise will be generated in the same manner as in current operation. The L/ILW repository's underground blasting work, ventilation system, transports of quarry material, the stacking of quarry material and the possible crushing of the quarry material will generate temporary noise.	The dismantling work and the crushing of concrete will cause occasional noise.	Some equipment generating noise will be in use; compared to the noise during the power plant's operation, this noise will be negligible. Occasional noise from dismantling work.
Vibration	Vibrations will be generated by underground blasting work, heavy-duty transports and the stacking of quarry material.	Occasional vibrations will be generated during heavy-duty transports and dismantling work of a larger scale.	Not much vibration.
Traffic	At this point, the power plant will continue to produce electricity; traffic will be at the same level as during current operation (total volume of traffic 500 vehicles/day, of which heavy-duty traffic 40 vehicles/day). A small increase to the personnel traffic during operation. Transport of quarry material: approximately 5,000–11,000 trucks. Individual transports by special vehicles.	Maximum passenger traffic 800 cars/day. Maximum heavy-duty traffic 100 vehicles/day. Waste transports to the L/ILW repository: roughly 3,000 truckloads and less than 70 heavy and oversized transports.	The maximum volume of passenger traffic during independent operation will be 250 vehicles/day. Heavy-duty traffic less than 40 vehicles/day. The maximum volume of passenger traffic during the second dismantling phase will be 800 vehicles/day. The maximum volume of heavy-duty traffic will be fewer than 100 vehicles/day. Waste transports to the L/ILW repository: roughly 1,000 truckloads and less than 10 heavy and oversized transports. Transports of filling material for repository's closure: roughly 5,000–11,000 truckloads.
Conventional emissions into the air	At this point, the power plant will continue to produce electricity; conventional emissions into the air will be generated in the same manner as in current operation. Emissions of nitrogen oxide and sulphur oxide resulting from underground blasting work: the quantity of explosives consumed will be roughly 50 tonnes, of which some will end up as emissions into the air. A small increase in tailpipe emissions due to the expansion of the L/ILW repository. Underground blasting work, as well as the crushing, transport and stacking of quarry material, will generate dust.	Tailpipe emissions and dust caused by the dismantling work.	Tailpipe emissions and dust caused by the dismantling work. Diesel generators and engines: some nitrogen oxide, carbon dioxide, sulphur dioxide and particulate emissions.

Table 5-11. The environmental aspects of decommissioning in terms of radioactive emissions.

Environmental aspect	Expansion of the L/ILW repository	The power plant's decommissioning (preparation phase and dismantling phase 1)	The operation and decommissioning of the plant parts to be made independent as well as the closure of the L/ILW repository
Radioactive discharges into water systems	The L/ILW repository's expansion will not generate radioactive emissions.	The emissions fall below the limits confirmed by STUK, which means that they have no impact on health.	
Radioactive emissions into the air			

reactor at 0.01 mSv (section 22 b 161/1988). The environmental aspects related to decommissioning are summarised in Table 5-11.

5.8.9.1 *Discharges into water systems*

Radioactive discharges into the sea during decommissioning will be mainly the result of the emptying of the process systems. The discharges generated will be limited by subjecting the process solutions to efficient treatment before directing them into the sea. The solutions will be treated with the best applicable methods, including various filtering methods or by using selective ion-exchange materials, which are efficient in removing radionuclides from the solutions. Delaying can also be used when necessary, in which case the radiation levels of radionuclides with a short half-life will have the time to decrease to an insignificant level. Following the treatment of wastewaters, prior to discharge into the sea, the water's activity level will be analysed, and based on the results, the liquid will either be directed for retreatment, or it will be permitted to be discharged into the sea. Some of the liquids (such as decontamination solutions) will probably be solidified due to their activity concentration and composition, and deposited for final disposal.

The power plant's extended operation (VE1) would allow for the treatment of liquid waste accumulated during operation before the operation comes to an end, and would therefore free tank capacity during the decommissioning phase for the solutions generated in the emptying of processes, providing more opportunities for the treatment of these solutions.

Given that the methods for treating the process waters and the cooling technologies have yet to be selected, the radioactive discharges into the water systems cannot yet be estimated. The methods to be used will nevertheless be selected in such a way that the confirmed emission limits are not exceeded, in which case there will be no health effects.

5.8.9.2 *Emissions into air*

Radioactive aerosol emissions into the air during the decommissioning phase will result from the opening of the systems and the dismantling of structures. To limit emissions, separate working spaces with negative pressure and furnished with filtered exhaust air will be built during the dismantling phase, provided that the object of the dismantling requires it. The used filters will be treated as radioactive waste, and the filtered air will be fed into the outdoor air through a ventilation pipe.

The dismantling methods to be used and the filtering of working spaces have not been specified at this stage of planning, which means the radioactive emissions into the air during decommissioning cannot be estimated yet. The methods to be used will nevertheless be selected in such a way that the confirmed emission limits are not exceeded, in which case there will be no health effects.

5.8.10 Summary of the environmental aspects of decommissioning

The environmental aspects of the decommissioning are summarised in Table 5-12.

5.9 DIFFERENCES IN DECOMMISSIONING IN THE DIFFERENT OPTIONS

In Option VE1, the decommissioning is implemented, for the most part, in a manner corresponding to how the decommissioning in VE0 is described, with the most significant difference being the time of the decommissioning. In the case of the extension of the power plant operation (Option VE1), commercial operation would be extended by a maximum of approximately 20 years, making the total service life of the power plant units about 70 years. The power plant's decommissioning would take place roughly between 2050 and 2060. The tentative schedules for Options VE1 and VE0 are presented in Chapter 3.

The other identified matters to be noted or differences between Options VE0 and VE1 are:

- In Option VE0, the duration of the preparation phase is approximately three years in terms of both power plant units, and the preparation phase is similar for both of the units. In Option VE0, the purchases made and waste handling spaces built during Loviisa 1's preparation phase can be utilised during the preparation phase of Loviisa 2. This is likely to slightly shorten the preparation phase of Loviisa 2. In the case of Option VE1, the operation of both power plant units can be discontinued simultaneously or with a shorter delay. If the preparation phases of the power plant units are not staggered, the schedule will not contain the aforementioned difference.

Table 5-12. Summary of the environmental aspects related to decommissioning.

Environmental aspect	Expansion of the L/ILW repository	Decommissioning of the power plant (preparation phase and dismantling phase 1)	The operation and decommissioning of the plant parts to be made independent as well as the closure of the L/ILW repository
Cooling water	The expansion of the L/ILW repository does not require cooling water. (At this point, the power plant produces electricity as usual; the need for and use of cooling water as during current operation: an average of 1,300 million m^3/year and 57,000 TJ/year).	The need for cooling water (roughly 1.6 million m^3/year) and the thermal discharge (at maximum 46.5 TJ a year) will be a fraction of what they are during the power plant's current operation.	
Service water requirement and supply	The quarrying work will require approximately 15,000–150,000 m^3 of water a year. (At this point, the power plant will continue to produce electricity; the need for service water is equal to current operation: Process water 100,000–200,000 m^3/year Domestic water 25,000–75,000 m^3/year	Domestic water 13,000–57,000 m^3/year Process water varyingly, but less than during operation, on average.	Domestic water less than during decommissioning. Process water markedly less than during operation.
Sanitary wastewaters	The impact of contractors' personnel will be minor.	The volume will be the same as or less than during operation.	The volume will be smaller than during the power plant's operation.
Construction and process wastewaters	Construction wastewater varyingly: 15,000–150,000 m^3/year for a period of three years; estimated total emissions: oils and greases < 2,000 kg phosphorus < 35 kg nitrogen < 2,600 kg solids < 63 t The volume of the L/ILW repository's seepage water will increase temporarily.	The average volume of conventional process wastewater is lower than during operation. Any unnecessary chemicals remaining in the tanks will be processed as harmful substances. Wastewater from the decontamination of individual pieces that falls below emission limits. Emptying of process systems: less than 12,000 m^3 of water that falls below emission limits.	The volume of conventional process wastewater will be markedly lower than during the power plant's operation. Emptying of process systems: less than 3,000 m^3 of water that falls below emission limits.
Spent nuclear fuel	At this point, the power plant still produces electricity, stored as during current use in the interim storages for spent fuel.	Stored in the interim storages for spent fuel which have been made independent of the power plant.	The use of the interim storages for spent fuel will end once the spent nuclear fuel has been transported for final disposal. The estimated number of road transports for final disposal is 6–8 per year; alternatively, approximately 2 maritime transports per year.
Operational waste	At this point, the power plant will continue to produce electricity; operational waste will be generated in the same manner as in current operation. The expansion of the L/ILW repository will not generate radioactive waste.	Operational waste will not be generated.	• Solidified liquid waste: 260 m^3 • Maintenance waste: 20 m^3.
Decommissioning waste		• Activated waste: 3,300 m^3 • Contaminated waste: 19,000 m^3 • Maintenance waste: 700 m^3 • Solidified liquid waste: 2,260 m^3 • Concrete with a very low level of activity: less than 50,000 m^3.	

Environmental aspect	Expansion of the L/ILW repository	Decommissioning of the power plant (preparation phase and dismantling phase 1)	The operation and decommissioning of the plant parts to be made independent as well as the closure of the L/ILW repository
Reusable material	The volume of rapakivi granite to be quarried is 71,000 m^3 which equates to 100,000 m^3 of quarry material. The L/ILW repository's expanded total volume will be around 188,000 m^3.	Recyclable metal (steel, stainless steel and copper) 21,000–37,000 t. Concrete resulting from the dismantling of buildings 178,000–320,000 t.	Recyclable metal (steel, stainless steel and copper) 4,000–21,000 t. Concrete resulting from the dismantling of buildings 36,000–178,000 t.
Maintenance waste cleared from regulatory control	At this point, the power plant will continue to produce electricity; conventional waste will be generated in the same manner as in the current operation. The expansion of the L/ILW repository will not generate maintenance waste, and the volume of conventional waste will be very low.	2 400 m^3	The amount of waste generated in the operation of the plant parts to be made independent which will be cleared from regulatory control will be specified later.
Hazardous waste generated during decommissioning		11,000–40,000 t	2,000–22,000 t
Other conventional waste		Approximately 100–200 t/year	The amount of conventional waste will be very low.
Chemicals	Explosives will be used in the quarrying of the L/ILW repository. At this point, the power plant will produce electricity normally. Chemicals will be used as during the current operation.	Chemicals will be used in decontamination work, the solidification of liquid waste, the neutralisation of waste solutions and in pH control, among other processes. Used in the decontamination of the primary system: Oxalic acid (11 tonnes) Permanganic acid (40 m^3) Hydrogen peroxide (2 tonnes) The chemicals will be treated appropriately.	At the liquid waste storage, chemicals will be used for solidification and the control of pH values, maintaining the boron content of the water in the interim storages for spent fuel and in the water demineralising plant/treatment of radioactive gaseous waste. The chemicals will be treated appropriately.
Noise	At this point, the power plant will continue to produce electricity; noise will be generated in the same manner as in current operation. The L/ILW repository's underground blasting work, ventilation system, transports of quarry material, the stacking of quarry material and the possible crushing of the quarry material will generate temporary noise.	The dismantling work and the crushing of concrete will cause occasional noise.	Some equipment generating noise will be in use; compared to the noise during the power plant's operation, this noise will be negligible.
Vibration	Vibrations will be generated by underground blasting work, heavy-duty transports and the stacking of quarry material.	Occasional vibrations will be generated during heavy-duty transports and dismantling work of a larger scale.	Not much vibration.
Traffic	At this point, the power plant will continue to produce electricity; traffic will be at the same level as during current operation (total volume of traffic 500 vehicles/day, of which heavy-duty traffic 40 vehicles/day). A small increase to the personnel traffic during operation. Transport of quarry material: approximately 5,000–11,000 trucks. Individual transports by special vehicles.	Maximum passenger traffic 800 cars/day. Maximum heavy-duty traffic 100 vehicles/day. Waste transports to the L/ILW repository: roughly 4,000 truckloads and less than 80 heavy and oversized transports.	The maximum volume of passenger traffic during independent operation will be 250 vehicles/day. Heavy-duty traffic less than 40 vehicles/day. The maximum volume of passenger traffic during the second dismantling phase will be 800 vehicles/day. The maximum volume of heavy-duty traffic will be fewer than 100 vehicles/day. Transports of filling material for repository's closure: roughly 5,000–11,000 truckloads.

Environmental aspect	Expansion of the L/ILW repository	Decommissioning of the power plant (preparation phase and dismantling phase 1)	The operation and decommissioning of the plant parts to be made independent as well as the closure of the L/ILW repository
Conventional emissions into the air	At this point, the power plant will continue to produce electricity; conventional emissions into the air will be generated in the same manner as in current operation. Emissions of nitrogen oxide and sulphur oxide resulting from underground blasting work: the quantity of explosives consumed will be roughly 50 tonnes, of which some will end up as emissions into the air. A small increase in tailpipe emissions due to the expansion of the L/ILW repository. Underground blasting work, as well as the crushing, transport and stacking of quarry material, will generate dust.	Tailpipe emissions and dust caused by the dismantling work.	Tailpipe emissions. Diesel generators and engines: some nitrogen oxide, carbon dioxide, sulphur dioxide and particulate emissions.
Radioactive discharges into water systems	The L/ILW repository's expansion will not generate radioactive emissions.	The emissions fall below the limits confirmed by STUK, which means that they have no impact on health.	
Radioactive emissions into the air			

- If operation is extended (VE1), due to the simultaneous end of both power plant units' operation, the dismantling phases may be carried out more quickly at the power plant units, and the duration of the dismantling phases would be between 3 and 3.5 years per power plant unit.
- The final disposal capacity of the L/ILW repository's current expansion plan has been deemed adequate for all of the waste, also in the event that the power plant's service life would be extended in accordance with Option VE1. The main reasons for this are the success achieved in reducing the accumulation rate of the operational waste generated during operation, and the fact that an extension of service life would not significantly increase the volume of the decommissioning waste.
- If 20 years is added to the power plant's service life in line with VE1, the volume of the nuclear waste generated during operation and the activity of some types of decommissioning waste will increase. The amount by which the total activity increases can be influenced by the accumulation rate of the waste type, the neutron flux it experiences, and the half-life of the nuclides it contains. In the case of a new operating licence, if it is assumed that the repository's closure is delayed by 20 years, the activity of the decommissioning waste when the repository closes, around 2088, will be in the region of 33,000 TBq. In Option VE0, the activity is estimated to be around 22,000 TBq.
- The total quantity of the spent nuclear fuel to be held in interim storage in the power plant area is approximately 7,700 bundles in Option VE0, and in Option VE1, with a 20-year extension period, no more than 12,800 bundles. Posiva's final disposal facility also has room for the amount of fuel generated during the 20-year extension of Loviisa power plant's operation (Posiva Oy 2008). Posiva possesses a decision-in-principle and a building permit for the final disposal of 6,500 tonnes of uranium (tU). The amount of spent nuclear fuel to be accumulated from the three Olkiluoto power plant units and two Loviisa power plant units during their service lives pursuant to current plans is roughly 5,500 tU. The extension of the service life of Loviisa's power plant units by 20 years would put the amount of spent nuclear fuel accumulated by the five power plant units at approximately 6,000 tU.
- According to current estimates, the transport of the spent nuclear fuel for final disposal will begin in the 2040s, lasting for approximately 10–20 years. In Option VE1, the transports will possibly begin later and last longer than in Option VE0.
- The power plant's extended operation (VE1) would allow for the treatment of liquid waste accumulated during operation before the operation comes to an end, and thereby provide more alternatives for the arrangement of the treatment of process waters during the preparation phase.
- More experiences of the decommissioning of nuclear power plants from other countries could be accumulated during the power plant's extended operation (VE1). Among other things, this would allow for the development of the techniques used in the decommissioning, due to which the impact on the environment could reduce.

6. VE0+: Radioactive waste generated elsewhere in Finland and received at Loviisa power plant

Option VE0+ is the same as Option VE0 (see Chapter 5) in all other respects except that Option VE0+ includes the possibility of receiving radioactive waste generated elsewhere in Finland and processing it, placing it in interim storage and depositing it for final disposal at Loviisa power plant. The same possibility is also included in Option VE1 (see Chapter 4), meaning that even if the power plant's operation is extended, it will be possible to receive radioactive waste generated elsewhere in Finland and process it, place it in interim storage and deposit it for final disposal at Loviisa power plant. Radioactive waste generated elsewhere can consist of the radioactive waste of the state, the industrial sector, universities, research institutions and hospitals, for example.

The reception of radioactive waste generated elsewhere in Finland at Loviisa power plant is assessed waste batch-specifically, taking into account the handling, packaging, storage and final disposal methods required by and available for the waste. As a rule, the methods are suitable for waste that is similar to low and intermediate-level operational waste generated by Loviisa power plant.

Receiving radioactive waste originating from elsewhere in Finland at Loviisa power plant during the current operating period or the extension of the power plant's operation is technically possible. The activities may continue during the operation and dismantling of the plant parts to be made independent for as long as the functions needed for the management and final disposal of waste are available.

6.1 GENERAL DESCRIPTION OF ACTIVITIES

The National Nuclear Waste Management Cooperation Group set up by the Ministry of Economic Affairs and Employment in June 2017 has considered it important that all existing and future radioactive waste in Finland, regardless of its origin, producer, or production method is managed appropriately (MEAE 2019). Since Loviisa power plant already has functions and facilities suitable for the handling and final disposal of radioactive waste in place, it would be natural and in line with the recommendations of the National Nuclear Waste Management Cooperation Group that they would be available as part of the overall social solution.

The activities would cover the reception, processing and interim storage of radioactive waste generated elsewhere in Finland at Loviisa power plant as well as its final disposal in a final disposal facility for low and intermediate-level waste. For example, the waste generated elsewhere may consist of the radioactive waste of the state, industrial sector, universities, research institutions and hospitals as well as the waste generated during the operation and dismantling of VTT Technical Research Centre of Finland Ltd's (VTT) FiR research reactor and Otakaari 3 research laboratory and the new VTT Centre for Nuclear Safety, all located in Espoo.

Among other things, the reception of the waste requires separate commercial agreements and a review of the suitability of the waste in question. A conditional agreement on the reception of the decommissioning waste of the FiR 1 research reactor and the Otakaari 3 research laboratory already exists. The agreement will be implemented if the licence for the activities is secured and if no impediments for the final disposal of the waste are encountered. No agreements currently exist for other potential waste, which is why no specifics on such waste is available at this time. Chapter 6.2.3 includes a review of what the waste possibly received could contain.

6.2 ORIGIN AND AMOUNT OF WASTE

The estimated maximum volume of waste originating from elsewhere in Finland and disposed of at Loviisa power plant is 2,000 m^3. Given that the total volume of the active waste to be deposited for final disposal in Loviisa power plant's L/ILW repository is no more than 100,000 m^3, the volume of waste originating from elsewhere in Finland and received at Loviisa power plant is small by comparison.

6.2.1 Decommissioning waste of the FiR 1 research reactor

VTT's FiR 1 research reactor in Otaniemi, Espoo, was procured by the State of Finland from the United States in 1960, for the training and research purposes of the Helsinki University of Technology (Figure 6-1). The research reactor was transferred into VTT's possession in 1971. Since 1962, the reactor has been used for research, instruction, isotope production and other service operations. In 1999–2012, the FiR 1 research reactor was also used for the administration of

Figure 6-1. The research space above VTT's FiR 1 reactor can be seen on the left and the research reactor is on the right (Ministry of Economic Affairs and Employment, 2019).

Table 6-1. Summary of the waste volumes of the FiR 1 research reactor. The masses and volumes are presented unpacked. (Räty 2019)

Material	Volume [m³]	Mass [kg]	Most important nuclides	Total activity [TBq]
Concrete of biological shield	25.0	61,000	H-3, Fe-55, Co-60, Eu-152, K-40	0.11
Graphite	2.6	4,450	H-3, C-14, Eu-152, Co-60, Ba-133, Cl-36	0.46
Steel	0.4	3,540	Ni-63, Fe-55, Co-60, Ni-59, C-14	1.91
Aluminium	0.8	2,230	Fe-55, Zn-65, Ni-63, Co-60, Mn-54, Fe-59	0.03
Fluental	0.5	1,330	H-3, C-14	1.30
Lithionised plastic	1.4	2,000	H-3, C-14	0.43
Other*	7.1	19,780		0.005
Total	37.8	94,330		4.24

** Includes: heavy-weight concrete, lead, wood, bitumen, boral, bismuth, ion-exchange resin*

radiotherapy. VTT closed the FiR 1 research reactor permanently in the summer of 2015 and in the summer of 2017, applied to the government for a licence for the research reactor's decommissioning and dismantling. The decommissioning is intended to begin no later than 2023 and the premises should be handed over to Aalto University by 2025. The FiR 1 research reactor is the first nuclear facility in Finland to be decommissioned. Its decommissioning and dismantling could also provide useful expertise and experience for the decommissioning of other nuclear facilities. (MEAE 2019)

The nuclear fuel used in the FiR 1 research reactor originates from the United States. The nuclear fuel is part of a global programme run by the United States' Department of Energy (DOE) within the framework of which the United States receives spent nuclear fuel and sees to its interim storage and final disposal (Työ- ja elinkeinoministeriön julkaisuja 2019:39). According to section 6 a of the Nuclear Energy Act (990/1987), spent nuclear fuel generated in Finland in connection with the use of a research reactor can be returned to its country of origin, the United States.

The FiR 1 research reactor's other radioactive waste is composed of waste generated during the operation of the research reactor and the dismantling waste generated during the decommissioning. Table 6-1 presents an estimate on the quantity of this waste. The dismantling waste will consist of a few dozen cubic metres of concrete, steel, aluminium, graphite and the moderator Fluental, used in the radiation therapy station, all with a low or intermediate level of activity (Räty, 2019). These materials are non-combustible. Most of the activity in the steel, graphite and aluminium parts is in particular sections that have been near the reactor core (such as the irradiation ring and graphite reflector), due to which most of the materials in question are of low activity.

The FiR 1 research reactor's operation and dismantling work has also resulted in a small quantity of mildly radioactive maintenance waste, such as overalls and plastic. Estimates put the packaged volume of the waste to be deposited in final disposal at approximately 100 m³, and the total activity of the waste is less than 5 TBq.

6.2.2 Decommissioning waste of the Otakaari 3 research laboratory

VTT also has a research laboratory at Otakaari 3, which VTT will decommission within the next few years (Figure 6-2). Radioactive material (including material research samples) has accumulated during the laboratory's approximately 40 years of use, in addition to which around 50 m³ of packaged radioactive waste will be generated during the laboratory's decommissioning (MEAE 2019).

The waste to be deposited in final disposal consists primarily of metal samples, concrete, maintenance waste as well as piping and equipment. As a rule, the metal samples are returned by VTT to their original owners, which also include Loviisa power plant, whose material samples have been studied at VTT. However, there are some samples

Table 6-2. Summary of the estimated quantities of the Otakaari 3 research laboratory's decommissioning waste. The volume of waste is shown as unpackaged. (Räty 2019)

Waste type	Mass (kg)	Volume (m³)	Activity (GBq)
Activated metal samples	300	0.01	1,640
Contaminated concrete	11,000	5	0.3
Contaminated equipment	3,500	5	0.03
Maintenance waste	2,500	10	0.03
Contaminated pipes	2,000	3	0.015
Other	2,000	3	0.015
Total	21,300	26	1 700

which can no longer be returned to their owners and the intention is to deliver these samples to Loviisa's L/ILW repository for final disposal. The unpackaged quantity of the waste to be deposited for final disposal is presented in Table 6-2. When packaged, the volume of the waste is approximately 50 m³.

6.2.3 Other waste

In addition to the decommissioning waste generated by the dismantling of the Otakaari 3 research reactor and the research laboratory, radioactive waste generated by other actors in society could also be deposited in Loviisa power plant's L/ILW repository. In addition to nuclear facilities, radioactive waste in Finland is generated in the fields of healthcare, industrial activities and research.

A significant portion of radioactive waste in the **field of healthcare** derives from various unsealed and sealed sources, the activity levels of which range from high to low. Sealed sources are normally returned to their foreign manufacturers. The return of certain Sr-90, Ra-226 and Co-60 sources has nevertheless proved difficult, which is why these sources will be processed and deposited for final disposal in Finland. Sealed sources in the **industrial sector** are used in a variety of analysing and metering equipment. The most common nuclides in use are caesium-137, cobalt-60, krypton-85, strontium-90, americium-241 and beryllium-9. The activity levels of these sealed sources vary, but are typically less than 100 GBq. Sealed sources used in the industrial sector are also normally returned to their foreign suppliers. There are nevertheless sealed sources in Finland which no longer have a foreign recipient, due to which these sources must be processed and deposited for final disposal in Finland. The industrial sector has some 6,000 sealed sources in use. This represents the majority of all sealed sources in the possession of operators in Finland. Figure 6-3 shows an example of a sealed source used in the industrial sector.

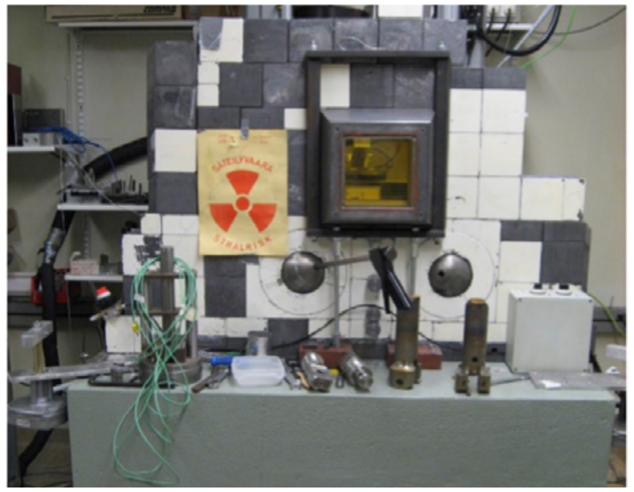

Figure 6-2. Contaminated facilities in VTT's Otakaari 3 research laboratory (MEAE 2019).

Figure 6-3. Radiation source Kr-85 (MEAE 2019).

Radioactive waste in the field of **research** is generated when using radioactive tracers, for example, or when using radiation sources. The waste generated typically consists of protective equipment as well as research and cleaning equipment contaminated by radioactivity. The waste is usually stored in the institutions' own facilities until final disposal or, when possible, disposed of in the same manner as conventional waste.

An operator using a radioactive material is obligated to ensure the processing of any radiation sources to be disposed of and any other material emitting radiation. Records must be kept of the material and it must be packed and labelled in the appropriate manner. The label must include the information necessary for the waste's safe processing.

STUK received the radioactive waste of other operators until 2010. Since then, this activity has been carried out by Suomen Nukliditekniikka Oy. Until 1996, the storage of the received radiation sources took place in an area controlled by the Finnish Defence Forces in Helsinki. At this point, the State of Finland leased a storage space from TVO's final disposal facilities for nuclear power plant waste in Olkiluoto. The total activity of the waste deposited in Olkiluoto's storage for small waste was around 50 TBq at the end of 2013, with the principal radionuclides being tritium, caesium-137, krypton-85, americium-241 and plutonium-239. New waste accumulates in the storage at a rate of 1–3 m^3 a year. TVO is also licensed to deposit small waste in its own final disposal halls.

The actual amount of waste generated by external operators and possibly to be deposited for final disposal in Loviisa remains unclear, because it is influenced by a large number of factors. A rough estimate made on the basis of current waste accumulation nevertheless puts the maximum volume of radiation sources to be deposited for final disposal at 100–200 m^3. In addition, waste to be deposited for final disposal will possibly be derived from the recovery of uranium and the new VTT Centre for Nuclear Safety. The maximum volume of such waste is estimated to be within the region of the sealed sources' volume. When accounting for the decommissioning waste of the FiR 1 research reactor and Otakaari 3 research laboratory, estimates put the maximum total volume of waste generated elsewhere in Finland and deposited at Loviisa power plant at 2,000 m^3.

6.3 WASTE PROCESSING AT LOVIISA POWER PLANT

The starting point for the processing of waste generated elsewhere in Finland and possibly received at Loviisa power plant is that its processing is carried out where it was generated up to the point where its reception in accordance with the procedures of Loviisa power plant is possible and its handling safe.

The final disposal of radioactive waste generated elsewhere in Finland in the L/ILW repository of Loviisa power plant is considered possible, even though the final disposal halls were not originally designed for the purpose in question. Especially for the final disposal of short-lived nuclides such as Co-60 and Cs-137, no long-term safety impediments are seen. Waste containing nuclides with a longer life, including C-14, Am-241 and Ra-226, or waste that clearly differs from Loviisa's nuclear power plant waste in terms of its physical or chemical properties may require additional reviews and measures, such as special packaging. Radioactive waste generated elsewhere in Finland must meet the waste acceptance criteria set by Loviisa power plant for the waste to be fit for final disposal in the L/ILW repository. If necessary, the impact of the waste is furthermore assessed by updating the final disposal facility's long-term safety case, which assesses the long-term radiation doses attributable to the waste deposited for final disposal.

The suitability of the waste for processing at Loviisa power plant and/or for final disposal in the L/ILW repository is ensured and, when necessary, referred to STUK for final approval well in advance of the waste's arrival to the power plant area. Waste to be received must be accompanied by package-specific basic information, such as activity content as well as physical and chemical properties. These details are entered in the power plant's waste records system.

Radioactive waste generated elsewhere in Finland can be transported to Loviisa with a variety of appropriate transport equipment, including a delivery van-type of vehicle. The transports account for the safety regulations required by the radioactivity. The traffic routes in Loviisa are the same as for the power plant's own transports.

When the waste arrives at the power plant, it is subject to an acceptance inspection during which it is ensured that the waste corresponds with the basic information. The acceptance inspection may include the measurement of individual waste packages with a gamma spectrometer to confirm the details on activity. If the waste has already been packed in the right kind of packaging in the location where it was generated, it is transported either to a waste disposal hall or to the waste management facility for interim storage to await final disposal or other processing. If necessary, the waste can also first be processed in the treatment facility for active waste. The re-packing of waste, solidification of liquid waste and/or activity measuring, for example, are normal operations in the power plant's waste treatment, and the procedures are applicable to external waste. After this, the waste can be placed in interim storage or deposited for final disposal in the L/ILW repository. In the repository, it is placed in a hall appropriate for the waste's activity and other properties. The ultimate processing method is determined in more detail on the basis of the waste's properties.

Table 6-3. The environmental aspects of receiving radioactive waste generated elsewhere in Finland.

Environmental aspect	Radioactive waste generated elsewhere in Finland
Total volume of waste	2,000 m^3, at maximum
Processing of the waste to be received	Processing mainly by applying the power plant's current waste management procedures, and final disposal in Loviisa power plant's L/ILW repository.
Traffic	The transport volume of the waste to be received is relatively small and spread over a long period of time; the estimated number of transports is 10 a year.
Final disposal	The volume of the waste to be received is accounted for in the expansion and long-term safety case of the L/ILW repository. The volume of waste is relatively small, no more than 2% of the total waste volume.
Radioactive emissions	Waste transported from elsewhere will not increase the emissions during the L/ILW repository's operational phase.
Long-term safety of final disposal	The impact that waste transported from elsewhere has on long-term safety is ensured, when necessary, with separate investigations. According to a preliminary assessment, however, the impact will be minor.

Waste of the FiR 1 research reactor and the Otakaari 3 research laboratory

For the waste of the FiR 1 research reactor and the Otakaari 3 research laboratory to be receivable by Loviisa power plant, the waste must undergo measures at the point of departure. The planning of the waste management measures is currently underway, and the preliminary plan is described below. The waste is packed, according to waste type, in packaging approved by Loviisa power plant. If the packaging functions as a technical release barrier, it must also be approved by the authorities. The packaging volume of the waste is reduced with the help of sorting, compression and cutting, insofar as possible.

At VTT, the concrete with a low level of activity in the biological shield of the FiR 1 research reactor is cut into pieces and placed, as is, in steel crates. Steel and aluminium parts are sorted separately. Parts with an intermediate-level activity (such as the irradiation ring and graphite reflector) require radiation shielding and will be packed in special, purpose-built packages. Low-level steel and aluminium parts are packed in steel crates and brarrels. While the processing of graphite, Fluental™ and lithionised plastics still requires further reviews, the current plan is to pack them, as is, in steel crates. Other low-level waste is cut into pieces and packed, primarily in barrels. Liquid waste is solidified in the location of its generation or transported to Loviisa for solidification with the power plant's processes. The metal samples of the Otakaari 3 research laboratory are placed in a capsule at VTT and transported to Loviisa under radiation shielding. The rest of the research laboratory's waste is placed in steel crates and barrels.

The activity of the packaged waste is determined at VTT and the waste packages are labelled before transfer to Loviisa. All necessary information is entered in the waste records and transferred to Loviisa power plant. The waste is transported in an IP2 class transport container by road to Loviisa power plant. Estimates put the number of transports at less than 10.

At Loviisa power plant, the packages are inspected for acceptance and transported to the L/ILW repository. According to current plans, the waste will initially be placed in interim storage in maintenance waste hall 3. Some of the waste may subsequently be moved and deposited for final disposal in one of the L/ILW repository's other halls, such as the solidified waste hall or the decommissioning waste halls to be built later. Some of the maintenance waste is deposited for final disposal in maintenance waste hall 3. Waste may also be cleared from regulatory control after interim storage. The research laboratory's metal waste is deposited for final disposal in concrete final disposal containers, deposited in the solidified waste hall.

6.4 ENVIRONMENTAL ASPECTS

Table 6-3 details the environmental aspects of receiving radioactive waste generated elsewhere in Finland.